THE EFFECT OF CONCEPTUAL CHANGE STRATEGIES TOWARDS FOSTERING CONCEPTUAL CHANGE IN STUDENTS' UNDERSTANDING OF MECHANICS

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ABSTRACT

The purpose of this research is to identify the conceptual understanding and determine the effect of conceptual change strategies towards the conceptual understanding in mechanics among physics trainee teachers. This research used the quantitative approach and quasi-experimental research design involving six research questions and two hypotheses. The research sample consists of 73 Basic Physics 1 students enrolled in two different campuses of Sriwijaya University, Indonesia. The respondents were selected using the purposive sampling technique. Two research instruments namely: the Force Concept Inventory (FCI) (Indonesian version) and the Certainty of Response Index (CRI) were used in the research. Meanwhile, the three conceptual change strategies used were the Predict-Observe-Explain-Apply (POEA), Conceptual Change Texts (CCT), and the analogy technique. The pre-test and post-test which used data from the FCI were analyzed to determine the mean N-gain while the t-test and Mann-Whitney test were used to test the hypotheses. The results showed that mean scores of students' conceptual understanding for both campuses was 18.08%. Based on the CRI analysis, students' conceptions can be categorized into three types: correct concepts (13.24%), misconceptions (61.51%), and lack of knowledge (25.25%). The mean N-gain of the experimental and control groups were 58% and -1.28%, respectively. There was a significant increase in students' conceptual understanding between the experimental and control groups for all the mechanics concepts and the six conceptual dimensions in mechanics being studied. In conclusion, all the chosen strategies had effectively improved the students' conceptual understanding and changed their misconceptions towards the correct one. The implication of this study is the conceptual change strategies can be used in the training of physics teachers.

KESAN STRATEGI PERUBAHAN KONSEP TERHADAP PEMUPUKAN PERUBAHAN KONSEP DALAM PEMAHAMAN MEKANIK PELAJAR

ABSTRAK

Kajian ini bertujuan mengenal pasti pemahaman konsep dan meneliti kesan strategi perubahan konsep terhadap konsep mekanik dalam kalangan bakal guru fizik. Kajian ini menggunakan pendekatan kuantitatif dan reka bentuk eksperimen-kuasi melibatkan enam persoalan kajian dan dua hipotesis kajian. Sampel kajian terdiri daripada 73 pelajar Fizik Asas 1 di dua kampus berbeza Universiti Sriwijaya, Indonesia. Responden dipilih menggunakan teknik persampelan bertujuan. Dua instrumen kajian iaitu Inventori Konsep Daya (IKD) (Versi Indonesia) dan Indeks Kepastian Jawapan (IKJ) digunakan dalam kajian ini. Manakala tiga strategi perubahan konsep yang digunakan adalah Ramal- Perhati-Terang-Guna (RPTG), Teks Perubahan Konsep (TPK), dan teknik analogi. Pra ujian dan pasca ujian menggunakan data IKD dianalisis untuk menentukan purata N-*gain* manakala ujian-*t* dan ujian Mann-Whitney digunakan untuk menguji hipotesis. Dapatan kajian menunjukkan bahawa skor purata pemahaman konsep pelajar bagi kedua-dua kampus adalah 18.08%. Berdasarkan analisis IKJ, konsepsi pelajar boleh dikategorikan kepada tiga jenis iaitu konsep betul (13.24%), salah faham (61.51%), dan kurang pengetahuan (25.25%). Purata *N-gain* daripada kumpulan eksperimen dan kawalan adalah masing-masing 58% dan -1.28%. Terdapat perbezaan yang ketara dalam peningkatan pemahaman konsep pelajar antara kumpulan eksperimen dan kawalan bagi keseluruhan konsep mekanik dan enam dimensi konsep mekanik yang dikaji. Kesimpulannya, semua strategi yang dipilih berjaya meningkatkan pemahaman konsep pelajar dan mengubah miskonsepsi mereka kepada konsep yang betul. Implikasi kajian ini adalah strategi perubahan konsep boleh digunakan dalam latihan guru-guru fizik.

