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Improving Students' Mental Model of Newton's Third Law: Local Wisdom, Modeling Cycle, and Problem-Based Learning

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ABSTRACT

Students need a proper mental model to advance mastery of physics and understand the application of the concept of science. Therefore, it is necessary to research how to improve students' mental models based on Newton's third law, which integrates modeling cycles into problem-based learning. As an anchor of learning, the students were asked to explain action and reaction forces and their effects on Borneo's local wisdom, balogo, and jukung barenteng. The research method used was quasi-experimental with a pretest-posttest control group design. The samples included 87 students of the 10th class in SMAN 1 Kelua and MAN 2 Tabalong. The essay test obtained students' mental models and was analyzed using N-Gain and a one-way ANOVA. The data analysis showed that every class has an average gain, and the p-value for the post-test score is less than 0.05. This means significant differences exist between students' post-test scores in the experimental class and students' post-test scores in the control class. It is indicated that problem-based learning with the modeling cycle and problems of balogo and jukung barenteng improves students' mental model of Newton's Third Law. Integrating local cultural elements such as balogo and jukung barenteng fosters deeper conceptual comprehension and offers an effective method for contextualizing abstract physics concepts through real-world examples. These learning strategies could be applied to other physics topics to improve students' mental models and learning engagement.

INTRODUCTION

Newton's Third Law (NTL) has been introduced in classical mechanics: "When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction" [1]. By this law, the consequences are when two bodies exert forces on each other: forces always come in pairs called third-law force pairs. Many physics concepts are related to NTL, such as gravitational, electrostatic, and magnetic interactions. Therefore, it is not only necessary for students to understand the relation between action and reaction forces but also for teachers to establish better learning [2] [3] [4] [5] [6] [7].

Zhou et al [7] explain that five aspects must be observed to understand Newton's third law thoroughly. The five aspects are existential, ontological, coarse quantitative, compositional, and causal. The existential aspect states that reaction-action forces can be present in all objects and situations, from intermolecular to celestial bodies. The ontological aspect explains that action-reaction forces are identical, such as magnetic force to magnetic force and frictional force to frictional force. Furthermore, the coarse quantitative aspect explains that the action-reaction has the same forces and opposite directions. The coarse aspect of quantitative is the most common aspect taught to students. The aspect that needs to be understood next is a compositional aspect that states the action-reaction forces act on different objects, not to negate each other. Moreover, the last aspect is causal, which explains that the action and reaction forces coincide and are not caused by any forces. The action force can be called reaction forces, also called action forces.

Newton's third law briefly looks simple and easy to understand. However, previous research showed a need for student mental models of Newton's third law in Indonesia [8]. Johnson-Laird [9] states that the mental model is a person's interpretation of the real world. In the context of this research, the intended world is a world tied to scientific laws. The study revealed that most students had understood Newton's third law's coarse quantitative aspects but had a misconception about existential, compositional, and causal aspects. Many students think the higher the mass, the greater the object's force to collide with other objects. A resting object cannot give reaction force, as a carriage does not exert traction when a horse pulls it. These results correspond to other studies that reveal that students need to understand that the action-reaction forces will always appear in pairs in any situation, working on two different objects, and cannot cancel each other [10] [11] [12]. These mental models do not conform to experts' concepts and must be remediated through learning interventions.

Several researchers have conducted studies related to Newton's third law study. Rahmawati et al [13] designed Newton's laws of learning using video and animation. The student was given the practice questions and then discussed the exercise. As a result, students' learning difficulties can be minimized. Subsequently, Risma et al [14] developed an interactive teaching material on Newton's laws to emphasize character formation. The teaching material contains video, sound, and virtual labs that allow learners to experiment virtually. Furthermore, Suma [15] formed students' conceptions of Newton's first and third laws using the refutation text. The text expounded a common misconception of Newton's law and then denied it by presenting arguments according to Newton's laws' genuine concept. On the other hand, Mansyur et al [16] used an interactive demonstration to teach Newton's third law. In that method, students were invited to a dialogue about the phenomenon demonstrated to form a conception of Newton's third law.

Many researchers suggest that just "telling" students that forces arise due to interaction is impractical to form students' conceptual understanding [7] [17] [18]. Therefore, specific learning is required to create a proper mental model of Newton's third law. Campbell et al [19] state that establishing a mental model takes a modeling cycle. The cycle consists of five stages, i.e., explore, create, test, evaluate, and revise. The Explore phase is an elaborate phase of knowledge that students have that intends to facilitate the creation of mental models. Once the cognitive model is created, it must be tested first to fit the expert view. The mental model will be evaluated, and then it will be decided whether it will be strengthened or precisely revised.

Explicit research on concept formation through modeling cycles has never been published in Indonesia. Nevertheless, the stages of modeling cycles can be matched to the previous study. The lessons learned by previous experts align with the modeling cycle, but some do not. The learning given by Rahmawati et al [13] facilitated the exploration phase but did not allow students to create, test, and evaluate their mental models. The same case occurs in the research of Risma et al [20].

