Available online at http://journal.um.ac.id/index.php/jps/
ISSN: 2338-9117/EISSN: 2442-3904

Jurnal Pendidikan Sains
Volume 6, Number 4, December 2018, pp. 110–119

Conception of Motion as Newton Law Implementation among Students of Physics Education

Eko Sujarwanto[*], **Ino Angga Putra**
Physics Education–Universitas KH. A. Wahab Hasbullah
Jl. Garuda 9, Tambak Rejo, Jombang, East Java-Indonesia 61451. E-mail: ekosujarwanto23@gmail.com

Abstract: The study was conducted by giving an identification test on Newton's laws of motion application in the form of multiple choice questions to students who were enrolled in Mechanics and Basic Physics Courses. The analysis was based on student answers and the level of student confidence in the correctness of the answers in quantitative descriptive and qualitative. The results of the analysis of identification tests were reinforced by thinking map of Newton's laws of student presentation and followed up by interviews. The results show that students' conceptions of motion and Newton's laws is insufficient. Prospective teacher students are required to learn the concepts of Motion and Newton's Law applied and influenced by common sense.

Key Words: conception, Newton's laws, motion

Abstrak: Penelitian dilakukan dengan memberikan tes identifikasi aplikasi hukum-hukum Newton tentang gerak kepada mahasiswa berupa soal pilihan ganda pada mahasiswa yang terdaftar pada matakuliah Mekanika dan Fisika Dasar. Analisis didasarkan pada jawaban mahasiswa dan tingkat kepercayaan mahasiswa terhadap kebenaran jawabannya secara kuantitatif deskriptif dan kualitatif. Hasil analisis tes identifikasi diperkuat dengan *thinking map* hukum-hukum Newton sajian mahasiswa dan ditindaklanjuti dengan wawancara. Hasil penelitian menunjukkan konsepsi mahasiswa tentang gerak dan hukum-hukum Newton dalam kategori "Kurang Paham". Mahasiswa calon guru perlu belajar dan mempelajari konsep Gerak dan Hukum Newton secara aplikatif dan dipengaruhi oleh *common sense*.

Kata kunci: konsepsi, hukum-hukum Newton, keadaan gerak

INTRODUCTION

Motion is one phenomenon that has long been studied by physicists, ranging from Aristotle, Newton, to Einstein. Learning about motion is the first step in learning Physics (Holzner, 2006). It is quite reasonable why it is necessary to investigate the conception of motion. Motion belongs in Mechanics study. The concept is used to explain the motion of objects with very large mass compared to atomic mass and very low velocities than the speed of light studied through Newtonian Mechanics. Newtonian mechanics implements Newton's laws of motion with mathematical representations.

Physics models and explains natural phenomena from simple to complex one (Holzner, 2006). Physicists use multiple representations as media to communicate knowledge and concepts of Physics (Etkina et al., 2006; De Cock, 2012). One representation that is used is a mathematical representation which is commonly referred to by students as a formula. Students need to understand the meaning behind mathematical representation in order to understand the concepts of physics communicated by mathematical representations. For example, students must understand the physical meaning behind mathematical representations of Newton's laws and then be able to apply them.

The mathematical representation of Newton's laws of motion of point particles is uncomplicated, namely without high-level mathematical operations such as vector calculus thus mathematical completion is relatively easier for students. The mathematical representation of Newton's laws of motion is different from the representation of Gauss's law and Faraday's law involving vector calculus. Although students can do mathematical completion, not all students

Article received 12/02/2018; Approved 15/10/2018

understand the physical meaning behind mathematical representations of Newton's laws of motion and its implications. Students tend to focus only on calculations and formulas (Kuo et al., 2013; Walsh et al., 2007). Students should be able to identify the concepts and principles of physics that are appropriate to the problem. After being able to identify relevant concepts and principles, students must be able to apply their knowledge to be able to solve physical problems well (Lin & Singh, 2015).

The topics of motion and force have been studied by several researchers. Halloun & Hestenes (1985) present students' common-sense of motion. Common sense is arranged in a systematic taxonomy. Meanwhile, Thornton & Sokoloff (1998) compiled assessment instruments to determine the understanding of concepts about Newton's laws. Based on tests on motion and style (Hestenes et al., 1992; Thornton & Sokoloff, 1998) carried out on students, misunderstanding of motion and force lead to errors in solving problems. The mistakes that occur for example in the introduction of appropriate concepts and the use of appropriate concepts. The structure of knowledge about good Physics concepts correlate strongly with understanding concepts and solving problems about motion and style (Malone, 2008). The structure of knowledge in question is a hierarchical arrangement of physical knowledge from general concepts to more detailed physical facts. Conceptual display of problems also affects how students use their concept in solving problems, for example in Newton's three legal problems (Bao et al, 2002). The conception used by students is also related to the resources used in understanding concepts (Hammer, 2000). Previous research has contributed to aspects of concepts, assessments, and learning strategies, but it needs a portion of research on understanding the physical meaning of Newton's laws of motion and the causes of students' failure to understand and apply it.