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CHAPTER 1

INTRODUCTION

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1.1 Background

Indonesia is facing a major problem with regard to the quality of education, especially the quality of science education. Based on the research reports of the Organisation for Economic Co-operation and Development (OECD) through its PISA program (Programme for International Student Assessment) for years 2000, 2003, 2006, 2009, and 2012 the science literacy of Indonesian senior high school students were at ranking 38 out of 41, 38 out of 40, the last out of 57, 57 out of 65, and 64 out of 65 countries, respectively. Similarly, according to a report of TIMSS (Trends in International Mathematics and Science Studies) for year 2011, Indonesia was at ranking 40 out of 42 countries. This finding was not better than the previous TIMSS findings, for example in 2003, Indonesia was at ranking 36 out of 45 countries both

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for science and mathematics. The condition of students' low achievements cannot be separated from how teachers teach and how the students learn.

It is a consensus of researchers and science educators that students come to class with their own concepts. It is not necessary whether the concepts are correct or not. There is no guarantee that the students' concepts are right. Their conceptions about nature have been constructed based on their own experiences from the beginning of their life, which may include observation, perception, culture, language, prior teachers' explanation, and prior instructional materials (Lin, 2004). Constructivism believes that people construct their understanding about nature based on their interaction with other objects or based on what they look in daily activities. The restriction of human senses and reasoning cause people construct different conceptions and it may differ from what the true conception is. Through experiences, students develop explanations for what they know; some of these explanations may be incorrect or naive, but nevertheless they form the basis for the foundation of their knowledge. This can be called as pre-conception. This pre-conception is resistant to change. Moreover, the conception will influence the acquisition of the next concepts. Students' prior conceptions have a substantial influence on their future learning, in terms of both conceptual accumulation and conceptual change (Tomita, 2009). To learn meaningfully, individuals must choose to relate new knowledge to relevant concepts and propositions that they have already known (Ausubel, 1968).

Conceptions that differ from what are understood correctly by scientists are called misconceptions. Unfortunately, there are many perceptions about the term "misconception" itself. Some researchers call it as preconception, alternative concept

(e.g. Rowlands, Graham, Berry, & McWilliam, 2007) as synonym of misconception (Hasan, Bagayoko, & Kelley, 1999), alternative conception (Özmen, 2007; Stein, Barman, & Larrabee, 2007) alternative idea, child concept, or even as students' conception (Hewson, 1992). Hewson (1992) called it as students' conception to state it as a scientifically incorrect perception. In addition, the term alternative framework is also used. These differences are because of different views or perceptions to see the misconception. For example, some researchers use the term alternative conception instead of misconception to avoid interpreting that conception that is not the same as scientists' conception is a wrong conception. Hasan et al. (1999) defined misconceptions as strongly held cognitive structures that are different from the accepted understandings in a specific field and that are presumed to interfere with the acquisition of new knowledge.

Misconception phenomena commonly happen in science such as in physics, astronomy, biology, chemistry, and earth science. A number of alternative conceptions appear across a wide variety of cultures, countries, and ages (Grayson, 2004). In a variety of science topics, a number of studies have shown that students from different ages have a wide spectrum of alternative conceptions (Yürük, 2007). Researches have shown that the same misconceptions are held by students from different countries and cultures. For instance, Bayraktar's (2009) study comparing different cultures from different countries on students' misconceptions for various topics of physics concluded that misconception is universal in nature. Moreover, misconception can happen to all level of students from elementary school to university. It is known that students of all ages (elementary, secondary, and undergraduate) can have alternative conceptions in all areas of science (Pinarbaşi,

Canpolat, Bayrakceken, & Geban, 2006) including their teachers. It is apparent that students enrolling in a college physics course do have misconceptions concerning force, and traditional instruction (by any instructor) does little to challenge them (Zukoski, 1996).

Before uncovering the misconceptions, an effort is needed to identify the misconceptions that students have. For instance, it needs to separate between misconception and lack of knowledge. People who have great concern about misconception studies question what researchers claim as misconception, just it means that it does not understand the content of subject-matter. Hasan et al. (1999) described a simple method for identifying misconceptions by utilizing the Certainty of Response Index (CRI) in conjunction with answers to other multiple choice questions. The CRI, in conjunction with answers to multiple choice questions, can identify misconceptions, can plot and distinguish between misconceptions and do not understand the subject-matters. Using the CRI, students' understandings about a concept whether a lack of knowledge, misconception, or have a correct concept can be figured out.

