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# The Use of Understanding by Design in Designing the Physics Lesson Plan about Newton's Second Law

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## ABSTRACT

Learning objectives, learning evaluation, and learning steps are the essential components in a lesson. They have to be interconnected to provide a qualified learning for students. Physics learning about Newton's Second Law faced problems in connecting those learning components. This study aims to make an alternative design of physics lesson about Newton's Second Law using Understanding by Design (UbD). The lesson plan and the review sheet were submitted to three reviewers. All data collected from the review sheet were analyzed using a descriptive qualitative method as the basic to revise the initial design into a better final design. The design was revised based on the recommendations of the reviewers. UbD can be used as an alternative design of physics lesson about Newton's Second Law. Designing a lesson using UbD is helpful in connecting the objectives, steps, and learning evaluations so that the students can achieve the objectives of the lesson.

**Keywords**: Newton's Second Law, Understanding by Design (UbD), physics learning

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## 1. Introduction

Learning objectives, learning evaluation, and learning steps are important components in a learning process (Dolong, 2016). All of these components must be interrelated to form a complete learning system (Dolong, 2016) through the design of lesson plans in order to achieve the specified competencies (Setyawanto, 2012). However, the competencies or learning objectives that have been made may not be achieved. Wiggins and McTighe (2005) found that there are several things that have become problems in designing a lesson plan, for example, teachers who prioritize the learning materials delivery based on the scope of the textbooks rather than the scope of learning objectives; evaluation questions are usually made before the test and they are only copied from the textbooks, without considering the relevance to the learning objectives and the learning steps; and the learning steps that are arranged only based on teacher's experience, as well as various learning methods and suitable models that have not been explored for the teaching materials (Wiggins & McTighe, 2005), and as a result, the learning objectives, learning steps, and learning evaluations are not often interrelated and it results in the lack of the learning quality.

Qualified learning will surely support the achievement of learning objectives and enhancement of the education quality (Yusup, 2017). In general, the learning quality is comparable to the results of evaluations that have been done by the students (Yusup, 2017). In this study, the learning quality

in a lecture of Fundamental Physics on Newton's Second Law was reviewed from the lecturers' and the students' point of view. It was done by looking at the relevance to the learning objectives, evaluations and learning steps of Newton's Second Law that have been carried out over the past few years at one of the private universities in Central Java.

Based on the teaching documents files owned by the teachers, learning objectives and evaluation questions have been related to each other. However, the results of the evaluation tests have not been satisfying. Based on the results of interviews with the lecturers of Fundamental Physics course at one of the private universities in Central Java, the difficulty in teaching Newton's Second Law material was that the concept of force is an abstract concept so that visualization was needed to help the students to understand and it needed something to attract the students' interest to practice doing the exercises. In addition, the duration of the lectures was inadequate for learning the material deeply because the students only wanted to do the exercises when they were in the class with the guidance of lecturers. With regard to this, the results of interviews with the students who took the Fundamental Physics course generally showed that they had difficulty in working on Newton's Second Law evaluation questions given by the lecturer. They claimed to have difficulty in analyzing the questions because these were descriptive answers that needed logic and accuracy to get the correct answers. Moreover, they were lack of experience in doing various questions as there were not enough practice on such questions and they could not predict the variation of questions that would appear in the evaluation. As a result, when there were rather complex evaluation questions, they had difficulty in working on them. This shows that the students do not know why learning a material must be evaluated by a specific evaluation instrument but they are not equipped with sufficient knowledge and ability to do it. Therefore, it needs to make an improvement of the learning quality using the proper method to design lesson plans where learning objectives, evaluation, and learning steps are truly interrelated and they will equip the students to achieve the expected competencies.

Understanding by design (UbD) or popularly known as the Backward Design is referred to as a learning approach focusing on the student's learning objective and comprehension (the learning objectives and the students' understanding). The Ubd approach is made as an alternative solution to improve learning quality by making connection between the objective, steps, and evaluation of the learning. In this UbD approach, the learning activities are designed by setting the learning objectives, making instruments of learning evaluation, and building the learning steps.