Although they allow students to test their understanding, the learning is still one-way and does not consider their preconceptions. Suma [15] provides better intervention through the refutation text. Students are given space in that text – though not much – to realize their already existing concepts. The concept was then tested, and truthfulness was questioned through the argument of the refutation text. In this method, Suma [15] instantaneously initiated cognitive conflicts in the students' minds, and then the students could change the structure of their concepts. Further, Mansyur et al [16] gave students more space for their preconceptions through open dialogue. Students were asked about the demonstrations they saw throughout the learning and were free to answer according to their respective understandings. At this point, the creation phase, test, and evaluation occur continuously on learners. The Mansyur study ended with the revised phase by presenting a similar problem at the beginning of learning.

Mental modeling processes must consider preconceptions, cognitive conflicts, and space to test mental models. Therefore, in this research, the modeling cycle will be integrated into problem-based learning, i.e., learning that uses problems from the real world as anchor learning in class [21] [22]. Problem-based learning is chosen because it provides space for student preconceptions and mental models based on their daily experiences [23]. Also, this model is a learning model suggested in science learning in the Indonesian curriculum.

Problem-based learning is a pedagogy in Indonesia that has been introduced previously because many previous studies related to this learning model. Some research uses PBL models to improve the skills and specific abilities of the students, such as creativity [24], belief [25], problem-solving, and scientific attitudes [26]. Besides, the researchers combine the PBL with local wisdom from Indonesia [27] [28]. Using local wisdom as anchor learning will make learning more meaningful because they have relevant preconceptions about the cultural object. However, to the extent that the authors browse, no single research in Indonesia has used South Borneo's local wisdom object as an anchor learning of problem-based learning. In this case, the local wisdom is *jukung barenteng* and *balogo*.

Jukung barenteng is transportation that consists of a motorboat (called *kelotok* in the Banjarese language) pulling dozens of boats (called *jukung* in the Banjarese language) with rope (Figure 1). Floating market traders use this mode of transport to get to the market faster than paddling. Nowadays, *jukung barenteng* is often shown at the floating market's cultural festival in Banjarmasin. Balogo is a traditional game of the Banjarese tribe that consists of sticks and a *logo*. A *logo* player will hit his *logo* with a stick to the other *logos* at a certain distance (Figure 2).

Fig 1. *Jukung barenteng at the floating market culture festival in Banjarmasin (source: beritabanjarmasin.com)*

Fig 2. *Balogo as a traditional game of the Banjar tribe (source: kompasiana.com)English translation*

On a *jukung barenteng*, dozens of *jukung* are pulled by *kelotok* (motorboat) using ropes. In this phenomenon, the kelotok pulls dozens of jukung with the same force as dozens of jukung pull Kelotok. Despite its equivalents, both forces work on different objects, not negating each other. The *kelotok* traction force works on *jukung* ($\vec{F}_{K,J}$), so the *jukung* can move forward. On the other, *the jukung* pulling force works on *kelotok* ($\vec{F}_{J,K}$) To inhibit the motion of *kelotok*. Kelotok has the advantage of having a machine thrust ($\vec{F}_M$) that helps it advance. The *balogo* game had the application of Newton's third law when it struck. The beater that has given force to the logo will produce the reaction with the same amount of force from the logo that works on the hitter. The force given to the beater to the logo accelerates the logo's movement, while the reaction force given to the beater can be perceived as a burden on the hand of the person hitting the logo. These two concepts are mental models that want to be formed through learning. The forces diagram on the *jukung barenteng* and *balogo* can be seen in Figure 3.

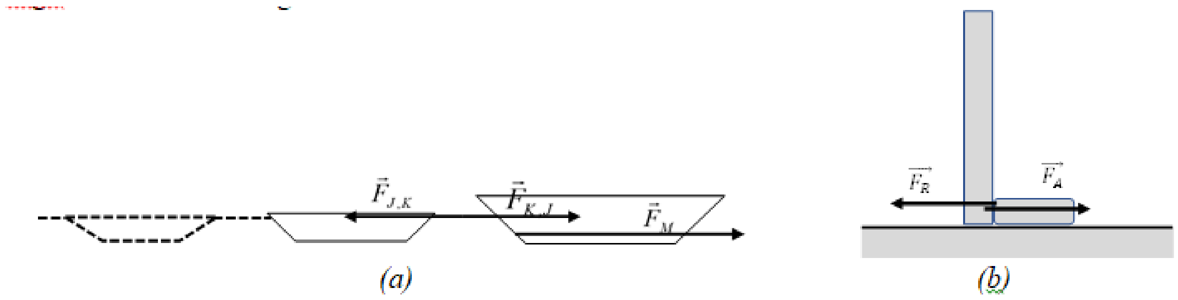


Fig 3. *Interaction forces diagram on jukung barenteng (a) and balogo (b)*

Jukung barenteng and *balogo* are used as anchor learning in this study, not only because of both of their attachment to the people of South Borneo as their local wisdom, but also *jukung barenteng* and *balogo* also contain Newton's third law concept in the interaction. The study aims to improve students' mental models of Newton's third law by integrating mental modeling into the PBL. The method section of this article will describe the treatment given to the students step by step and the measuring instrument of the mental model. Furthermore, the discussion section will outline the influence of the creation model stage with the *jukung barenteng* and *balogo*, the test stage with the computer program, the elaboration of the investigation results with a forces interaction diagram, and the revising phase by reanswer questions about the *jukung barenteng* and *balogo*.