The researcher believes that there is a difference between "mistake" in understanding a concept and misconception. In constructing their knowledge, students are in progress to assimilate and accommodate knowledge to their schema. In this case when a person does not show conception like an expert, it means that they do not finish constructing the conception in their mind yet. They are in a step or several steps below an expert's belief. In another case, people can build different understanding based on their experience. Throughout their lives, students form explanations for the

phenomena that they see in nature. The environment where they interact every day gives them conceptions about the nature. Ideas that students have already held about natural phenomena that are inconsistent with established scientific theories and laws are referred to as alternative conceptions. This term is used because it suggests that the ideas that students hold are "not a matter of" not understand but of "understand differently" (Nussbaum & Novick, 1981).

Newtonian mechanics is an important topic in physics. It is the main concept that students need to have an adequate understanding in order to move to the next steps of physics study. Almost all of other physics topics, such as electricity and magnetism, vibration and waves, optics, thermodynamics depend for example on displacement, distance, speed, velocity, acceleration, force, momentum and energy as concepts in Newtonian mechanics. Newtonian mechanics is usually studied in the beginning of physics study and is given from junior high school to university. In the Curriculum of Physics Education Study Program of Faculty of Teacher Training and Education of Sriwijaya University, mechanics is in *Fisika Dasar 1* (Basic Physics 1) course, given in the first semester to freshmen students. In this course, students learn more deeply than what they have already learnt in senior high school. The course than is basic for the physics course in the next semester. However, so far, it has been found that many students have serious problems with their conceptions in the mechanics area. Students, for example, can calculate quickly the time needed by a stone to reach the ground in free fall motion, but unfortunately they give the wrong answer when they are asked which one of two different weight objects will get to the ground first if these two objects are dropped from the same height. They usually think that the heavier one will arrive on the ground faster than the lighter one. It is a paradox.

Research done by Syuhendri and Mayanti (2013) to first year Physics Education Study Program students based on three entry ways to university found that their conceptual understandings on Newtonian mechanics were very low, namely 13.42%, 14.42%, and 14.12% respectively for invitation students, national university entrance exam students, and university entrance exam students. In addition, based on preliminary research using FCI to Physics Educational Study Program students enrolled in 2010, it was found that students' mean scores were 20.17% and 15.33% for regular class and for extension class, respectively. It is far below the Newtonian concept mastery threshold 85% or even for entry threshold for Newtonian physics 60% (Hestenes & Halloun, 1995).

Mechanics is a basic area of Basic Physics I course that is generally taught in the first seven or eight meetings before mid semester of the initial semester of year one level course of Physics Education Study Program of Sriwijaya University curriculum. There are two broad subsets of mechanics: (1) kinematics, which deals with concepts like vector, displacement, time, position, velocity, acceleration, trajectories, and reference frames; and (2) dynamics which covers force, inertia, gravitational fields, friction, work, energy, momentum, torque and equilibrium.

Because mechanics covers a wide range of topics and is a prominent portion of Basics Physics 1 course, much research in physics teaching has been done in this area. Along this line there are a number of papers concerning students' misconceptions in mechanics from other countries. However, there is a few papers concerning this topic based on research in Indonesia.

1.2 Statement of the Problems

Physics educators have long been aware that the study of physics, especially in the Newtonian mechanics area, is problematic for many students. Common experiences of many instructors show that conceptual difficulties occur frequently and predictably among introductory physics students (Trowbridge & McDermott, 1980). Mechanics is a major part of the content of introductory physics course whether in high schools or in universities. Many students exhibit intuitive beliefs regarding force and motion that are at odds with the concept of force in Newtonian mechanics (Rowlands et al., 2007). Many researchers have found that this is not only because physics is hard to understand by some students but more also due to the misunderstanding in interpreting the nature phenomena that lead to misconceptions. If this misunderstanding or alternative conceptions are not challenged, it becomes integrated into students' cognitive structures and interferes with subsequent learning and as a consequence students will experience difficulty in integrating any new information to their cognitive structures and in turn result in an inappropriate understanding of new concept (Treagust, 2006). If the recipient is ill-prepared to understand, the information will be lost or misconstrued (Hestenes, 1998). It seems as a dangerous circle. Any misconception causes difficulties to understand the next materials and the difficulties might create another misconception.