In the UbD there is a pedagogic term called "Twin Sins of Traditional Design" i.e. mistakes in learning because first, teachers only focus on the learning steps yet they do not adjust them with the learning objective and second, they only use text books as the primary source of studying. The activity-based curriculum puts less emphasis on the important ideas as well as appropriate goal of learning, especially concerning the students' understanding. They commonly consider that their task is to get engaged in the learning process, they are told to think that learning is simply an activity rather than to see that learning in fact is to understand the meaning of the learning itself. Another mistake that most teachers make is they ask the students to read the text books page by page to obtain information and ideas of the subject.

It is suggested that the teachers set the objectives in advance before applying them into the lesson. When the desired objective or output have been set, it would be easy for the teachers to develop the instruction and assessment about the result of the learning activities. If the learning objective of a subject has been clearly set, they will definitely have a better idea concerning what they want the students to obtain after the learning activities have been completed. The backward design can

also minimize the possibility of performing the learning activities without obvious objective. It is essential that they include ideas and purpose in the instructions and assignment in accordance with the main goals of the subject the students are learning. Teaching does not always mean to get students involved in the learning activities; it requires that students have adequate ability to comprehend the whole ideas in the subject. The students' learning and understanding of subjects can be measured accurately using backward design approach, since it provides students with basic necessities to understand the whole ideas in the subject during the learning activity. When teaching, the teachers are required to be coaches for the students' ability to get actively involved in the learning processes and understanding, not to be the tellers of their understanding to the students on the sidelines. One of the objectives of the UbD is to assist the students to obtain key knowledge through learning and to transfer the knowledge from the context given by the teacher on their own to themselves. (Wiggins & McTighe, 2005)

The problem of this research is whether Understanding by Design can be used as an alternative design of physics lesson about Newton's Second Law. The purpose of this study is to make an alternative lesson plan of Physics about Newton's Second Law using Understanding by Design (UbD). This research will be beneficial to provide examples of the application of Understanding by Design as an alternative lesson plan that can improve the learning quality.

## 2. Materials and Methods

There were some steps in finishing process of this research,including those in making lesson plan, collecting data, and processing data. Those steps were shown at Figure 1 below:

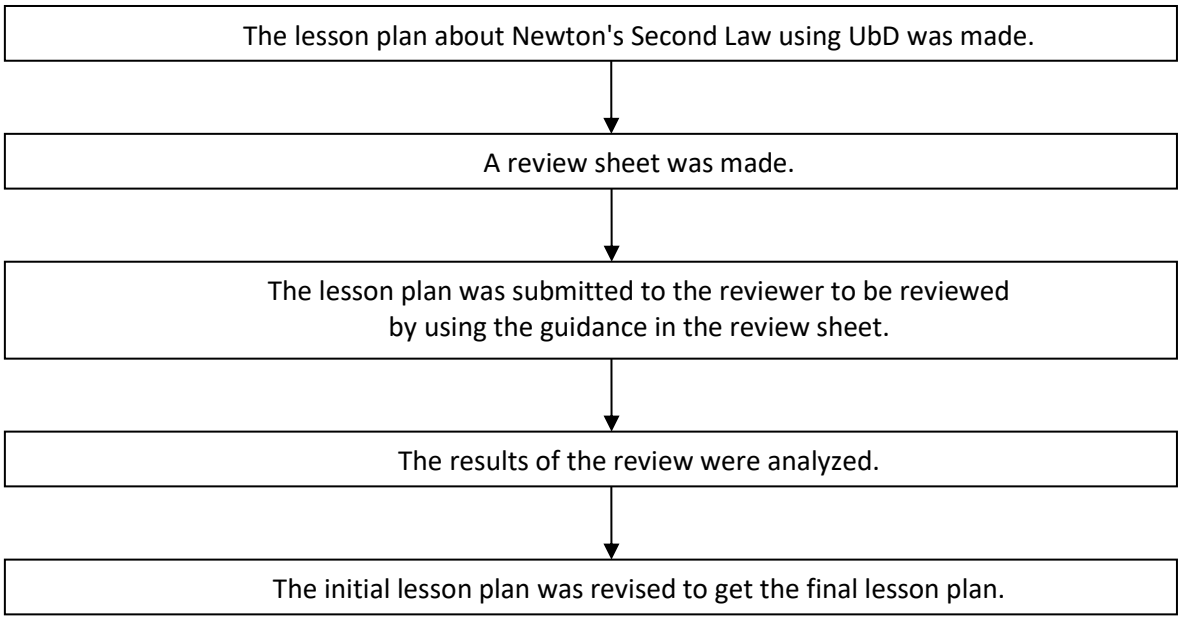


**Figure 1.** Research steps.

The details of the steps explained in **Figure 1** can be seen as follows:

