

Misconception and Difficulties in Introductory Physics Among High School and University Students : An Overview in Mechanics

Miskonsepsi dan Kesukaran Fizik Pengenalan dalam Kalangan Pelajar Sekolah Menengah Atas dan Universiti : Satu tinjauan bagi tajuk Mekanik

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Abstract

Students come into the classroom with prerequisite theories and conceptions as results from everyday experiences and commonsense beliefs. As they progress through their education, these conceptions will be reinforced and it will be extremely difficult to change. Physics is no exception as the subject matter deals more closely about concepts in everyday situations. In order to teach physics effectively, it is the utmost important to identify these ideas beforehand. This paper provides an overview of some literatures pertaining to misconceptions and difficulties in introductory physics among high school and university students. Misconceptions and difficulties in mechanics are listed and described based on past studies in science education. Consequently, this paper also presents the implications these misconceptions have on teaching and learning physics and its role in conceptual changes.

Keywords misconception, introductory physics, mechanics, teaching and learning physics

Abstrak

Apabila pelajar memulakan pelajaran, mereka membawa teori dan konsep-konsep prasyarat yang terhasil daripada pengalaman harian dan kepercayaan umum yang terbina dalam minda mereka. Semakin maju pelajaran mereka berkembang, konsep-konsep ini akan mengental dan sangat susah untuk diubah. Fizik tidak terkecuali kerana ilmu fizik adalah ilmu yang sangat rapat dengan kehidupan harian. Untuk menjadikan pengajaran fizik itu supaya berkesan, maka adalah penting bagi guru mengenal pasti idea-idea tentang miskonsepsi fizik sebelum memulakan pengajaran. Kertas ini menerangkan satu tinjauan terhadap banyak kajian lalu tentang miskonsepsi dan kesukaran yang dihadapi oleh pelajar sekolah menengah atas dan universiti dalam mempelajari fizik pengenalan khususnya bagi tajuk mekanik. Miskonsepsi dan kesukaran dalam mekanik disenarai dan dibincangkan berdasarkan kajian-kajian yang telah dijalankan dalam pendidikan sains. Kertas ini juga membincangkan implikasi miskonsepsi fizik terhadap pengajaran dan pembelajaran fizik dan bagaimana peranannya digembeling bagi mengubah miskonsepsi ini.

Kata kunci miskonsepsi, fizik pengenalan, mekanik, pengajaran dan pembelajaran fizik

INTRODUCTION

One important goal of learning science is for students to understand the concepts of scientific nature itself. The success of this particular goal can foster interests, values and attitudes towards science among students that underlies lifelong and meaningful learning. Hence, studies on students' understanding of science concepts have come to the fore in the last four decades and eventually become one of the major fields of research in science education.

Most researchers agreed that students do not come into classroom as "blank slates" but rather with prerequisite theories and concepts as a result from everyday experiences and beliefs. Mostly the concepts are deviated from the scientific view and more to the common sense when students are asked to explain some of the scientific concepts. From the studies that have been done, all are in agreement that these "alternative conceptions" are highly resistant to change and strongly influence teaching and learning of any subject matter, especially in physics (Pfundt & Duit, 1994).

Physics is commonly known as the fundamental science as it studies the natural phenomena of the world around us. However physics has become a very difficult subject and it is a common occurrence for students to have some alternative conceptions and difficulties regarding the subject matter. As a result, students have a wide gap in their understanding of important topics such as mechanics, electricity, magnetism, thermodynamics, wave, and optics (McDermott & Redish, 1999). Researchers started to approach this problem from a scientific perspective by conducting detailed systematic studies on the learning and teaching of physics among students, ranging from elementary to tertiary levels.

The early studies followed the Piagetian views and approaches in conducting research in Physics Education. The importance of prior knowledge and the mechanisms of assimilation, accommodation and equilibration in the context of constructivism are important contributions of Piagetian theory to learning and instruction. For Piaget (1978), children and adults use mental patterns or schemes to guide behavior or cognition, and interpret new experiences or material in relation to existing schemes.

Research by Silva et al. (2006) and Scoboria et al. (2006) has shown that instead of remembering a host of accurate details, people tend to remember events by incorporating a few details within a schema for the event. Alternative conceptions often result when new experiences are interpreted in light of prior experiences, and new understandings are grafted onto prior understandings. Memories in general are retrieved by first recalling the schema and then the associated details. If a concept does not fit a pre-existing schema and it is not relevant, it likely will be forgotten or even rejected.