Prospective Physics teachers tend to use common sense about motion. Common sense that contradicts Newton's laws cannot be avoided in physics learning (Halloun & Hestenes, 1985). Formica et al., 2010) also mentions that first-year students did not use Newton's laws of motion well but instead used common sense about motion or could be called Aristotelian thinking. Meanwhile, the initial findings confirmed that the failure to understand and apply Newton's laws of motion were not only experienced by first-year students but also second-year students even though students could write mathematical representations and memorize Newton's laws of motion. Second-year students have even taken the Basic Physics I course and are taking the Mechanics course.

Conception is an individual understanding that can not be in accordance with the opinions of experts who have been more inclined to a general explanation and form a concept (Linuwih, 2011). The concept is the way in which a concept of a system-environment is considered or accepted. Meanwhile, the concept indicates a category that is used to classify phenomena, ideas, or objects that have similarity in character (Moreno, 2010). Concepts are abstract in that they do not have their own form other than in a person's thinking structure. The concept of mental representation is used for various cognitive functions, such as reasoning (Goldstein, 2011). The concept is very basic for the thought process so that the concept can be called the smallest unit of thought processes (Ferrari & Elik, 2003). Concept formation is a continuous process as a result of interaction with the environment, the media, and other people (Moreno, 2010) including teacher-student interactions during learning.

Physics teacher is one of the important factors in building students' physical conceptions. Students of Physics Education who are oriented as prospective Physics teachers need to master the concepts of Physics in accordance with scientific truth. The importance of conceptualizing and mastering lies in the fact that concepts help to represent and organize information (Mandler, 2007). In addition, if the prospective Physics teacher still does not master the concept of Physics, it will be a serious problem, namely the transmission of misconceptions. Lemma (2013) found that teachers who have not mastered the concept play a large role in the misconceptions experienced by students.

Motion is an important concept for prospective students of Physics thus it is necessary to identify conceptions and causes of failure to understand and use Newton's laws of motion. Previous research has identified a level of understanding of the concept of Newton's Law (Sudibyo & Supardi, 2013; Handhika et al. 2016). Handhika et al. (2016) tried to uncover students' conceptions of motion by reviewing the perceptions that students have. These studies have tried to uncover and map the level of understanding of Newton's law but have not revealed a more structured cause of failure to understand the concept of motion in accordance with Newton's law. This study aims to identify the level of conceptual understanding of students and the causes of failure of students to understand and use Newton's laws in motion problems. This study used the principle of CRI (Certainty of Response Index) and used a thinking map to determine the level of understanding and causes of failure to understand and used Newton's law structurally in solving problems. This study presents data on the results of identification tests and the level of trust in the truth of the answers. This study also presents the level of student understanding through thinking map of Newton's laws of motion. Thinking maps are used to find out maps of student thinking about Newton's laws of motion.

METHOD

This research was descriptive qualitative research. The subjects of this study were the first-year of undergraduate students enrolled in the Basic Physics I course as many as ten students and second-year students enrolled in the Mechanics course as many as five students in the 2016/2017 academic year. 15 Students are students of physics-oriented study programs who are candidates for physics. The research subjects were selected by purposive sampling since they still receive material related to Newton's Law of motion with a conceptual approach and mathematical formalism and as a basis for taking higher material to Physics. The topics discussed in the subject of Basic Physics I and Mechanics include Newton's laws of motion. In accordance with the Unwaha Physics Education study program curriculum, the Basic Physics I course emphasizes qualitative and quantitative aspects and problem-solving with the help of mathematical representation. The mechanic's courses include discussing Law I, Law II, and Newton's Third Law presented in the discussion of 1 dimension for constant force, force depending on time F(t), speed F(v), and position F(x). This study only examined the topic of Newton's laws for constant force. The research subjects were divided into two classes according to the courses taken and taught by two different lecturers. Learning was done by student discussion methods, lectures by lecturers, and presentations by students. Learning also involved Phet animation.