*Step 1.*
The lesson plan about Newton's Second Law was made using UbD. It consists of three stages: Stage 1 – Learning Objectives, Stage 2 – Learning Evaluation, and Stage 3 – Learning Steps. The UbD

template used in this study is simpler than the UbD template from Grant Wiggins and Jay McTighe since it is made based on the context of European education, so it needs to be adjusted to the Indonesian education context. The UbD template used in this study can be seen in Table 1.

**Table 1.**UbD templates which is appropriate with the Indonesian education context.

| Stage 1 :Learning Objectives<br>Stage 2 :Assessment&Learning Evaluation |
|---|
| 1. Learning Objectives<br>1.1. Learning Assessment<br>1.1.1. Learning Evaluation<br>1.1.2. Learning Evaluation<br>Etc. |
| 2. Learning Objectives<br>2.1. Learning Assessment<br>2.1.1.Learning Evaluation<br>2.1.2. Learning Evaluation<br>Etc. |
| Etc. |
| Stage 3 : Learning Steps<br>Time Allocation :<br>Material : |
| - Lecturers and the students activities during the learning and teaching session<br>- Exercises |

The three UbD stages have their own coverage. Stage 1 which contains learning objectives is made based on basic concepts of Newton's Second Law which must be mastered by the students. These basic concepts are the basic abilities to achieve certain competencies. Stage 2 contains assessments and learning evaluations which are made based on the learning objectives on Stage 1. Assessments contain descriptions of student acquisition measurement so that the operational verb on Bloom's Taxonomy is used in the assessment statements. The learning evaluation contains questions that test the students' understanding of Newton's Second Law. The form and type of questions are adjusted so that the students can think critically in a variety of real contexts where Newton's Second Law can be applied. Stage 3 contains learning steps in the form of lecturer and student activity description in the classroom to equip the students with basic abilities stated in the learning objectives and exercises to strengthen the students' understanding so that at the end of the lesson the students can work on the evaluation questions. These learning steps are taken from active learning steps that have been used and are generally effective for teaching this material.

*Step 2.*
After the learning design was complete, the review sheet was made as a guide for the reviewer to

see the relevance among the learning objectives, evaluation, and steps in the detailed learning design. Items in the review sheet were in the form of questions with "no", "fair", and "yes" answer options to state the relevance of the three stages in the design that were made along with the response/suggestion column for the design.

*Step 3.*

There were three physics teachers who became reviewers in this study. The lesson plan and the review sheet were submitted to the reviewers to be reviewed.

*Step 4.*

All data collected from the review sheet were analyzed using a descriptive qualitative method as the basic to revise the initial design into a better final design.

*Step 5*.

Then the design was revised according to the recommendations of the reviewers. The initial lesson plan was revised to get the final lesson plan.

## 3. Results and Discussion

The lesson plan that was made with the three stages in UbD was a lesson plan about Newton's Second Law. Stage 1 contained the learning objectives, the ones which were made to make the students understand that an object with a resultant force not equal to 0 will move with a speed that changes regularly or changes irregularly with a formula $\sum F = ma$.

Stage 2 contained evaluations and assessments. There were 3 assumptions for 15 evaluations made in the form of 2 written tests and 1 practical test. The assessments were (1) from the existing case/system in which the students were assigned to identify a system that fulfills Newton's concept of Second Law and to describe a force diagram that works in various cases/systems; (2) the students were given several questions to calculate physical quantities (force, time, distance, speed, and acceleration) based on Newton's Second Law equation and GLBB; and (3) the students were assigned to analyze physical quantities (force, time, distance, speed, and acceleration) in a video of moving objects on a flat area and on an inclined area using the tracker analysis program. The form of evaluation questions were varied in order to provide space for the students to think critically so that they must use logic to do it. Evaluation questions were made varied aiming at the students not to work on monotonous questions and only to memorize the material. The selected case/system was the one that was simple and close to the students' daily life, which was also often contained in reference books.