METHOD

The type of this research was quasi-experimental research conducted in 2017/2018 in two schools in Tabalong Regency, South Borneo. Researchers used the running 10th class in schools for research objects. The 10th grade was chosen because it has Newton's Law topic on the curriculum. The first school was SMAN 1 Kelua, which had two 10th classes and 47 students. The experimental design was a pretest-posttest control group design to maintain internal validity that applied to SMAN 1 Kelua. Internal validity is vital for quasi-experimental research to assure PBL caused mental model formation. The control group was required to maintain the historical aspect of the research's internal validity because it received the same events as the experimental group, except for the learning treatment. If there is a significant difference in learning outcomes, the learning intervention is the cause.

Quasi-experimental research also needs to control external validity. It relates to research accuracy if the treatment is applied in different situations. Research may succeed at once but fail on another attempt in a different place and time. Researchers required another school to ensure that the PBL with jukung and balogo can improve the student mental model. Therefore, MAN 2 Tabalong was selected as a second school because its students has similar characteristics to SMAN 1 Kelua. The same experimental design was applied to MAN 2 Tabalong, which has two 10th grade classes containing 40 students. The experimental and control groups were determined in both schools by cluster random sampling. The experimental class at SMAN 1 Kelua has 23 students, while the control class has 24 students. The MAN 2 Tabalong experiment class numbered 20 students, while the control class had 20 students.

The given treatment in the experimental class is problem-based learning with modeling (X_1) cycles. This learning uses the problem of *jukung barenteng* and *balogo* as anchors of the lesson. On the other hand, the control class has received learning that teachers usually use. In that learning, the teacher demonstrates a science phenomenon and asks students to inquire about the phenomenon. The learning activity then continues with the teacher explaining the material, giving some examples, and linking it to the phenomenon that students have observed before. This learning is categorized as conventional learning (X_2). The experimental design can be seen in Table 1.

Table 1. Experimental design

School	Design			
SMAN 1 Kelua	Experiment	O	X1	O
	Control	O	X2	O
MAN 2 Tabalong	Experiment	O	X1	O
	Control	O	X2	O

The two experimental classes in both schools included a control group at the same class level, receiving the same subject matter and number of study hours. Therefore, the events outside of the treatment experienced by the control groups are also experienced by the experimental group. The same teacher taught all experimental and control classes to eliminate the effects of pedagogical differences. Besides that, instrument differences between the pre-tests and post-test measurements can adhere to the student score results. Therefore, the pre-test and post-test used the same question and scoring technique. This method can be detrimental because the tests performed can affect the same results at the next opportunity. Therefore, pre-tests and post-test measurements were given a 3-week delay.

This study's treatment was divided into five phases of problem-based learning. The teaching will be integrated with the modeling cycle shown in Table 2.

Table 2. Integration of the modeling cycle to the syntax of PBL

The syntax of PBL	The modeling cycle
Orienting the problem	Explore
	Create
Planning the investigation	
Doing the investigation	Test
Developing and presenting the result	Test
	Evaluate
Reflecting and evaluating	Evaluate
	Revise

The details of each PBL stage and its relation to the modeling cycle are explained further.

Orienting the problem ("Explore" and "Create" in the modeling cycle)
In this phase, students were asked to watch a video about *balogo* and *jukung barenteng* and answer the questions below.

1. *Balogo*: When a stick hits it, is it "true" to declare that "*The logo pushes a person who hit it by the same amount of forces that the person exerts to the logo*"? If it is "true, " why are people not pushed back because of a logo boost?
2. *Jukung barenteng*: A *kelotok* pulls dozens of *jukung* and moves forward. Is it correct to declare that "the *kelotok* pulls *jukung* with a greater force than the jukung pulls the *kelotok*"?

Afterward, the student was asked to complete the force interaction diagram in Figure 4.