A variety of terms is used by researchers to describe students' views that contradict those scientists about concepts of physics: Novak (1977) called them preconceptions, Driver & Easley (1978) referred to them as alternative conceptions; Helm (1980) called them misconceptions; Sutton (1980) used the term children's scientific intuitions; Gilbert, Watts & Osborne (1982) called them children's science; Halloun & Hestenes (1985a) called them common sense concepts; and Pines & West (1986) called them spontaneous knowledge. In this study, "misconceptions" is used to indicate the erroneous or novice-like ideas about the physical world, whereas "preconceptions" is used to indicate prior beliefs students have before formal instruction in introductory physics course.

In general, alternative conceptions about science, particularly in relation to physics, can have some common characteristics such as:

- a. Students develop some beliefs, ideas or knowledge about physics concepts through their interaction with objects in their everyday life.
- b. This naive ideas based on experience is often implicit and may help or block of scientific findings.
- c. Often these students' ideas (misconceptions) about science are highly dependent on the task and the methodology employed to identify them.
- d. These students' ideas are resistant to change.
- e. Students' ideas about science are often based on macro-level analysis (what they can observe through their senses), and not on micro-level analysis (not observable through senses without the help of apparatus).
- f. Students' epistemological beliefs about science may help or block conceptual change.
- g. Alternative conceptions about science are often highly useful and can predict everyday life phenomena, though they are not seemed to be correct from the scientific point of view.
- h. Sometimes, these ideas about science and particular science concepts appear to be coherent and systematic. In other cases they appear to be fragmented and unsystematic.
- i. Students often fail to differentiate between academic and everyday life contexts.

SIGNIFICANCE OF THE STUDY

Sadly within current education system, more emphasis is towards learning a lot of basic and detailed concepts in physics without considering if students really have alternative conceptions, or even "captured" the understanding about concepts after instructions. In truth, high school and university students often make use of the "dead leaves model" mentioned by Redish (1994) as a means for learning physics:

- a. Write down every equation and law the teacher puts on the board that also in the book.
- b. Memorize them, together with the list of formulas at the end of each chapter.
- c. Do enough homework and end of chapter problems to recognize which formula is to be applied to which problem.
- d. Pass the exam by selecting the correct formulas for the problem on the exam.
- e. Erase all information from the brain after the exam to make room for the next set of material.

In this modern era of post-secondary education and its relevance to the society, more people are going to university and college realizing the opportunities, both personal and professional, that formal education awards. And yet, the students bring together with them their misconceptions from school years despite the fact that they pass the most difficult university entrance test. The prevalence of those misconceptions hinder students from learning more advanced physics concepts at university level, as they continue to build up knowledge; it becomes more difficult to rectify the misconceptions.

If their initial understanding of physics concepts is not rectified from the early stages of Physics Education in high school, they may fail to grasp new concepts and information presented in a lecture. They may learn all the necessary physics concepts on purposes to pass the tests but then they will revert back into their preconceptions outside the class.

In actuality, the sources of alternative conceptions are really hard to be determined and documented. According to Wandersee et al. (1994), they are only derived from direct observations and perceptions where the primary data collected by researchers are self-reported statements provided by the subject themselves. Nevertheless, there are general evidences that alternative conceptions have their origins from the following sources: 1) experiences and perceptions; 2) social interactions; 3) resource materials; 4) improper instructions; and 5) language.

It is known for a fact from extensive literature that students commonly develop misconceptions about physical phenomenon by using common sense or naive reasoning to explain what they observed and experienced. Some misconceptions held by students are very popular and largely known to researchers for a long time, especially in mechanics: force (Clement, 1982); motion (McCloskey, 1983b); velocity and acceleration (Trowbridge & McDermott, 1980, 1981); projectile motion (Eckstein & Shemesh, 1993); weight and free fall (Bar et al., 1994). The misconceptions also persist despite formal education in school and university over a number of years.

Since many misconceptions in physical phenomena identified among children are also common among high school and university students, getting familiar with children's conceptual understanding is essential if researchers want to investigate students of any age. Driver et al. (1994) presented information on the ideas children's brings to lessons about living processes; materials and their properties; and physical processes.

From the literature, researchers found that students held the same views and beliefs with the historical views of science. Halloun & Hestenes (1985a) examined the responses of 22 college physics students concerning gravity, force, and motion and found the similarity with a mixture of Impetus, Aristotelian, and Newtonian theories. Clement (1982) also noted the similarity between misconception of motion implying force to the arguments in the writings of Galileo.

Several instructional instruments were designed to identify student's misconceptions in physics, mostly in mechanics. Gunstone (1987) designed and administered multiple choice tests to 5,500 high school students. The test are based on four research probes by Clement's rocket and pendulum problems, Gunstone and White's pulley problem, and Warren's bouncing ball problem. The result confirmed the present of misconceptions even after instructions.