The research data was obtained from multiple-choice identification tests conducted after discussing the topic of Newton's laws of motion. Multiple choice tests are designed to have five alternative answers. Students were asked to choose one correct answer. In addition, students must also determine the level of confidence in their answer choices. The level of confidence was indicated by a Likert scale between 0 to 3. Number 0 indicates the level of "not sure" while number 3 shows the level of "sure" and among those values students can choose number 1 or 2. The combination of answer choices and confidence level were used to measure students' conceptual understanding of the topic of Newton's laws of motion as shown in Table 1. This method has been done by Potgieter et al. (2010), Sutopo (2016), and Putra and Sujarwanto (2018). The results of the grouping were then percentage to find out the level of understanding and use of Newton's laws of motion problems.

The research data was also obtained through thinking maps of Newton's laws of motion by students. Student-made thinking maps are used to find out maps of student thinking about Newton's laws. Interviews were conducted to investigate more deeply about student conceptions of motion. Student-made thinking maps and interview results were analyzed qualitatively by selecting data related to Newton's laws of motion, grouping data based on the kinds of answers and tendencies of thinking maps in thinking maps, and describing the results.

RESULTS

Newton's Motion and Law I

The concern from the results of student tests on the topic of Newton's Law I is most students assumed that there must occur a force thus objects remain in motion. This can be seen in the student answers shown in Figure 1. The distribution of student answers to the questions is presented in Table 2. The choice of the correct answer is D. For students who consider the choice of answer A, the student does not under-

Table 1. Conceptual Understanding Categorization Rubric Based on Suitability of Answers and Levels of Confidence

Answer	Understanding categorization based on confidence scores			
	0	1	2	3
Correct	Low	Low	Moderate	High
Incorrect	Low	Low	Low	Misconception

Which statement is the most correct?
(A) It is possible for an object to move even though there is no force acting on it
(B) It is possible for an object to work a force even if the object does not move
(C) A and B are incorrect
(D) A and B are correct
(E) All statements are incorrect

Figure 1. Questions about Motion and Newton's First Law

When you ride a motorcycle at a speed of 40 km/h, a dragonfly hit your motorcycle headlights. Shortly after the collision, which one has greater acceleration?
(A) A dragonfly
(B) A motorcycle
(C) Both have an equal acceleration
(D) Both have a null acceleration
(E) All statements are incorrect

Figure 2. Questions about Motion and Newton's Second Law

stand Newton's I Law, the concept of inertial frame of reference which is an implication of Newton's Law I. For students who reject the truth of the statement of choice B, the student does not understand the resultant concept of force well.

Based on Table 2, it shows that the level of understanding of prospective teacher students related to the material of motion and Newton I law is low. This is indicated by the highest percentage value of 66.67% with ten prospective teacher students answering questions at a low level of understanding. In addition, five prospective teacher students experienced a misconception with a percentage of 33.33%. No student belongs to high and moderate categories. Another interesting finding based on the results of the analysis of the answers to the questions in Figure 1 is that the majority of students (66.66%; the number of students who answered C and E) consider stationary objects has no force acting on the object. Based on these data, most students experienced misconceptions or lack of understanding and did not understand Newton's first law. The findings are reinforced by the results of the interview. All students interviewed (five students) stated that there must always be a force that maintains the motion of objects. When the researcher asks, "Does force occur when the object is moving?", the student answers, "Yes, because when the object is moving there is clearly a force that pushes". When asked, "what if the force is removed after the object moves", the student explains that the object will eventually stop because there is a friction.

Newton's Motion and Law II

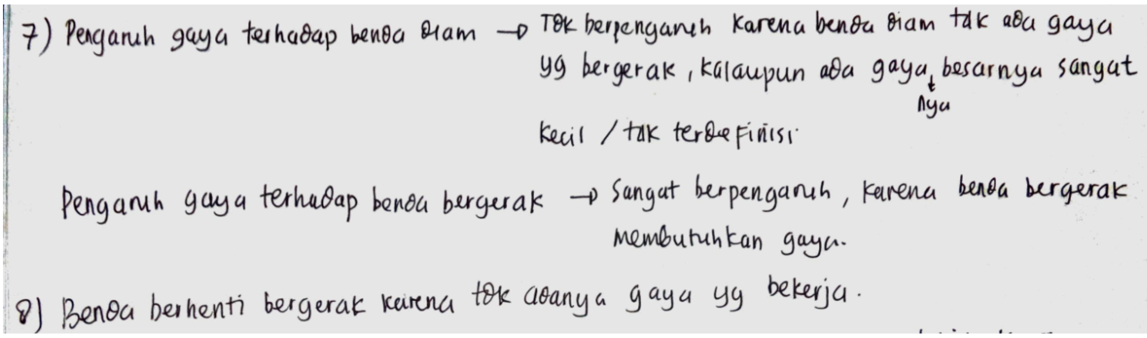
Most students incorrectly applied Newton's Second Law to the collision problem. This can be seen in the distribution of question answers as in Figure 2. The results are shown in Table 3. Students who answered choice B, thought that the larger mass has greater acceleration as well. Students who answered