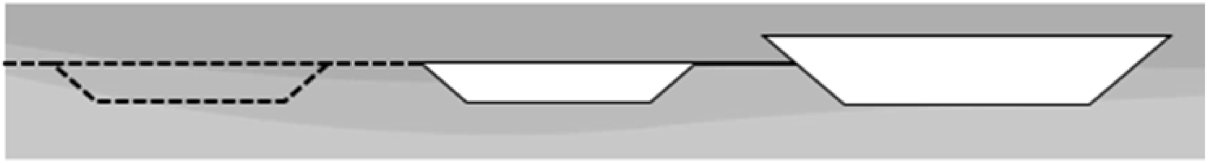


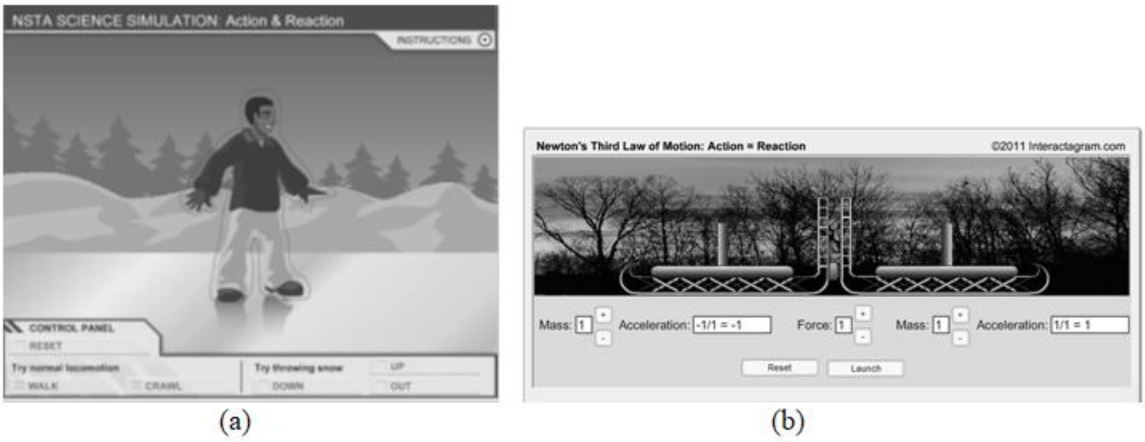
Fig 4. *Jukung barenteng problem*

The question of *balogo* and *jukung* will make students recall their various experiences of hitting, pushing, or pulling objects. Were they thrown out when hitting or pulling objects with a higher force than the object that drew them? The memories are recalled from memory to produce answers to the questions teachers provide. Students' minds' externalization is facilitated by offering figures illustrating the forces' interaction diagram. This method will make it easier for teachers to understand students' preconceptions.

Planning investigation
The students planned to investigate the action-reaction forces in *Balogo and Jukung Barenteng*. The focussed concept concerns the influence of reaction force toward the object that exerts action force. The other concept concerns the influence of action-reaction forces on objects with a different mass. The students should make the problem statement, formulate the hypothesis, determine the investigation's goal, and determine the investigation variable. They work in groups of four or five students.

Doing the investigation ("test" in the modeling cycle)
The students investigated the problems using Throwing programs from the National Science Teacher Association and the Newton Third Law program from Interactagram. The appearance of both programs can be seen in Figure 5. The throwing program is a simulation of a man standing on slippery ice. This man can be moved through the available buttons. Five activities can be ordered to the man, i.e., walking, crawling, throwing snow upwards, throwing snow down, and throwing snow out. When the man walks and crawls, he cannot shift because of the proper ice. Similarly, when the man throws

snow straight up and down, it does not shift. However, the man's body will move backward shortly after throwing the snow. This method is the only way for the man to shift somewhere.



Mass: 1 Acceleration: -1/1 = -1 Force: 1 Mass: 1 Acceleration: 1/1 = 1

(a) (b)

Fig 5. *(a) Throwing program from NSTA and (b) Newton's Third Law program from Interactagram*

The NTL program of Interactagram contains modeling of snow sleds on the ice. There are two simulated snow sleds. These snow sleds are connected by a spring attached to the right snow sled. The spring's potential energy can be released by pressing the launch button, and it will push the snow sled on the left. As a result, both snow sleds move forward with a specific acceleration. The number of springs attached to the right train can be manipulated to enlarge or minimize the thrust. Also, the mass of both snow sleds can be personalized as desired. At the beginning of the study, students' answers to Balogo and Jukung Barenteng's problems will be tested at this stage.

Developing and presenting results ("Evaluate" in the modeling cycle)
After doing virtual simulations with the Throwing program, the students will answer three questions about the simulation. The questions are, "*Why can't the person shift when walking and crawling? Why does that person move backward when he throws the snow forward? Why do people who hit the logo not shift backward?*".

For the NTL program of Interactagram, students were required to draw a forces interaction diagram on the snow sled in the simulation program (Figure 6). Three types of force must be drawn: the force on the left snow sled only, the force on the right snow sled only, and the forces when both snow sleds are connected. Students must consider the vectors' direction and length when drawing the forces vector. The depiction of forces interactions is on the mass-equivalent snow sleds and snow sleds with different masses. The students then use the concept obtained from this phase to respond to *balogo* and *jukung barenteng* in the early stages. The result of this stage is then presented in groups in front of the class.

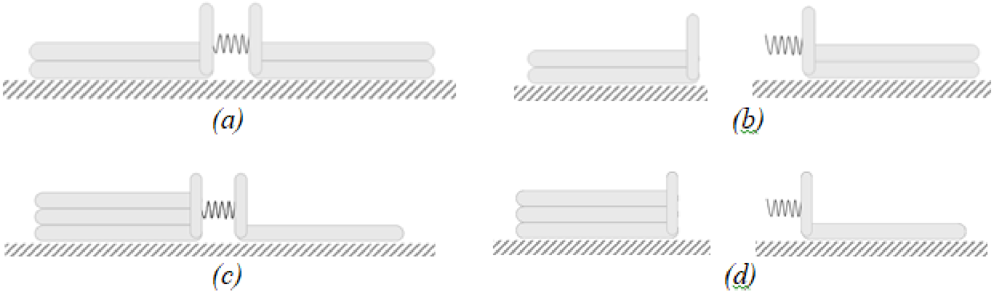


Fig 6. *Objects to draw forces interaction diagram: (a) two same-mass sleds before the launch; (b) two same-mass sleds after the launch; (c) two different-mass sleds before the launch; (d) two different-mass sleds after the launch*

Reflecting and evaluating ("Evaluate" and "Revise" in the modeling cycle)

Students were given reflection questions related to Newton's third law, investigations that have been conducted, and examples of NTL phenomena in daily life. Students were asked: "*What are the differences between your answers about jukung and balogo at the beginning and the end of learning?*". Students were asked to realize the conceptual changes they were experiencing from these questions.