Meanwhile, Halloun & Hestenes (1985b) designed and validated an instrument, the Mechanics Diagnostic test, for assessing the knowledge state, beliefs and mathematical knowledge of students taking introductory physics. One important conclusion from the studies suggested that mathematical knowledge alone is not enough for success in physics, consequently showing that students prefer to 'formula-seeking' when solving physics problems.

According to this 'classical approach' to conceptual change, Posner et al. (1982) hypothesized that there are four fundamental conditions that need to be fulfilled before conceptual change can happen: 1) there must be dissatisfaction with existing conceptions,

Table 1 Overall Plan of Review

View	What is conceptual change?	What changes?	Who changes?	How does change occur?	Where does change occur?	What is prior knowledge?
Vosniadou's synthetic meaning	Change as synthesis	mental model (from incoherent to coherent)	Learners as synthesizers	gradual: adding new information from instruction to initial explanation and reorganizing conflicting representations into a scientific theory	mind	obstacle and vehicle
Chi & Roscoe's misconceptions repair	Change as replacement	mental model (from flawed to correct)	Learners as fixers	gradual: repairing incorrect conceptions	mind	obstacle
diSessa's knowledge in pieces	Change as organizing	knowledge (from unstructured to structured)	Learners as organizers	gradual: organizing p-prims	mind	vehicle
Ivarsson et al's sociocultural	Change as tool appropriation	tool use (from ineffective to effective)	Learner as tool users	gradual: appropriating and mastering mediated means through participation in cultural practices	society	neither

(Mayer, 2008)

2) there must be a new conceptions that is intelligible, 3) the new conception must appear to be plausible, and 4) the new conception should suggest the possibility of a fruitful program. Some researchers even proposed new views in conceptual change such as Vosniadou’s synthetic meaning, Chi and Roscoe’s misconception repair, diSessa’s knowledge in pieces, and Ivarsson et al.’s sociocultural (Mayer, 2002) which have been summarized in Table 1.

According to Ruhf (2003), conceptual change only occurs when students have begun to view the world and developed frameworks of knowledge based on ‘core’ concepts that are scientific in nature. This statement stands in disagreement to the following insufficient but popular ideas about how misconceptions can be altered: the extinction of old conceptions and their replacement with new conceptions, 2) the addition of new ideas, and 3) the arrangements of ideas. Most educators want to see alternative conceptions held by students obliterated and replaced with conceptions that more scientifically in nature.

However it is not very effective as alternative conceptions are so robust to change. Simply adding new ideas to the existing schemes (ideas) is also inadequate. The simple rearrangement of ideas was also insufficient as demonstrated by Carey (1988) who clearly distinguished relational change among concepts from conceptual change. Ruhf (2003) stressed the importance of ‘core’ concepts rather than emphasizing detailed coverage of concepts, as to prevent the difference in meanings with scientists’ views when students use the word force, motion and acceleration, for example

RESEARCH METHODOLOGY

The overall plan for narrative review is constructed beforehand which consists seven phases (steps) of review. The phases with descriptions on what will happen in each phases are summarized and listed in Table 2.

Table 2 Overall Plan of Review

Step	Phase of Review	Key Activities
1	Identification of review research question(s)	Listing the objectives for literature review research
2	Developing inclusion and exclusion criteria	Enable decisions to be made about which studies are to be included in the review
3	Searching	Search of literature for potentially relevant reports of research studies, including electronic databases searching and hand searching
4	Keywording	Applying core and specific keywords to include studies and characterize their main contents.
5	Screening	Applying inclusion and exclusion criteria to potentially relevant studies
6	Data extraction	Extracting the key data from studies included in the in-depth review
7	Producing report	Writing up the research review to a specified format

RESEARCH FINDINGS ON MISCONCEPTION IN MECHANICS

Only students' misconceptions and difficulties in introductory physics mechanics will be covered in this paper. However, not all the subtopics will be reviewed as the literature is too much to be all covered. Only studies which have been published are included to ensure the reliability of the review. Different misconceptions are listed and described in a loose sequence.