In the assessment (1) there were 10 evaluation questions. It was in the form of a case/system that must be identified and the students were assigned to find a case/system that fulfills Newton's Second Law and drew a force diagram for each given case. Five questions were deceptive questions about Newton's Law 1 (1.1.a, 1.1.d, 1.1.f, 1.1.h, 1.1.i).

In the assessment (2) there were 5 evaluation questions. On the first evaluation problem, there was an object placed on the slippery floor, and then the object was given a force forming an angle towards the floor. The students were assigned to describe the system to find out the magnitude of the acceleration experienced by the object, as well as to find the distance and speed experienced by the object with a predetermined time. On the second evaluation problem, two objects were attached to a slippery pulley. The mass of the two objects were known. The students were assigned to draw the forces acting on the system, and then to calculate one of the accelerations experienced

by the objects, and to calculate the amount of rope tension experienced by one of the objects. On the third evaluation problem, a child with a known mass was in a moving up elevator. When the elevator moved up, the weight of the child changed and the weight changes were noted. The students were assigned to find out the speed of the elevator when moving. On the fourth evaluation problem, a motorcycle with the known motorcycle and driver masses moved at the speed that was noted, at a certain distance there was a car that suddenly stopped as it stalled. The students were assigned to find out the required force so that the motorbike could stop and would not hit the car and they should also find out the time needed for the motorcycle to stop. On the fifth evaluation question, two objects were attached on a fixed and slippery pulley. Both objects were on the rough inclined area. Both object masses, slope angle, magnitude of gravitational acceleration, and friction coefficient were known. The students were assigned to describe the forces acting on the system, to find out the magnitude of the system's acceleration and direction, and to find out the tension of the rope on one side.

Different from the assessment (1) and (2) in which evaluations were in the form of a written test, evaluation of assessment (3) was a practical test. This was done to test the students' comprehension accurately. The evaluation problem on assessment (3), the students were given two videos displaying an object that moves on a flat and inclined area. The students then were assigned to calculate the physical quantities (force, time, distance, speed, and acceleration) using the tracker analysis program, then they were assigned to find the speed and acceleration of objects in the video using the position and time of the tracker analysis manually, and to compare their results with the results of the tracker analysis that have been obtained.

On Stage 3, the learning step is designed. In the initial activity, the first learning step is that the lecturer reviewed Newton's Second Law, GLB, and GLBB materials. On the second step, the students were given two videos displaying an object moves on a flat area and an object moves on an inclined area. On the third step, the lecturer held a demonstration with the help of a student to analyze the physical quantities (force, time, distance, speed, and acceleration) in the first video, namely an object that moved on a flat area using a tracker analysis program. Then the students were assigned to calculate speed and acceleration (with data of position and time obtained from the tracker analysis results) manually and to compare the results with the results of the tracker analysis. On the fourth step, the lecturer discussed the work of the students. On the fifth step, the lecturer divided the students into two groups and gave each group a picture of a case of an object that moved on a different rough are a related to Newton's Second Law, and mentioned and explained 3 other cases that fulfill the concept of Newton's Second Law. On the sixth step, the lecturer assigned the representatives of each group to come to the front of the class and to write down the results of the discussion on the board. On the seventh step, the lecturer corrected and discussed the results of the discussion of each group and explained the picture about working force vector of a moving object on a flat area if the floor was slippery. On the eighth step, the lecturer gave two exercises about Newton's Second Law to the students; in this case the students were assigned to draw the force vector and to find out the physical quantities (force, time, distance, speed, and acceleration). On the ninth step, the lecturer assigned 2 students to come to the front of the class and to write down the results of their work on the board. On the tenth step, the lecturer corrected and discussed the students' works that had been written on the board. Meanwhile, on the eleventh to the eighteenth steps were the same as the second to the tenth step, but the eleventh step was a combination of the second and third steps with the case/system was an object that moved on an inclined area.

