The Learning Reconstruction of Particle System and Linear Momentum Conservation in Introductory Physics Course

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Abstract. This study is initiated by low achievement of prospective teachers in understanding concepts in introductory physics course. In this case, a problem has been identified that students cannot develop their thinking skills required for building physics concepts. Therefore, this study will reconstruct a learning process, emphasizing a physics concept building. The outcome will design physics lesson plans for the concepts of particle system as well as linear momentum conservation. A descriptive analysis method will be used in order to investigate the process of learning reconstruction carried out by students. In this process, the students’ conceptual understanding will be evaluated using essay tests for concepts of particle system and linear momentum conservation. The result shows that the learning reconstruction has successfully supported the students’ understanding of physics concept.

1. Introduction

Common lecturers expect that expected learning objective should be achieved effectively by students in each learning process. Ideally, lecturers should have given their knowledges comprehensively in conducting the materials. In fact, some students still could not achieve these learning objectives. In this research, the learning of introductory physics course, which has been investigated for two years reports the students’ average score achievement. The students’ score of unit test II has gained by 41/100 in the academic year of 2012/2013 and by 46/100 in the academic year of 2013/2014. In accordance with the students’ answers analysis, it shows that 65% students feel difficult in understanding the concept of both particle system and linear momentum conservation.

According to conceptual difficulties encountered by students, a diagnostic test has been given to students, who have learned the concept previously. The preliminary study has found students’ specific difficulties in the concept of momentum. Firstly, students feel difficult in applying some concepts of momentum defined qualitatively. Students often solve a qualitative question without the appropriate physics principles. Secondly, students consider that a concept of momentum is rather equal to a concept of energy as a scalar quantity. Thirdly, students have difficulties in applying a conservation law of linear momentum for novel physics exercises such as an object with a different mass. For instance, students are too focused on a velocity parameter during solving a momentum problem. Fourthly, there are some fallacies related to the applicability of momentum conservation law concept not only for a system but also for a particular object. Fifthly, students are not able to describe a
momentum, momentum changes, and an impulse expressed in vector representations [1]. This result of the students’ diagnostic test shows that students’ conceptual understanding needs to be further improved.

A learning process is one of the important aspects for the improvement of students’ conceptual achievement [1-2]. According to the preliminary studies and the reflection of the previous learning process, the previous learning cannot facilitate students in constructing their knowledges. These problems will be solved adapting several actions as previously proposed by McDermott [3]. The learning construction deficiency will be observed from the classroom activity as well as the lesson plan analysis. The observation shows that the previous learning process is based on transferring materials and providing some problem-solving exercises. This learning process poorly facilitates students to directly construct the knowledge themselves [3]. Students usually receive the physics concepts presented by telling without any comment, but these concepts are easy to lose from the student’s mind. The informative learning conducted by a lecture will result the ineffective learning. Therefore, the learning reconstruction should be designed to keep the students’ mind [4].

The learning reconstruction is also an important for developing a curriculum. Heuvelen has successfully integrated instructional approaches in an introductory physics course exploring physics problem-solving using multiple representations [5]. Aiello-Nicosia and Spерандеo-Mineo have reconstructed physics contents conducted for pre-service teachers [6]. Moreover, Duit has provided an educational reconstruction framework investigating both a design and an evaluation of learning environment [7]. In this study, the effective learning form in constructing physics concepts achieved by students will be investigated. The learning reconstruction will be limited to the physics concepts of particle system and linear momentum conservation comprehended by pre-service physics teachers.

2. Method
The descriptive study will be employed to analyze the learning reconstruction process towards students’ physics-conceptual understanding. Research subjects that involved in the conventional learning and the reconstructed learning were respectively 43 and 41 prospective physics teachers taking the introductory physics course (PHY 100) in the academic year of 2014/2015 at Indonesia University of Education, Bandung. The students’ conceptual understanding will be tested using six questions representing topics of the particle system and linear momentum after implementing the learning reconstruction process.

3. Discussion
This section will discuss about the learning reconstruction and the students’ conceptual understanding achievement.

3.1. The learning reconstruction
The learning reconstruction is designed based on the analysis of student difficulties in learning the concepts of the particle system and linear momentum conservation. Reconstruction activities are undertaken including determining the expected learning objectives, the learning sequences, and the evaluation. The meetings are conducted four times consisting of 100 minutes (2 credits) for each lecturing. The learning reconstruction lesson plan will be constructed referring to a lesson plan as given in table 1.