Force and Motion

A lot of studies into students' ideas about force are always related to the horizontal motion, gravity and free fall. The first and foremost is the misconceptions students have regarding the nature of force. Watts (1983) presented several categories of students' views when describing about force:

- a. **Affective forces.** Force is regarded as an inner drive, capable of 'forcing' something to do, and is seen as intentional, not accidental or naturally occurring (regards them as agents not unlike living things).
- b. **Configuration forces.** Force has a bonding power to hold objects in stable position and the higher the object, the more force it had. The word 'force' is also associated with coercion or opposing resistance.
- c. **Designated forces.** Certain objects are endowed with force and that force activates an object or body.
- d. **Encounter forces.** Force existed as single entities and they can change the movement of an object when two or more forces combine together.
- e. **Impact forces.** The larger or faster an object is, the greater or more force it has. It appears to have something in common with physicists' momentum (Viennot, 1979; Clement, 1982; McCloskey, 1983a).
- f. **Motive forces.** Forces are a requirement in order to cause and maintain a motion. When the forces run out – something like a fuel, moving objects will stop (McCloskey, 1983b; Fischbein, 1989).
- g. **Operative forces.** Force is seen as an action, the amount of force is proportional to the amount of activity taking place; and it can be transferred.
- h. **Substantial forces.** Forces are effective when they come into contact with objects.

The studies of students' misconceptions about the relationship between forces and motion can be generalized with these following main ideas (Driver et al., 1994): (a) if there is a motion, there is a force acting; (b) if there is no motion, then there is no force acting; (c) there cannot be a force without motion; when an object is moving, there is a force in the direction of its motion; (d) a moving object stops when its force is used up; (e) a moving object has a force within it which keeps it going; (f) motion is proportional to the force acting; and (g) a constant speed results from the constant force.

Viennot (1979) conducted a study among European students on situations such as a mass oscillating on a spring. The result indicated students believed a linear relationship between force and velocity: if $v=0$, then $F=0$; and if $v \neq 0$, then $F \neq 0$. Caramazza et al. (1981) asked fifty university students to trace the path that a pendulum bob would follow

if the string were cut at each of four different positions along its path in a study involving curvilinear motion and trajectories of moving objects. Over half of the students drew a line straight down for the case when the string was cut at an equilibrium position. Several indicates that when the string was cut, the ball will continued in its original arc for a short time before either fall straight down or follow a more or less parabolic trajectory.

Velocity and Acceleration

Trowbridge & McDermott (1980) investigated students' understanding of the concept of velocity. They found that students confused position with velocity. Several ideas had been detected such as two objects would never have the same speed if they were not side by side; being ahead means that the object is faster; and being behind means the object is slower. Meanwhile, Jones (1983) investigated students' understanding in speed, velocity and acceleration. He found that students believed that velocity is the same as speed and acceleration.

It is also believed that velocity can be either speed up or slow down but speed could not. During test, students gave their explanation on several situations such as: (a) going faster means catching up; (b) when two runners who started at the same time but in different places and finished in the same place at the same time, the runner who covered the greater distance was running faster; and (c) when a van overtakes a car, the two vehicles are travelling at the same speed for a short time when the van is alongside the car.

Halloun & Hestenes (1985a) found students have many common sense views about motion before and after instruction. In regards with description of kinematical concepts, students accept these following characteristics: (a) the concepts of "time interval" and "instant of time" are not differentiated, an "instant" means a very short time interval; (b) velocity is defined as distance divided by time, thus average velocity is not so different from instantaneous velocity; and (c) concepts of distance, velocity, and acceleration are not well differentiated.

Gravity and Free Fall

Gunstone & White (1981) discussed students' difficulties in situations involving gravity and found the following ideas: (a) the heavier object would fall faster; (b) gravity decreases with height; and (c) air resistance, temperature and distance from the equator effect gravity. They also noted that students tend to "observe the prediction".

Then, in 1987, Gunstone made another study among high school students using multiple-choice questions. One question asked students to predict what will happen when one of the two weights which initially at rest at the same height on Atwood's machine, was lowered to a new position and released. Most predicted the weight would move and 'seek' the same level because the weights have equal mass.

Watts (1982) described eight alternative frameworks of student's conceptions of gravity: (a) gravity needs a medium through which to travel; (b) where there is no air, there is no gravity, like in space; (c) gravity increases with height, the higher an object the more gravity is exerted; (d) gravity only exists when things fall and not when they are moving upwards, stops when the object is resting on the ground; (e) gravity is known to be the

largest force known to man; gravity is selective, it does not act on all things the same way or on the same things in the same way at all times; (f) gravity is not weight but can work with weight for holding something down; and (g) gravity was constant.

Students explained the “gravity was constant” based on the example of a golf ball in flight. When the golf ball is on the way up, the upward force is greater than the gravitational force; at the top, the upward force and gravity are equal; and on the way down, gravity overcomes the upward force while the force fades away or runs out. Misconceptions about thrown or fired objects are dominated by the notion of impetus (McCloskey, 1983b).