Table 2. Distribution of Answers and Student Categorization on Newton's I Law Problems

Distribution of Answers			Distribution of Student Understanding		
Answer	N	Percentage (%)	Level of Student Understanding	N	Percentage (%)
A	0	0	High	0	0
B	4	26,67	Moderate	0	0
C	5	33,33	Low	10	66,67
D	1	6,67	Misconception	5	33,33
E	5	33,33			
Total	15	100	Total	15	100

Table 3. Distribution of Answers and Student Categorization on Newton's II Law Problems

Distribution of Answers			Distribution of Student Understanding		
Answer	N	Percentage (%)	Level of Student Understanding	N	Percentage (%)
A	5	33,33	High	1	6,67
B	2	13.33	Moderate	1	6,67
C	4	26,67	Low	12	80,00
D	3	20	Misconception	1	6,67
E	1	6,67			
Total	15	100	Total	15	100


7) Pengaruh gaya terhadap benda diam → tdk berpengaruh karena benda diam tdk ada gaya yg bergerak, kalaupun ada gaya, besarnya sangat kecil / tdk terdefinisi.

Pengaruh gaya terhadap benda bergerak → sangat berpengaruh, karena benda bergerak membutuhkan gaya.

8) Benda berhenti bergerak karena tdk adanya gaya yg bekerja.

Figure 3. Student's Note of Force Effect on Object

the C option equate acceleration and force concepts. It also found in the research conducted by Bao et al. (2002). Students who answered D, assumed that shortly after the collision, the object involved in the collision will stop. Most students have a low understanding (46.67%) of Newton's second law applies to collision problems. The results of the interview show that students understand that force causes objects to move and no force in stationary objects. This is shown in student interviews as shown in Figure 3.

Based on Table 3, it shows that the level of understanding of most prospective teacher students related to the material of motion and Newton II law is low. This is indicated by the largest percentage value of 80% with 12 prospective teacher students having a low understanding. While only one student is categorized in high, moderate, and misconception (6.67%).

Newton's Motion and Law III

Students considered objects with larger masses contributes greater force to objects with smaller masses when they collide. This is seen when students answer the questions in Figure 4. The results of student answers are presented in Table 4. Based on resource theory (Hammer, 2000), to answer questions correctly, the student must have knowledge of the concepts of force and mass. Students who answer A and B do not yet have complete knowledge of the concepts of force and mass and still use common sense about Domination Principles (Maloney, 1984).

Based on Table 4, it shows that the level of understanding of prospective teacher students related to the material of motion and Newton III law is still low. This is indicated by the percentage value of 73.33% with 11 prospective teacher students who at the low level of understanding. Only one student (6.67%) categorize at the high level of understanding and answered correctly. Three students with a percentage of 20% were having a misconception. Students also think that objects with greater speed will work on larger forces on objects with smaller speeds just as they collide. The problem that reveals this is shown in Figure 5. Student answers are shown in Table 5. Table 5 shows the majority of students experience misconceptions in Newton's third law (66.67%). Misconceptions that occur can be explained by common sense by using the principle of Domination. In general, the principle of dominance states that objects with dominating features will give a greater force.

Based on Table 5, it shows that the level of understanding of prospective teacher students related to

When you ride a motorcycle at a speed of 40 km/h, a dragonfly hits your motorcycle headlights. Which experiences a greater force?
(A) A dragonfly
(B) A motorcycle
(C) Both have an equal force
(D) Both have a null force
(E) All statements are incorrect

Figure 4. Questions about Motion and Newton's Third Law: Mass Variation and Speed (Collision 2 1 Dimensional Objects)

Object B that moves at a speed of 5 m / s to a stationary object A. When object B hits object A, which one experiences greater force?
(A) Object A
(B) Object B
(C) Both have a null force
(D) Both have an equal force
(E) No sufficient information to answer

Figure 5. Questions about Motion and Newton's Third Law Variation of Speed (Collision 2 Objects 1 Dimension)

Table 4. Distribution of Answers and Student Categorization on Motion and Newton's Third Law: Mass Variation and Speed (Collision 2 1 Dimensional Objects)