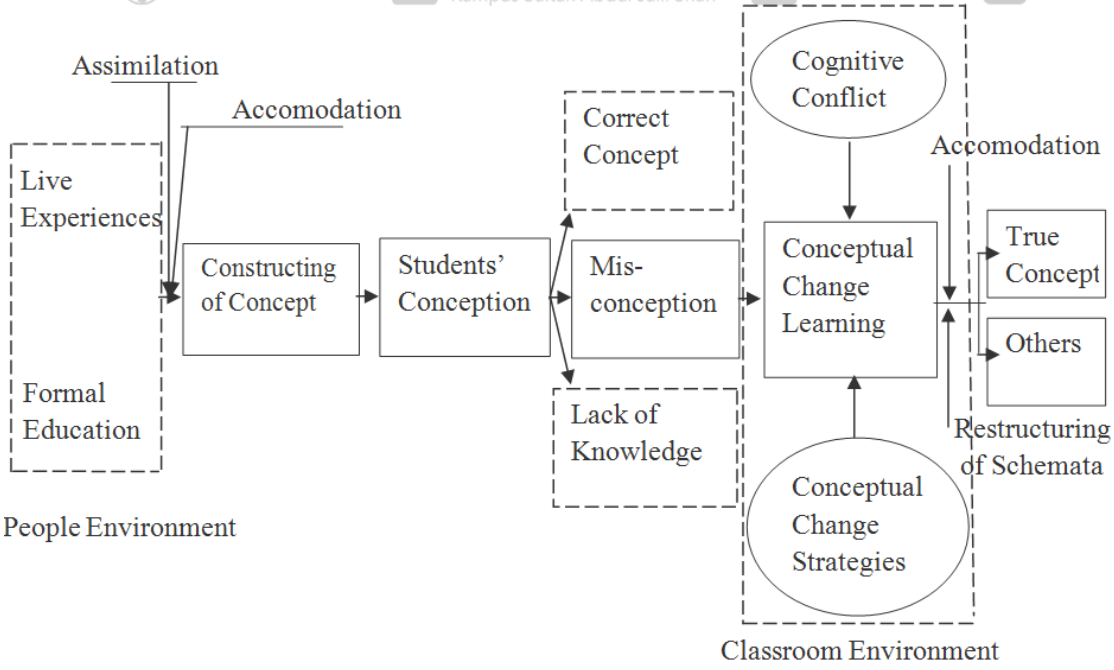
A lot of research conducted around the world focused on misconceptions in Newtonian mechanics. Because students' knowledge is constructed based on their experiences, influenced by environment and culture, it needs to figure out students' conceptions in a particular region. In the past years, there has been a few physics

education research, if any, which studied misconceptions in Indonesia, particularly in South Sumatera. Furthermore, this small number of the misconception studies is also focusing on how to identify the misconception among high school students, not yet how to overcome it. The limitation of study is inappropriate to wide-culture country and big problems of science achievement such as Indonesia. The Indonesian Government has made some efforts to improve students' achievement in science, such as by improving teacher qualification at least to *Sarjana* (undergraduate level), increasing teachers competencies through non-degree programs, improving facilities and infrastructure, revising curriculum, and even by doing a Constitution Amendment to allocate 20% of national and local budget for the education sector; nevertheless all of these efforts do not seem much influence in the gaining of science competencies nationally. In this study, the researcher turns to a point to evaluate students' conceptions and to foster conceptual change learning to overcome misconceptions. Numerous studies, for example by Brown (1989) and Balci, Cakiroglu, and Tekkaya (2006) have shown that conventional instruction produce little change in students' beliefs/conceptions (Kang, Scharmann, & Noh, 2004; Zukoski, 1996). It is believed that particular strategies or methods in physics instruction based on conceptual change theory are needed to change and develop students' conceptual understandings.