Instrumentation

The instrument to measure students' mental model consists of four essay questions related to Newton's third law. The questions asked students to explain, predict, and evaluate the action-reaction forces. The instrument has been tested empirically to determine its validity and reliability. The trial results are then analyzed with the QUEST program, and the result is shown in Table 3. The instrument's validity can be seen on the infit mean square, which indicates the item matches the model Rasch, and the outfit-T shows the level of the item's acceptability. The value of the infit mean square, considered matching to the model Rasch, is at intervals 0.77 to 1.30, while the acceptable outfit-T value is at a range of -2.0 to + 2.0.

Table 3. The instrument to measure the mental model of Newton's Third Law

Items	Description	Infit Mean Square	Outfit-t	Reliability
1st item	Explain the action and reaction forces in a cart pulled by a horse	0,89	-0,3	0,84
2nd item	Predict the motion caused by the action and reaction forces	0,90	-0,2	
3rd item	Evaluate the action and reaction forces in a collision car	0,86	-0,6	
4th item	Evaluate the action and reaction forces when a car pushes the other car	0,81	-0,8	

Data Analysis

The student's scores on Newton's third law mental model test will be analyzed using a descriptive method. Then, the pre-test and post-test scores will be analyzed using N-gain analysis. The criteria used for N-gain scores are in Table 4.

Table 4. N-Gain Score Criteria [29]

Interval	Criterion
$X \geq 0,7$	High
$0,3 \leq X < 0,7$	Medium
$0,3 < X$	Low

Furthermore, the one-way ANOVA test determined the average difference in students' mental model scores between experimental and control classes. The test normality and homogeneity will be undertaken first as a prerequisite statistic parametric.

Hypothesis in this research include:

H0 : There are no significant differences between students' post-test scores in the experimental class and students' post-test scores in the control class.

H1 : There are significant differences between students' post-test scores in the experimental class and students' post-test scores in the control class

The calculation was done to answer this hypothesis using one-way ANOVA in SPSS. The test criteria: Ho is rejected if P-value < 0,05

RESULTS AND DISCUSSIONS

Result

Table 5 describes the students' pre-test and post-test scores of the control and experimental classes at SMAN 1 Kelua and MAN 2 Tabalong.

Table 5. Result of the mental model test

School	Class	Test	Min	Max	Mean	Std dev	N-Gain	Category
SMAN 1 Kelua	Exp.	Pre	18	41	27,52	6,0	0,63	Medium
		Post	50	89	73,30	14,6		
	Contr.	Pre	19	50	33,25	8,4	0,43	Medium
		Post	43	95	60,96	14,3		
MAN 2 Tab	Exp	Pre	18	50	28,55	8,5	0,59	Medium
		Pos	49	99	71,95	14,5		
	Contr.	Pre	18	36	26,25	5,2	0,45	Medium
		Pos	36	95	59,25	16,6		

Based on Table 5, the N-gain score in all classes is in the medium category. However, there are exciting patterns where experimental and control classes have an equal N-gain category. Next, a one-way ANOVA test is done on the post-test score only. Table 6 summarizes the test normality, homogeneity test, and Anova on the post-test score.

Table 6. One-way ANOVA test based on post-test score

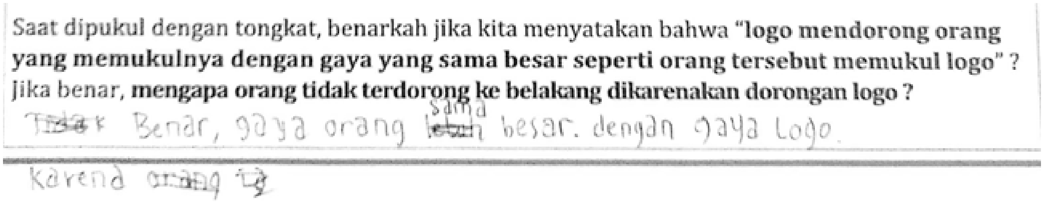
School	Class	Sig. Value of Normality Test	Homogeneity Test	Sig Value of Anova Test
SMAN 1 Kelua	Exp	0,063	0,911	0,030
	Contr.	0,210		
MAN 2 Tab	Exp	0,668		0,044
	Contr.	0,175		

The normality and homogeneity test indicates that data is regular and homogeneous, thus qualifying the parametric test's requisite. Further calculations on one-way ANOVA indicate that the Sig's value between the experimental and control classes at both schools is smaller than 0.05. Thus, the H0 hypothesis was rejected, and H1 was accepted. In conclusion, there is a significant difference between the experimental class students' post-test scores and the control class. This conclusion applies to SMAN 1 Kelua and MAN 2 Tabalong.