Distribution of Answers			Distribution of Student Understanding		
Answer	N	Percentage (%)	Level of Student Understanding	N	Percentage (%)
A	6	40	High	1	6,67
B	5	33.33	Moderate	0	0
C	2	13.33	Low	11	73,33
D	1	6,67	Misconception	3	20
E	1	6,67			
Total	15	100	Total	15	100

Table 5. Distribution of Answers and Student Categorization on Motion and Newton's Third Law Variation of Speed (Collision 2 Objects 1 Dimension)

Distribution of Answers			Distribution of Student Understanding		
Answer	N	Percentage (%)	Level of Student Understanding	N	Percentage (%)
A	3	20	High	1	6,67
B	9	60	Moderate	0	0
C	2	13,33	Low	4	26,67
D	1	6,67	Misconception	10	66,67
E	0	0			
Total	15	100	Total	15	100

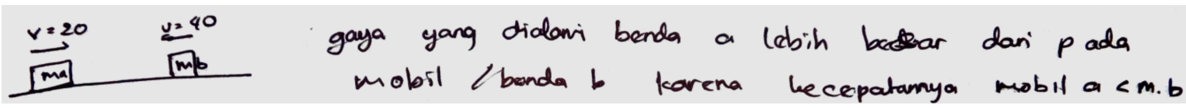


Figure 6. Student Notes about Newton's Third Law on Collisions with Speed Variations

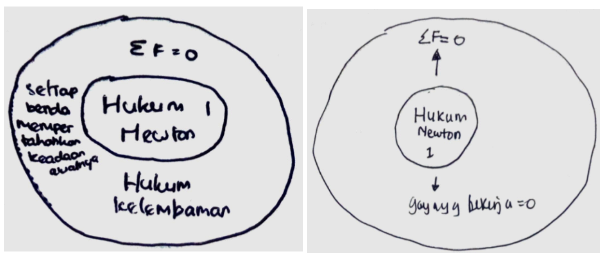
motion material and Newton III law is still far beyond the expectation. This is indicated by the percentage value of 66.67% with ten prospective teacher students who are having a misconception. Only one student (6.67%) categorize at the high level of understanding and answered correctly and four students with a percentage of 26.67% have a low understanding. The results of the interview reinforce the Domination principle used by students as indicated by the student's notes during the interview in Figure 6.

Students Thinking Map about Newton's Law

The research that has been done also compared the misconception with thinking maps made by students. By using a thinking map, researchers tried to know students' thought maps about Newton's laws of motion. In analyzing thinking maps, we focused on the aspects that students filled in thinking map, instead of the form or suitability of thinking maps. The results of the analysis of thinking map were validated using the member check method.

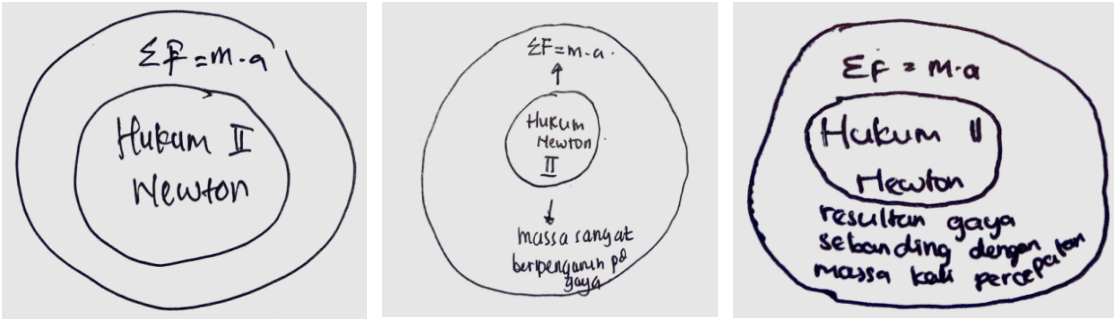
In Newton's first law, students drew thinking maps of the type of bubble map to write ideas about Newton's first law (Figure 7). Students wrote down their ideas according to what was written in the dictate book. However, based on the results of the analysis on the level of understanding, students seemed to have difficulty in applying Newton's law to solving problems. There was an error in understanding that mathematical representation $\Sigma F = 0$ was Newton's first law. Researchers assumed that students thought $\Sigma F = 0$ was that there is no force acting on a stationary object. Yet, $\Sigma F = 0$ means that the total force acting on a stationary object is equal to zero and/or when an object moves at a fixed speed.