The three UbD stages that have been made were then reviewed by the reviewers using a guide in the form of a review sheet. After the lesson plan was reviewed by the reviewer, there were several suggestions/inputs that were useful to improve the lesson plan that has been made.

**Table 2.**The relation among learning objectives, learning evaluations and learning steps.

| Learning Objectives | Evaluation | Learning steps |
|---|---|---|
| 1. The students can understand that an object that has a force not equal to 0 will move regularly or irregularly with formula $\sum F = ma$ | 1.1. Decide which system that fulfills the concept of Newton's Second Law and draw a force diagram on each system (1.1.a–1.1.j)! (Written Test) | 5-7<br>13-15 |
| | 1.2. Calculate the physics magnitudes (force, time, distance, speed and acceleration) on an object that moves based on equation of Newton's Second Law and GLBB (1.2.1-1.2.5). (Written Test | 8-10<br>16-18 |
| | 1.3. Determine the extent of distance, time, speed and acceleration of an object in the following video using *software Tracker* then calculate the total working force of the object using equation of Newton's Second Law $\sum \mathrm{F} = \mathrm{m\ a}$. (Practical Test) | 2-4<br>11-12 |

Based on the results of the review in Table 2, the learning objectives, learning evaluations and learning steps have been interrelated. First, the learning objectives (1) were related to learning evaluation (1.1). Both were related to the learning steps (5)–(7) and (13)–(15). Second, the learning objectives (1) were related to the evaluation (1.2). Both were related to the learning steps (8)–(10) and (16)–(18). Third, the learning objectives (1) were related to the evaluation (1.3). Both were related to the learning steps (2)–(4) and (11)–(12).

**Table 3.**Results of exercise problems correction (1.1.b).

| Before corrected | After corrected |
|---|---|
| Vertical upward motion with initial velocity of $v_0$ with time from t = 0s to t = 4s is shown in the figure below. Describe the force acting on the ball when it is at its peak! | Vertical upward motion with initial velocity of $v_0$ with time from t = 0s to t = 4s is shown in the figure below with t = 4s is the time when the ball reaches its peak. Describe the force acting on the ball when it is at its peak! |

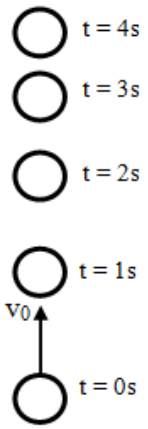


**Figure 2.**The ball is thrown vertically in the evaluation (1.1.b).

The result of the first review located in the evaluation number (1.1.b), given the suggestion to add the statement "t = 4s is the time when the ball reaches its peak", as shown in Table 3 and Figure 2. The suggestion was accepted because if the information was not given, it would lead to the perception that it could be when t = 4s the position of the ball has not yet at the top point.

**Table 4.**Correction result on evaluation (1.1.c).

| Before corrected | After corrected |
|---|---|
| An object associated with a spring moves on a rough floor. The position of the object from t = 0s to t = 4s is shown in the figure below. | An object associated with a spring is pulled and moves on the rough floor. The position of the object from t = 0s to t = 4s is shown in the figure below. t = 0s is a spring equilibrium point. |

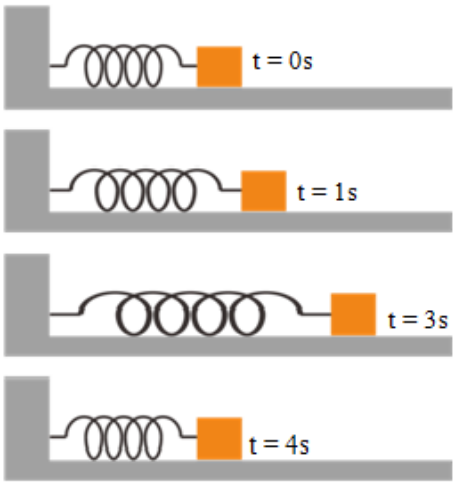


**Figure 3.**System in the exercise (1.1.c).

The result of the second review could be found in the evaluation number (1.1.c) with a suggestion to add information that the spring moved because it was drawn and the spring position was balanced at t = 0s, as shown in Table 4 and Figure 3. The suggestion was accepted to clarify the caption of the figure.