Discussion

Mental models are subjective interpretations of the natural world due to the interaction through the senses [9] [30] [31]. It can understand, explain, and predict the world [32]. The given daily life problems make it more natural to create mental simulations as part of the cognitive modeling [30], and it can make the students understand the applied concepts [33]. The students must explore the brain's schemata information and experiences to understand the given problem at this phase. They used the information from previous experiences to explain the situation of *jukung barenteng*. The students create a mental model even if its truth and precision are still in doubt. The main objective is to use Newton's Third Law information acquired during junior high school to explain a phenomenon [34].

The initial mental model of one of the students on the problems of the *balogo* strike can be seen in Figure 7. According to the student, when the logo is struck, it will exert the same force on its hitter. However, he could not explain why the person who hit it was not shifted backward. The inability to explain this phenomenon and scribble on the answer paper shows the student has a cognitive conflict. The scribble indicates that initially, it will answer "not true," i.e., the person who hits the logo gives a greater force than the logo. Nevertheless, he realized it was not following Newton's third law.



Saat dipukul dengan tongkat, benarkah jika kita menyatakan bahwa “**logo mendorong orang yang memukulnya dengan gaya yang sama besar seperti orang tersebut memukul logo**” ? Jika benar, **mengapa orang tidak terdorong ke belakang dikarenakan dorongan logo ?**

~~Tidak~~ Benar, gaya orang ~~lebih~~ sama besar. dengan gaya Logo.

Karena ~~orang~~ ~~tg~~

Question:

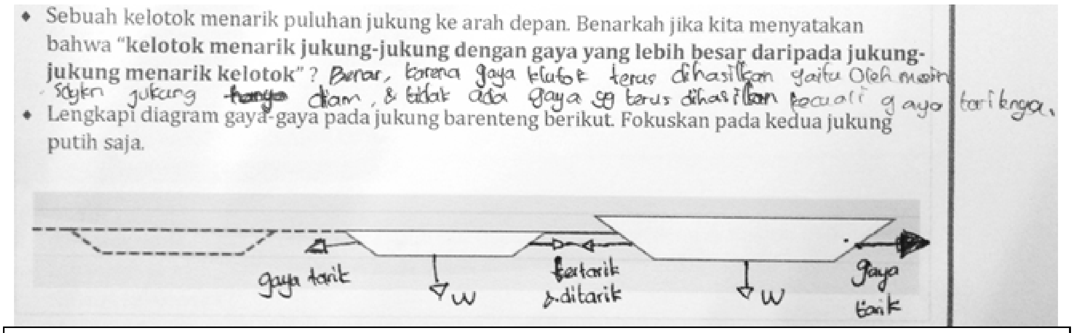
When the stick hits the logo, is it “true” if we declare that "**the logo pushes the person who hit it by the same force that the person exerts to the logo"?** If it is “true,” why are people not pushed back because of a logo boost?

Answer:

~~No~~ Yes, it is true. The hitter’s force is ~~greater~~ equal to the logo’s force.
Because the person he

Fig 7. *An initial student’s mental model of the balogo game*

Furthermore, the results of another student's answers on *jukung barenteng* are shown in Figure 8. The answer shows the student thinks the *kelotok* pulls *jukung* with a greater force due to the machine's existence, while *jukung* gives a smaller force because it stays at rest. Also, the force diagram described by the student provides exciting information, where the student includes the weight force of the *jukung*, but no floating force balances the weight force.



- Sebuah kelotok menarik puluhan jukung ke arah depan. Benarkah jika kita menyatakan bahwa “**kelotok menarik jukung-jukung dengan gaya yang lebih besar daripada jukung-jukung menarik kelotok**” ? Benar, karena gaya klotok terus dihasilkan yaitu oleh mesin sdgkn jukung ~~hanya~~ diam, & tidak ada gaya yg terus dihasilkan kecuali gaya tariknya.
- Lengkapi diagram gaya-gaya pada jukung barenteng berikut. Fokuskan pada kedua jukung putih saja.

Question:

A *kelotok* pulls dozens of *jukung* and moves forward. Is it “true” if we declare that "**the *kelotok* pulls *jukungs* with a greater force than the jukungs pulls the *kelotok***"?

Answer:

This is true because the engine continues to produce the kelotok’s force, whereas the jukung is just not moving, and no force is produced except for the pulling force.

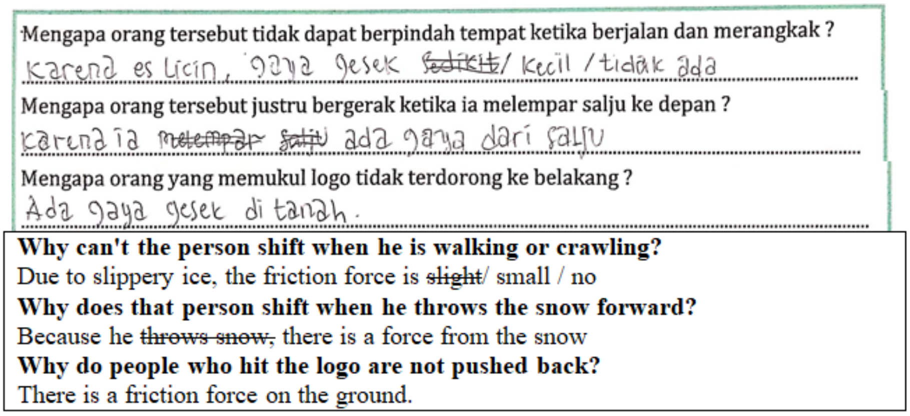
Fig 8. *An initial student’s mental model of jukung barenteng*

This modeling cycle's creation phase allows learners to be aware of the concepts already possessed [12]. It is essential as part of the mental modeling process, which is not provided in the control class. Conventional learning in the control class only generally asks about the student's experience in pushing or pulling objects. That is, not all students have the opportunity to answer teacher questions. Unlike the control class, each student must answer the initial question in the experiment class. True or false is not considered. The important thing is to respond according to their understanding.