The previous lesson plan is started with an introduction showing the content that will be studied, and it is followed by elaborating main contents exercised by some practice questions. This learning process emphasizes quantitative problem solving questions rather than qualitative questions. Unfortunately, this condition will affect to the less construction of students’ knowledge. The learning could not explore the students’ conceptual difficulties, which should be accomplished to improve students’ comprehensions in the basic concepts of physics [3].
The learning reconstruction is then designed in order to improve the students’ conceptual comprehension. Table 2 shows a draft of learning reconstruction. This learning reconstruction design is developed referring to five stages of learning model firstly developed by Driver and Oldham [11]. Generally, the stages include orientation, elicitation, restructure, application and review. For example, a learning reconstruction for the first meeting explaining the sub-concept of mass center will be described. The expected learning objectives reveal that a "particle" approach for all kinematics and dynamics cases can be accounted directly. This phenomenon indicates that a mass center concept is important to understand the particle system motion characteristics. Afterward, the mass center position

| Basic competencies | Indicators | Topic / Sub-Tops | Learning Experiences | Media | Evaluation | Sources |
|--------------------|------------|------------------|---------------------|-------|------------|---------|
| To master the basic concept of linear momentum and collisions comprehensively, and to develop and to apply concept of physics in accordance with the development of science and technology | • Describing and formulating the center of mass.  
• Describing the motion of mass center.  
• Describing, formulating and applying the linear momentum of particles.  
• Describing, formulating and applying the linear momentum of particle system.  
• Describing, formulating and applying the law of linear momentum conservation.  
• Describing the collision and impulse.  
• Applying the law of energy conservation and momentum during collisions.  
• Describing and analyzing the elastic collisions in one and two dimensions.  
• Analyzing and describing the system due to mass changes. | Linear momentum and collisions | • The center of mass  
• The motion center of mass  
• The linear momentum of a particle  
• The linear momentum of the particle system  
• The conservation of linear momentum  
• The collision and impulse  
• The law of energy conservation and momentum during collisions  
• The elastic collision in one dimension  
• The elastic collision in two and three dimensions  
• The systems with mass changes | • Receiving and discussing the information about the mass center, the motion of mass center and linear momentum of a particle and particle systems.  
• Observing the demonstrations and discussing the collision and the momentum conservation law.  
• Receiving and discussing the elastic collision compared to the inelastic collision  
• Receiving and discussing the collision in one and two dimensions.  
• Receiving and discussing the system due to mass changes.  
• Practicing the relevant questions | • Computer  
• OHP  
• Air track | • Homework 6  
• Mid-term exam | • Page: 240 - 300  
• Tipler (Basic Physics Book) |
can be determined as discrete and continuous particles mathematically. Finally, the mass center position of irregular shapes can also be determined experimentally.

Table 2. The learning reconstruction process design

| Previous Learning Construction | Deficiencies | Learning Reconstructions |
|-------------------------------|--------------|--------------------------|
| Preliminary activities        |              | Orientation              |
| Exposure of the subject matter and the sub-subject matter that will be studied | • The lecturing was not begun from a related previous concept review | • The previous learning review has engaged students to recall their previous concepts. |
|                               |              | • The lecturing did not motivate student to learn in physics concepts in detail | • The learning has been started with a demonstration and a video simulation of related physics phenomena motivating students |

| Core activities | Elicitation and Restructure | Application |
|-----------------|-----------------------------|-------------|
| Explanations of all concepts | • Students have less opportunities in elaborating, discussing, and constructing the concept | • Students discuss the comprehensive concept of momentum |
|                   | • Learning is mainly dominated by a lecturer as an actor while a student as a knowledge receiver (transfer of knowledge) | • Students arrange some solutions solving the main physics problems. |
|                   | • Students’ experiences only focus on minds-on activities rather than hands-on activities [8-9] |             |

| Closing Activities | Review |
|--------------------|--------|
| Giving exercises to check the student’s conceptual understanding | Students are well-guided to solve some problems in a new situation and context. |

In this first step of orientation, a learning reconstruction is started by arranging some groups. The lecturer considers the students’ distribution based on their academic abilities and gender in order to reach better students’ discussions. A lecturer is conducting initially by recalling student’s prior knowledge about a particle obtained from the previous meeting. In this question, a lecturer said“ can a particle approach be justified as a truth?”. In this first stage, students will discuss in group, and they write the results on a worksheet. This activity will review student’s knowledge obtained from the previous learning. In these discussions based on their answers on the worksheets, students commonly express that all sized-objects are viewed as a particle when they are moving. This students’ answers are quite right for a while, before learning objects as a rigid body. Interestingly, despite the false answer, some students argue that a particle mass can be ignored during the motion, but their friends attempt to clarify its statement. Furthermore, each student group investigates a pen motion thrown vertically and horizontally. The motions have been recorded and tracked using a video processing software. Lecturers organize the discussions. By the instruction from a lecturer, students attempt to track a pen motion from a point to other points. The Students conclude that this pen motion is similar to a stone motion subsequently tracked again by the video analysis.