In Newton's Second Law, thinking map ideas students tended to write mathematical ideas from



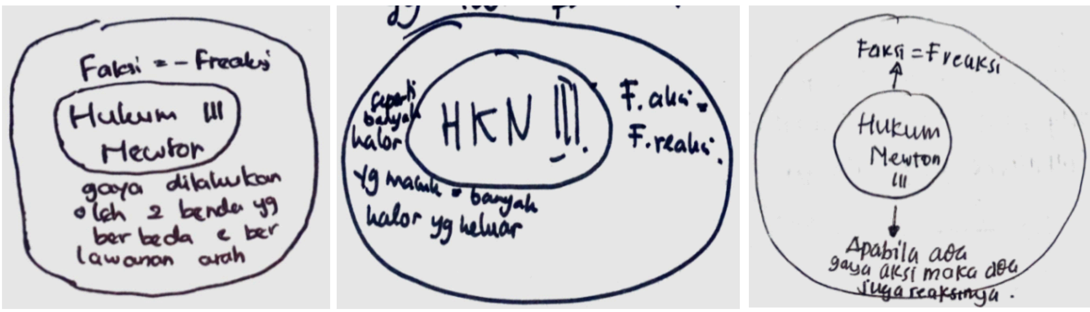
A **B**

Figure 7. Students Thinking Map about Newton's Law I



A B C

Figure 8. Students Thinking Map about Newton's Law II



A B C

Figure 9. Students Thinking Map about Newton's Law III

Newton's second law as shown in Figure 8. The idea is a statement of mathematical relations between *F*, *m*, and *a*, either in the form of mathematical representation or sentence representation. There is an error in reading the mathematical representation of Newton's Second Law, in which "the resultant force is proportional to the mass times acceleration" which should be a mathematical representation that does not indicate a comparable relationship. Other representations show that in Motion and Newton II Law where "mass is very influential on force". Researchers assume that students only think moving objects are influenced by the size of the object's mass not because of changes in speed (*v*). Yet, the resultant Style F in Newton II law is more influenced by the change in speed (*v*) or the acceleration (*a*). This shows that students still have difficulty in analyzing the resultant forces acting on moving objects.

In Newton's third law, bubble thinking map was used by students to write ideas about Newton's third law as in Figure 9. Students wrote mathematical representations of Newton's third law. Students also interpreted mathematical representations of Newton's third law by saying that the reaction force of action is equal but works in opposite directions and works on two different objects. Some of them also draw an analogy with Newton's Third Law with the Principle of Black ($Q_{release} = -Q_{receive}$). Another representation shows that $\mathbf{F}_{\mathbf{action}} = \mathbf{F}_{\mathbf{reaction}}$. The researcher assumes that students only think the force opposite to the other direction of the force is the reaction action force. Whereas, in Newton's law III, forces acting on an object will have another force that is equal in magnitude and opposite direction to a different but interacting object.

DISCUSSION

Newton Newton's Motion and Law I

Most students assume that force always occurs in moving object. This can be seen in the students' answers to the items shown in Figure 1. Students were only able to define that inertia is the ability of objects to maintain the state of motion as seen in student thinking maps. Students who considered the choice of answer A are not correct in Figure 1, the student does not yet have a good understanding of Newton's Law I and contact/non-contact force because it incorrectly considers the existence of gravitational forces. This fact is reinforced by common sense theories (Halloun & Hestenes, 1985). The common sense that is most likely to be used is "every movement is caused by force". Students who assumed that the statement on the choice of answer B in Figure 1 is incorrect, did not understand the concept of the resultant force/ Newton's II Law properly. They are most likely to use common sense "moving objects means there is a force acting on the object".

Students who consider that stationary object has no force acting on the object have misconception and do not understand the addition of force vectors properly. Based on resource theory (Hammer, 2000), students do not have a good source of knowledge about vector addition. Students state that there is a force at first, gravity, but the gravitational force is finally lost because there is a normal force. Students have a conception if there are vectors that are summed and cancelled each other, then the summed vector components finally disappear. When analyzed based on common sense taxonomy of motion (Halloun & Hestenes, 1985), students use a common sense "every movement is caused by a force" and this can be interpreted as "a stationary object has no force acting "Another common sense that supports this misconception is "things keep moving if there is always a force acting on that thing". Force is not what causes objects to move instead of maintaining the movement of objects, force is what causes the state of motion of objects to change. The findings are reinforced by the results of interviews and thinking maps that were made.