The investigation aimed to test the truth of students' mental models. Computer simulations were a crucial part of the process, and they were used as idealized forms of Newton's Third Law to observe them in their ideal form [6]. The throwing investigation related to simulations of people who throw snow on ice and sleighs moved when they received action-reaction forces. This activity will lead to the concept that the person who threw an object receives the reaction force from the object he threw. As a man throws a lump of snow, he is shifted backward because the snow chunk exerts a force back to the man throwing it.

Furthermore, the NTL program of Interactagram suggests that a snow sled that pushes another snow sled receives reaction force and moves forward. The active and passive objects receive the same force but in opposite directions. Besides, the interaction of different snow sludge masses produces different accelerations. Although the received force is equal, the lighter trains will move faster as the mass is smaller, while the heavier trains move slower because the mass is larger than the other. This simulation aims to test the effect of action-reaction forces on objects with different masses and works on various objects.

The students elaborated on the data obtained at the investigative stage by answering the worksheet's questions. Figure 9 shows a student's elaboration related to the Throwing program. The answer indicates that the student understands that throwing snow will shift backward as the ice is slippery and thrust from the snow he is throwing. He then made an analogy with the man who hit the logo on rough ground. He realized that hitting the logo was not pushed back due to friction.



Mengapa orang tersebut tidak dapat berpindah tempat ketika berjalan dan merangkak ?

Karena es licin, gaya gesek ~~sedikit~~/ kecil / tidak ada

Mengapa orang tersebut justru bergerak ketika ia melempar salju ke depan ?

Karena ia ~~melempar salju~~ ada gaya dari salju

Mengapa orang yang memukul logo tidak terdorong ke belakang ?

Ada gaya gesek di tanah.

Why can't the person shift when he is walking or crawling?

Due to slippery ice, the friction force is ~~slight~~/ small / no

Why does that person shift when he throws the snow forward?

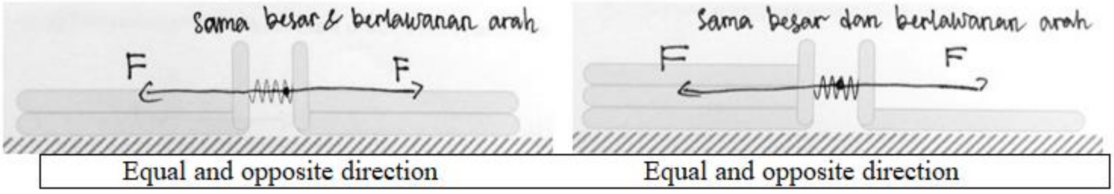
Because he ~~throws snow,~~ there is a force from the snow

Why do people who hit the logo are not pushed back?

There is a friction force on the ground.

***Fig 9.** The elaboration of the Throwing program*

The elaboration related to the Interactagram program, where a student made a force interactions diagram on the snow sleds, can be seen in Figure 10. Savinainen et al [12] state that using force interaction diagrams in learning can reinforce students' concepts. Also, the simulation sequences' formulation plays an essential role in forming the mental model [35]. For that, students first observe the action-reaction force simulation on the snow sleds with the same mass. It is intended for students to understand that the action-reaction forces work on different objects. The active objects will also receive the same force as the passive objects. Afterward, the simulation of force interactions resumed on snow sleds with different masses. This time, the simulation aims to understand that the action-reaction forces can differ if applied to other mass objects, as did Newton's second law. With that method, students can know that the magnitude of the forces between the snow sludges, whether having the same mass or not, is the equal and opposite direction.



Equal and opposite direction | Equal and opposite direction

***Fig 10.** The elaboration of action and reaction force on the snow sleds*

The mental model change was not directly successful for all students, as some still assume that the force of the snow sludge is different. The heavier snow sludge drives a light train with a greater force (Figure 11). The teacher persuaded students to engage in dialogues regarding each snow sludge force for students who still have this mental model. First, the teacher discusses the snow sludge with the same mass. The students agree that the force between the two snow sleds is equal. The teacher then explained that the same force is applied to the snow sludge with a different mass. The teacher also linked the simulation to Newton's first and second laws, which are inertia-related, and the mass influence on acceleration. At the end of the dialogue, the students agreed that the action-reaction forces were equal between the snow sludges with different masses.