A lecturer prepares some simulated object motions such as a picture motion wrench, a marching band stick, and an object system connected to a stick. The movement of these objects has then been analyzed by each two groups following the sequences, including discussing, concluding, and
presenting the students’ work. This class discussion run well, but there are different opinions come from each group regarding determining object movement positions. A lecturer also emphasizes the kind of object movements consisting of a rotational and a translational movement. In a case of the translational movement, it will occur when each object point moves uniformly. Consequently, students implicitly learn the concept of mass center. Lecturer asserted that however the complexity of a moving object, it always be considered as a point moving uniformly. Therefore, all forces will act to and from this point when the whole mass of objects is a point of view. This final step completely answer the questions delivered at the beginning sequence confirming that the concept of mass center is important to view a particle system as a point.

In the second step of elicitation and restructure, this activity has already been done by each group. However, the actions are still focused on the reinforcement and the previous material review. The subject matter is developed from the physics concept of mass center. In this section, a lecturer states why the concept of mass center is important. Subsequently, students discuss the statement directed by a lecturer. The guided inquiry questions are given to students as described in the following sentences. (1) Is a moving object or particle system neglecting its complexity considered as a mass center movement? (2) Does the mass center movement of an object represent its entire system movement? (3) What did you know about the momentum concept of a moving object? How is the momentum of a particle system related to the concept of mass center? (4) Is the mass center acceleration of particle system equal to the net external force acting on the system divided by the total object’s mass? In this step, students will discuss with their friends in the group. Students can use kinds of resources or references in supporting their answer.

The investigation results of student’s science conception and their conceptual difficulties have been reported in the following sentences. Firstly, the all object motions are not necessary to be seen as a mass center movement especially for non-uniform objects. Secondly, students cannot express their mathematical algorithms regarding the mass center movement representing the movement of the whole system. Thirdly, Students view that a momentum parameter is only seen as a multiplication of an object mass and its velocity. These three findings indicate their poor conceptions. By utilizing group discussions, a lecturer has improved the students’ conception. The action is important to restructure the students’ concept towards the correct conception of physics. Furthermore, a lecturer then gives problems of particle system on the topic of a discrete particle. The sequences are begun from a simple question to some complex questions such as from the two discrete particle systems to three discrete particle systems. Subsequently, students are guided to find its mass center for discrete systems.

In the third step of application, students are expected to find a mass center formula for continuous objects after finding the general formulation of mass center. A lecturer shows the problems about mass center for several continuous objects, such as a sphere, a cylinder, a cone. Afterward, students should express a general formula of mass center mathematically for discrete objects as well as continuous objects. Due to their mathematical literacies obtained by taking the previous calculus course, students look quite easy in determining the position of mass center. Moreover, a lecturer also provides several irregular objects and assign tasks to each group about determining the position of an object mass center tested experimentally. The tools and materials consist of 6-7 pieces of stand, various irregular objects obtained from a piece of plywood, a roll of thread, a pencil, and a ruler. All of the objects have been tested in order to find the location of mass center. Students must be able to find a point of mass center. Subsequently, they have to prove these phenomena analyzed mathematically.

In the fourth step of review. Students are requested to review all of the lessons. Then they solved available exercises given in a fundamental physics book, which is written by Tipler [12]. This activity can be expected to reinforce students’ conceptual understanding.

3.2. The students’ conceptual understanding achievement
The students’ conceptual understanding achievements of particle system as well as momentum are evaluated from the correct answers in each sub-concept, including the mass center (C1), the
conservation linear momentum law (C2), reference frames of mass center and momentum conservation for various cases of collision have been investigated for one, two and three-dimensions (C3), impulse (C4) and the thrust force of a rocket (C5). The students’ percentages answering provided questions correctly for each sub-concept have been presented in figure 1.

![Figure 1. Percentages of students who answered questions correctly for each sub-concept](image)

Based on the available data as depicted in figure 1, students’ percentage is more than 66% in answering all sub-concept questions correctly. This data indicates that the implementation of learning reconstruction gives a positive impact on the student’s conceptual understanding achievements. According to the students’ interview result, some students have experience to the improvement of learning model. Although students feel confused at the beginning sequence, they then make this learning style slowly as their habit. Most students have been motivated to study physics actively in the class. While in the conventional method which students seem just receive information from their lecturer. Question and answer among students in a discussion setting rarely occur; only one or two students interacts each other. The lack engagement of the student indicates that the learning is less facilitated the students in thinking skills. Consequently, students' understanding of the concept of momentum is less than the fixed learning goal. It can be seen from figure 1, an average of 50% students were able to answer correctly the conceptual momentum test.

4. Conclusion
The learning reconstructions of particle system as well as linear momentum conservation have been implemented. The study facilitates the prospective physics teachers in constructing their concepts. Moreover, the result also provides positive impacts in achieving the physics conceptual understanding. This learning reconstruction has been used as an alternative learning style implemented for studying the concept of momentum and particle system.

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