Newton's Motion and Law II

Students seem to have difficulty when applying Newton's Law II to the problem of colliding objects. Student difficulties are shown in the distribution of an-swers presented in Table 3. Newton's laws are indeed more difficult to use to solve problems related to physical conditions after collisions than linear momentum conservation laws, but can still be used to determine the acceleration and force acting on the right object during a collision. The choice of the correct answer in the question in Figure 2 is A. The students who answered choice B, think that the larger mass has greater acceleration as well. This can be explained by the principle of domination (Maloney, 1984). Students who chose C option show that they use logic acceleration proportional to force. Students who chose the C option, based on resource theory (Hammer, 2000), activate the wrong source of knowledge. The source of knowledge used is in the equation $F = m.a$, mathematically a velocity is proportional to force F. Students to assume "when the collision, the force acting on objects collides is large hence the acceleration of the object involved in the collision is also equal". Students did not pay attention to mass factors. Students who chose the D option assume that shortly af-ter the collision, the object involved in the collision will stop and then assume that the object that stops has an acceleration equal to zero. The results of the interview also confirm that students think that force causes moving objects and stationary objects to mean there is no force on the object.

Students have the conception that objects with larger masses give greater force to objects with smaller masses when they collide. To answer the questions in Figure 4 correctly, students must have an understanding of the concepts of force and mass. Students who chose A and B are likely to use common sense in accordance with the Domination principle (Maloney, 1984), "the greater the mass of the object, the greater the force the object is working on". Students who answered A assumed that "because dragonflies are smaller than a motorcycle, dragonflies get a bigger force than bicycles that have greater mass". Students who answered B focus on objects that have a greater mass hence they are interpreted to experience a greater force. They employed reversed common sense of logic.

Newton's Motion and Law III

Students who had misconceptions regarding "objects with greater speed doing greater force on objects with smaller speeds when they collide". It can be explained using common sense, the principle of Domination. The principle of domination states that objects with dominating features (for example, mass, speed, or objects that pushes force), will give a greater force. Another common sense that can support this misconception is "objects that cause other objects to move to work on a larger force". The tendency of students to use common sense is also evident from other studies (Bao et al., 2002) which show that when students are faced with Newton's Laws problems, students consider surface features (Maloney, 2007) namely masses, objects that give force (push), speed, and acceleration.

Students' Thinking Map About Newton's Law

Thinking maps drew by students seemed perfect. However, a student merely wrote what is written in the book, for example, mentioning the proportions between force and acceleration and the relation of direction and value between the force of action and the reaction force. The ideas have not reached at the level of application to the problem and have not even shown the level of understanding of Newton's laws properly. Thus, students had misconceptions when dealing with motion problems because students fail to apply their knowledge about Newton's laws of motion to concrete problems. As a result, the identification tests on Newton's laws of motion show a high number of misconceptions. In addition, the conception of students is also still influenced by common sense about motion.

The ideas written by students in thinking map show that students have correctly written mathematical representations of Newton's Third Law and are able to "read" the mathematical representation. However, it is not enough, for example, students know that $\mathbf{\Sigma F_{action} = -\Sigma F_{reaction}}$ is the value of the action and reaction force are identical but in the opposite direction, yet the student has not physically interpreted Newton's Third Law. Newton's III Law seems uncomplicated. The application of the questions in the final exercise of the book at the level of junior high school was made uncomplicated. However, the comparison of the level of misconception in Newton's Third Law occupies the highest position as shown in Table 5.

CONCLUSION

The study concluded that students assume that motion in the certain object must be pushed by force, if the object is stationary, it has no force that pushes. In addition, as for the conception of motion of colliding objects, larger objects will have greater acceleration. Another conception that is revealed is that colliding objects have an acceleration equal to zero. The conception of the relationship between the force and state of motion of objects that collide is that objects that have attributes (speed and mass) are more likely to work on larger forces on objects that have smaller attributes.

Students must be able to identify the concepts and principles of Physics that are relevant to the problem and apply their knowledge to solve problems well. However, the majority of students have conceptions that are not in accordance with scientific truths. Therefore, they are unable to solve Physics problems. Although students have been involved in learning about Motion several times before the college level, the level of student misconception remains high. This is due to students understanding of Newton's laws which is limited to textual context and have not been applied well to the problem. In addition, students still activate the wrong sources of knowledge because they are influenced by common sense.

Common sense expressed by Halloun & Hestenes (1985) cannot be avoided in Physics lesson. Common sense possessed by students will eventually become a resource of knowledge that is not in accordance with scientific truth. However, these resources can be used as a starting point in developing learning strategies hence it is important to know the knowledge resources possessed by students and also need to know the causes. This study used a thinking map as a tool to detect maps of student thinking and metacognition tools by students. Furthermore, related to common sense related to Newton's third law which has a high number of misconceptions in this study, it requires problems that do not merely ask for mathematical relationships, or direction of pairs of force reaction-action, but also the problem of collision with surface features mass, speed, acceleration, source of impulse.