**Table 5.**Correction result of evaluation number (1.1.e).

| Before corrected | After corrected |
|---|---|
| The ball position in water from t = 0s to t = 7s is illustrated in the scheme below. | A ball is dropped into a container filled with water. The ball positions from t = 0s to t = 7s are illustrated in the scheme below. |

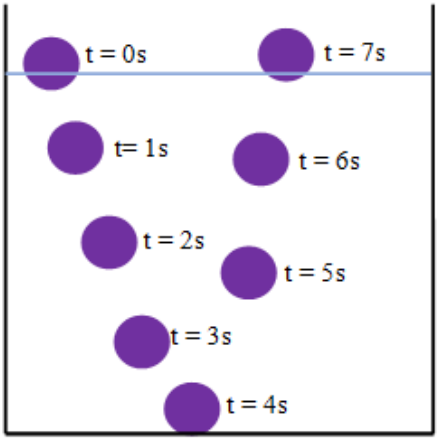


**Figure 4.**System in the exercise (1.1.e).

The result of the third review was located on the question of the evaluation number (1.1.e) with a suggestion to add a statement "the ball is dropped into a container filled with water", as shown in Table 5 and Figure 4. The suggestion was accepted to clarify that the ball did not have an initial velocity because it was only released and it was not thrown. The next suggestion was that the motion of the ball was affected by water flow, and it was not accepted because the condition of the water would be calm and would not stream if it was in a container.

**Table 6.**Correction result of evaluation number (1.2.4).

| Before corrected | After corrected |
|---|---|
| A motorcycle moves at a speed of 40 m/s, at a distance of 40 m and right in front of the motorcycle a car suddenly breaks down and stops immediately. The mass of the motorcycle is 200 kg. What force is needed to stop the motorcycle so that it can stop and it does not hit the car? How long does it take until the motorcycle stops? | A motorcycle moves at a speed of 12.5 m/s, at a distance of 40 m right in front of a motorcycle a car suddenly breaks down and stops immediately. The mass of the motorcycle is 200 kg and the mass of the rider is 48 kg. What force is needed to brake the motorcycle so that it can stop and it does not hit the car? How long does it take until the motorcycle stops? |

The result of the fourth review was found in the evaluation number (1.2.4) with a suggestion to add the mass of the driver, as shown in Table 5. The suggestion was accepted because the mass of the rider also affected the weight of the motorcycle.

The results of the fifth review could be found in the learning steps number (3) and (11) with a suggestion to add information that the position and time data to calculate the speed and acceleration using the GLBB equation was taken from the tracker analysis data, as shown in Table 7. This suggestion was accepted to clarify instructions in that learning step.

**Table 7.**Correction result of learning steps (3) and (11).

| Before corrected | After corrected |
|---|---|
| 3. The students were assigned to find the speed and acceleration of an object moving on a flat area as shown in a video using the GLB/GLBB equation and the students were asked to calculate the forces experienced by the object using Newton's Second Law equation that works on it. | 3. The studentswere assigned to find the speed and acceleration of an object moving on a flat field as shown in a videowith the position and time data obtained from the results of tracker analysis using the GLB/GLBB equation and the students were asked to calculate the forces experienced by the object using Newton's Second Law equation that works on the object. |
| 11. The studentswere assigned to find the speed and acceleration of an object moving on an inclined area as shown in the video using the GLB/GLBB equation and the students were asked to calculate the forces experienced by the object using Newton's Second Law equation that works on the object. | 11. The studentswere assigned to find the speed and acceleration of moving object on an inclined field as shown in the video with the position and time data obtained from the results of tracker analysis using the GLB/GLBB equation and the students were asked to calculatethe forces experienced by the object using Newton's Second Law equation that works on the object. |

**Table 8.**Correction result of learning steps (5) and (13).

| Before corrected | After corrected |
|---|---|
| 5. The lecturer separated the students into 2 groups and then each group was given a different case and assignment to discuss and draw working force vector in the case, and mention 3 cases that fulfill Newton's Second Law. | 5.The lecturer separated the students into 2 groups, then each group was given a different case (illustration of the case and the information can be found in the learning step number 6) and they were assigned to discuss and draw the working force vector in the case, and to mention 3 cases that fulfill Newton's Second Law . |
| 13. The lecturer separated the students into 2 groups, each group was given a different case and assignment to discuss and draw the working force vector in that case. | 13. The lecturer separated the students into 2 groups, then each group was given a different case (description of the case and the information is in step 14) and assignment to discuss and draw the working force vector in that case. |