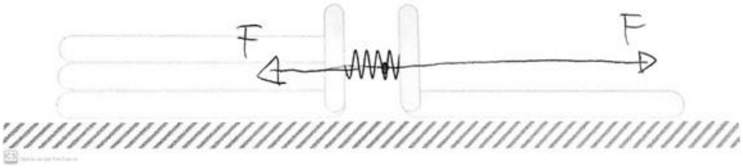
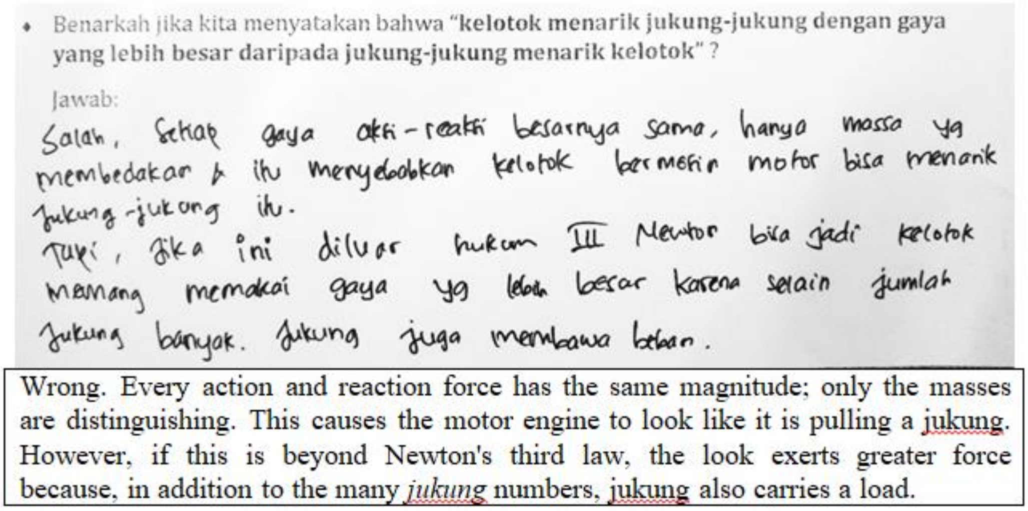


Fig 11. *The elaboration of action and reaction force on the snow sleds*

Then, Figure 12 is a student's answer after doing the investigation. This student is the same student who wrote the answer in Figure 10. He realises that jukung can pull kelotok with the same force as kelotok pull jukung. The kelotok can move forward because of the force of the machine, and the jukung can move forward because of the pulling force of the kelotok. He realizes that the action and reaction forces act on different objects and cannot cancel each other. However, interestingly, the student still assumed a chance that Newton's third law would not apply. The teacher then explained the existential aspect of Newton's third law to the student. The teacher describes Newton's third law as applying to every interaction between small objects and celestial bodies.



- Benarkah jika kita menyatakan bahwa "**kelotok menarik jukung-jukung dengan gaya yang lebih besar daripada jukung-jukung menarik kelotok**" ?

Jawab:

Salah, Setiap gaya aksi-reaksi besarnya sama, hanya massa yg membedakan ~~b~~ itu menyebabkan kelotok bermesin motor bisa menarik jukung-jukung itu.
Tapi, jika ini diluar hukum III Newton bisa jadi kelotok memang memakai gaya yg lebih besar karena selain jumlah jukung banyak. Jukung juga membawa beban.

Wrong. Every action and reaction force has the same magnitude; only the masses are distinguishing. This causes the motor engine to look like it is pulling a jukung. However, if this is beyond Newton's third law, the look exerts greater force because, in addition to the many *jukung* numbers, jukung also carries a load.

Fig 12. *Student's mental model about jukung parenting after doing the investigation*

The investigation results and discussion questions will guide students in forming a mental model that agrees with the scientists. Students receive such information through assimilation and accommodation to create a new equilibration phase of Newton's Third Law. This new understanding will help review student predictions and explanations. If the explanations made at the beginning of the lesson are correct, the students will reinforce their mental model. However, if it is accurate, students will accept or revise their mental model.

Providing space for students to use the preconception is worth noting in improving the mental model. It also agrees with Smith & Wittman [36], explaining that learning involving the raw intuition of students will deliver more effective results. According to them, learning should allow students to display and test their opinions. Besides that, Savinainen et al [12] stated that the given cognitive conflict would make students hesitate with their knowledge and be directed to rebuild their minds to reduce misconceptions.

The objects used to trigger preconceptions should also be noted because the students' mental model is strongly influenced by experience [37]. Integrating local culture into science learning will provide meaningful learning for students [27] [28]. In the learning, students were asked to make predictions or explain the problems of *balogo* and *jukung barenteng*. Predictions will strengthen students' mental modeling [38] [39] [40]. Predictions also train students to explain and analyze scientific phenomena as a part of mental modeling [39] [41]. Those conditions successfully affected students in reconstructing their mental model of Newton’s Third Law.

CONCLUSION AND SUGGESTION

The cognitive conflicts given through the problem of *jukung barenteng* and *balogo* can facilitate the disclosure of students' preconceptions. Using computer simulations to test students' mental models also results in the desired mental modeling process. Besides, interaction diagrams can strengthen the structure of students' mental models. The student can explain that force always comes in pairs and has the same magnitude, even if the object's mass is different. The student also comprehends that the action and reaction forces will never cancel because they act on various objects. We hope other teachers can apply this treatment to improve students' mental models so that they can understand and apply the concept of Newton's Third Law in jukung barenteng and other daily life contexts. It can facilitate students' study of other ideas of mechanics.

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