REFERENCES

Bao, L., Hogg, K., & Zollman, D. (2002). Model analysis of fine structures of student models: An example with Newton's third law. *American Journal of Physics*, *70*(7), 766–778. https://doi.org/10.1119/1.1484152.

De Cock, M. (2012). Representation use and strategy choice in physics problem solving. *Physical Review Special Topics - Physics Education Research*, *8*(2), 020117. https://doi.org/10.1103/PhysRevSTPER.8.020117.

Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., … Warren, A. (2006). Scientific abilities and their assessment. *Physical Review Special Topics-Physics Education Research*, *2*(2), 020103. https://doi.org/10.1103/PhysRevSTPER.2.020103.

Formica, S. P., Easley, J. L., & Spraker, M. C. (2010). Transforming common-sense beliefs into Newtonian thinking through Just-In-Time Teaching. *Physical Review Special Topics-Physics Education Research*, *6*(2), 020106. https://doi.org/10.1103/PhysRevSTPER.6.020106.

Halloun, I. A., & Hestenes, D. (1985). Common sense concepts about motion. *American Journal of Physics*, *53*(11), 1056–1065. https://doi.org/10.1119/1.14031.

Hammer, D. (2000). Student resources for learning introductory physics. *American Journal of Physics*, *68*(S1), S52–S59. https://doi.org/10.1119/1.19520.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158. https://doi.org/10.1119/1.2343497.

Holzner, S. (2006). *by Steven Holzner* (1st ed.). Indianapolis: Wiley Publishing, Inc.

Kuo, E., Hull, M. M., Gupta, A., & Elby, A. (2013). How students blend conceptual and formal mathematical reasoning in solving physics problems. *Science Education*, *97*(1), 32–57. https://doi.org/10.1002/sce.21043.

Linuwih, S. (2011). *Konsepsi paralel mahasiswa calon guru fisika pada topik mekanika* (Unpublished doctoral dissertation). Universitas Pendidikan Indonesia, Bandung, Indonesia.

Lin, S.-Y., & Singh, C. (2015). Effect of scaffolding on helping introductory physics students solve quantitative problems involving strong alternative conceptions. *Physical Review Special Topics-Physics Education Research*, *11*(2), 020105. https://doi.org/10.1103/PhysRevSTPER.11.020105.

Malone, K. L. (2008). Correlations among knowledge structures, force concept inventory, and problem-solving behaviors. *Physical Review Special Topics - Physics Education Research*, *4*(2), 020107. https://doi.org/10.1103/PhysRevSTPER.4.020107.

Maloney, D. P. (1984). Rule-governed approaches to physics - Newton's third law. *Physics Education*, *19*(1), 37–42. https://doi.org/10.1088/0031-9120/19/1/319.

Potgieter, M., Malatje, E., Gaigher, E., & Venter, E. (2010). Confidence versus performance as an indicator of the presence of alternative conceptions and inadequate problem solving skills in mechanics. *International Journal of Science Education*, *32*(11), 1407–1429. https://doi.org/10.1080/09500690903100265.

Putra, I.A. & Sujarwanto, E. (2018). Analisis pemahaman konseptual mahasiswa pada materi kinematika partikel melalui tes diagnostik. *Jurnal Riset dan Kajian Pendidikan Fisika*, *5*(1), 10–16. http://dx.doi. org/10.12928/jrkpf.v5i1.8923.

Sudibyo, M.I., & Supardi, Z.A.I. (2013). Profil konsepsi hukum Newton dan kecakapan berpikir kritis mahasiswa angkatan 2012 kelas internasional prodi pendidikan Fisika FMIPA Universitas Negeri Surabaya. *Jurnal Inovasi Pendidikan Fisika*, *2*(3), 38–43.

Sutopo. (2016). Pemahaman mahasiswa tentang konsep-konsep dasar gelombang mekanik. *Jurnal Pendidikan Fisika Indonesia*. *12*(1), 41-53. https://doi.org/10.15294/jpfi.

Thornton, R. K., & Sokoloff, D. R. (1998). Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula. *American Journal of Physics*, *66*(4), 338–352. https://doi.org/10.1119/1.18863.

Walsh, L. N., Howard, R. G., & Bowe, B. (2007). Phenomenographic study of students' problem solving approaches in physics. *Physical Review Special Topics-Physics Education Research*, *3*(2), 020108. https://doi.org/10.1103/PhysRevSTPER.3. 020108.