The results of the sixth review could be found in the learning steps number (5) and (13) with a suggestion to add the information that "figure of the case that will be given to the student group described in steps number (6) and (14)", as shown in Table 8. This suggestion was accepted so that it was shown that the learning step in question was interrelated.

Every lesson plan that is made surely has several advantages and disadvantages. The most important thing in making the design and lesson plan is among the learning objectives, learning steps, and their interrelated evaluations. The first advantage, when using UbD as an alternative lesson design is that the relationship among the learning objectives, learning steps, and learning evaluation that becomes a deliberate focus in making of lesson design so that the lesson will be effective for the students. The second advantage is that the evaluation model is made various and it provides space for the students to think critically so that they have to use their logic to do it. The evaluation questions are made various also with the aim that the students will not work on monotonous questions and will not only rely on memorizing of the material. The shortcoming in

this design is that in using the tracker analysis program, teachers are required to master the program in order that teachers can guide their students to comprehend in using the program. In addition, the thing that needs to be anticipated is the use of this tracker analysis program which requires a longer time to ensure that each student can use this program properly.

Several previous studies have emphasized on the important aspects in making lesson designs. Sgro and Freeman (2008) emphasized that a lesson that focuses on the students' understanding and provokes the students to think critically. They stated that one of various assessment clues that show students' comprehension is that they will be able to critically value the efficacy of recent manufacturing systems so that they can change those systems by themselves (Sgro & Freeman, 2008). In the lesson plan created in this study, it has focused on the students' comprehension for critical thinking. It can be seen when the students were able to work on varied evaluation questions. In working on these evaluation questions, the students were required to think critically using their logic and to apply the concept of Newton's Second Law concerning the dynamics of the motion of objects. Sergio and Steve's research confirms that the lesson plan created in this study is good enough to be used.

The students' comprehension is certainly related to concepts and misconceptions. The hardest part in studying physics is the abundance of abstract physical concepts that will likely cause the students to experience misconceptions (Wulandari, 2014). This misconception will influence the consistency of the students in answering evaluation questions (Yudianti, 2013). The results of the study conducted by Tuder and Urban (2015) showed that the type of misconception experienced by the students on lesson of Newton's Law is that they are confused about understanding of force, speed, and energy. It is clear that some students are unaware with the real definition of physics and the differences between those three terms. Thus, they can't distinguish each of them has a direction or not (Tuder & Urban, 2015). All types of misconceptions are very important to be remedied so that the students can understand a concept correctly and thoroughly. In our lesson plan, we have not considered about prevention or remediation of those misconceptions because we only focused on made the connection or linkages between the learning objectives, learning steps, and learning evaluations. It has become one of the shortcomings in this design and it can be revised in future studies.

In addition to the students' understanding and misconceptions, the choice of lesson methods is very important to consider because lesson methods determine the students' understanding of the material. Wittmann and Anderson (2008) found the results that teaching of Newton's Second Law material is best performed by using the Tutorial method in Introductory Physics (TIP) compared to Activity-Based Tutorials and Open Source Tutorials based on the results of evaluations done by the students. In addition, TIP is specially designed for the students in order to gain answers based on facts, to accept if their answers are wrong, and to solve the problems related to physics (Wittmann & Anderson, 2008). This TIP method can be integrated in the UbD to improve the lesson plan that has been made, because this TIP method works by exposing the students to the experience so that it is possible to remedy the students' misconceptions when they have repeated incorrect answers in doing the exercises.

## 4. Conclusion and Remarks

UbD can be used as an alternative design of physics lesson about Newton's Second Law. Designing a lesson using UbD is very helpful in connecting the learning objectives, learning steps, and learning

evaluations so that the students can achieve the objectives of the lesson. When using this design, it is suggested to develop it in order to anticipate/overcome misconceptions from the students.

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