However, in overcoming misconceptions, the results are not always that learner changes his/her existing views towards the correct conceptions. Therefore, firstly science teachers or researchers need to understand how the learner responds when he/she encounters scientific information that contradicts his/her existing views about the physical world. In other words, teacher or researcher need to know how does the learner respond when his/her beliefs about the physical world conflict with

the information coming during instruction? Chinn and Brewer (1993) postulate that there are seven distinct forms of learner's response to anomalous data. Among the seven distinct forms only one of which is to accept the data and change learner's views, while the other six responses involve discounting the data in various ways in order to protect his/her preinstructional views. Based on Chinn and Brewer's (1993) postulate, in this research, the researcher needs to find appropriate strategies in order to foster conceptual change in students' mind as maximal as possible. This research wants to address this gap by implementing conceptual change strategy(ies) that is (are) rooted in conceptual change learning theory.

1.3 Theoretical Framework



(Arends, 1989; Wardsworth,1984; Posner, Strike, Hewson, & Gertzog, 1982; Hewson, Beeth, & Thorley, 1998).

Figure 1.1. Theoretical Frameworks

This research makes use of constructivism paradigm theoretical framework. A person always constructs his/her concept about science/physics based on natural phenomena he/she encounters in day to day activities. Formal educations and life experiences before and out of schools contribute to the concept formations. Teachers, methods, facilities of schools are among examples of factors in the formal educations that influence students in learning physics. On the other hand, environment, technologies, and family background are some examples of aspects that contribute to students' concept constructions in terms of out of schools context.

As students always develop their schemata, conceptual change always takes place. Whenever students are asked about physical phenomena, they are already with their own concepts. There are two possible answers, i.e. students arrive at the correct or incorrect answer. If students have already constructed the correct concepts so far or their schemata already get what scientists have, they will arrive at the correct answer. Nevertheless, we cannot always conclude that students hold the correct concepts. It needs an instrument to distinguish between using correct concepts and lucky guesses in answering the problems. Because of that, in this study CRI instrument (Hasan et al., 1999) is used in conjunction with physical phenomena problems, FCI (Hestenes, Wells, & Swackhamer, 1992). A misconception can be summarized when students get the incorrect answer. But it also needs to be summarized carefully. Researcher or teacher cannot conclude that students have misconceptions, unless students choose their answers with high confidence. Because of this reason, CRI needs to accompany the FCI.

Misconception is resistant to change. It is deeply rooted in a person's mind. If lack of knowledge could be approached with common constructivism based teaching, misconception, in contrast, needs a modified instruction with the explicit intent of removing the misconception (Hasan et al., 1999). Cognitive conflict must be present in students' minds to make them ready to change their beliefs. Once they are ready to change their concept, then an instruction could facilitate to foster the conceptual change toward the true concept.

1.4 Aims of the Research

The objectives of this study are, firstly, to identify student teachers' conceptions of a faculty of education from a state university in Indonesia on Newtonian mechanics, whether they have misconceptions, correct concepts, or lack of knowledge and specify the types and level of the misconceptions they hold on mechanics domain, so the status of their conceptions can be figured out. The second objective of the research is to find good strategies in order to foster conceptual change in students' mind, and then to determine whether the chosen conceptual change strategies are effective in improving students' conceptions toward the true Newtonian mechanics concepts. Specific strategies are needed to stimulate conceptual change in students' mind in order to allow exchange of the conception from the old to the new one. To achieve those objectives, several research questions are addressed as mentioned below.

1.5 Research Questions

This research is to uncover the misconceptions of student teachers who have enrolled in the Physics Education Study Program (PESP) of Faculty of Teacher Training and Education (FTTE) in a state university in South Sumatera, Indonesia, and to administer a learning process that can eliminate those misconceptions. Several research questions were promoted to be answered. Specifically the study attempts to answer the following research questions:

1. What are the types of conceptions in Newtonian mechanics domain of the Physics Education Study Program (PESP) students, Faculty of Teacher Training and Education (FTTE), Sriwijaya University, South Sumatera, Indonesia?

2. What are the levels of conceptual understandings of Newtonian mechanics concepts of the Physics Education Study Program students?

3. What are the levels of misconceptions that the students have for each of the misconceptions of the Newtonian mechanics concepts?

4. What are the most common misconceptions in the Newtonian mechanics domain held by the Physics Education Study Program students?

5. Is there a significant difference of the improvement in conceptual understanding toward the true concepts in Newtonian mechanics domain of those Physics Education Study Program students who are taught by using