The idea of acceleration due to the force of gravity is often confused with gravitational field. Rogers (1984) found that students recognizing a negative acceleration ($-g$) as a ball is thrown up and a positive acceleration ($+g$) as it falls, combining these and concluded that it is not a zero acceleration but no gravitational force at the vertex of movement. On the other hand, Dall’Alba et al. (1993) found that students have misconceptions about relationship between gravity and acceleration: (a) acceleration would be constant both on the way up and on the way down; and (b) acceleration was a result of gravity while going down and a result of force while going up.

Impulse and Momentum

Lawson & McDermott (1987) interviewed several university students taking introductory physics about a demonstration task using two pucks. They wanted to know students’ ability to relate the actual motion with impulse-momentum and work-energy theorems through algebraic formalism. According to them, students apt to use “compensation argument” to justified their reasons in which they could not relate force and time with the change in momentum and could not explain the momentum in terms of impulse, even though they can use mathematical solution to deal with the material.

Students seem to think momentum in terms of definition rather than a concept. The understanding of the conceptual work seems to be limited to repeating the elements of a formula and not able to connect the symbols with the features of demonstration. Jung (1981) found that students have difficulty in relating time to forces as they see forces as being ‘above’ time. Consequently, the relationship between an impulse (a force applied for a short time) and a continuous force (a force applied for a long period of time) is problematic for many students.

Regarding to work-energy theorem, Lawson & McDermott (1987) showed students have tendency to make incorrect comparison of the kinetic energies of the pucks as they concluded that since momenta are equal, the lighter puck have more kinetic energies. Students also used mathematical reasoning to justify their reasons which the speed appears quadratically rather than linearly in definition. Lawson & McDermott (1987) concluded that students were lacking in any references to the way in which work done on the puck is related to the change in kinetic energy. Students seemed to be distracted by the observed differences of the masses and speeds. They did not actually make the connection between the work-energy theorem and the moving pucks.

Pride et al. (1998) found out that after tutorials have been given to help develop conceptual understanding and reasoning skills, students still have considerable difficulty especially on the work-energy comparison task. Many students used $F=ma$ and the

definition of the acceleration, $a = \Delta v / \Delta t$, to make momentum comparison. A few students used the relationship $F = \Delta p / \Delta t$. Comparison of momentum is relatively simple for students, but the failure of most students to refer to the impulse-momentum theorem suggest that they had failed to recognize its generality.

Students had not developed a functional understanding of the concept that a force acting on an object for an interval of time causes a change in momentum of the object. Instead, students re-derived for a specific situation the relationship expressed by the impulse-momentum theorem (Pride et al. 1998). Their study also found that students did not re-derive the work-energy theorem to compare the final kinetic energies.

Graphical Representations in Kinematics

McDermott et al. (1987) identified two categories of students' difficulty in interpreting the kinematics graphs: difficulty in connecting the graphs to physical concepts; and difficulty in connecting graphs to the real world. In each category, five specific difficulties were identified and explained. From the first category, students cannot discriminate between the slope and height of a graph to extract the desired information. They found that it is more difficult to interpret the changes in curved graphs than straight-line graphs.

Many are unable to relate one graph to another, for example from displacement-time graph to velocity-time graph. When they tried to construct one graph from another, students often seem unable to ignore the shape of the first graph. Also, the task of finding area under a graph of velocity-time requires interpreting the area as lengths. Students often find it difficult to envision on a quantity with square units as representing a quantity with linear units.

McDermott et al. (1987) also pointed out that the difficulties mostly related to the inability to visualize the motion that is depicted in the velocity-time graph. The task of matching the information in a narrative passage of questions to a graphical presentation is also one of difficulties faced by many students.

The second category comprised five specific difficulties in connecting the graphs with the real world (McDermott et al., 1987). First, students have difficulties in representing the continuous motion by a continuous line. They do not recognize that the motion of an object should be represented in a continuous line instead of a series of separated points. Some students may not join the points in a smooth curve but make point-to-point connection that form disjoint lines.

Second, students have difficulties in separating the shape of a graph from the path of motion. They seem to expect that the graph should resemble the shape of the track where the object moves. Then, students are mostly unable to represent a negative velocity on a velocity-time graph. They tend to produce a graph which has a "V" with a vertex marking the instant of turnaround for negative velocity, as well as in the case where a moving object reverse direction.

In conjunction with Goldberg and Anderson (1989), their research shown that the students exhibited a great deal of difficulty when the motion involves a reversal of direction. They were thinking only the graphical representation of speed rather than paying more attention to the directional information. Representing acceleration on an acceleration-time graph also became one of the difficulties faced by many students (McDermott et al., 1987;

Beichner, 1994). They associate a negative acceleration as decelerating and fail to realize that an object with a negative acceleration maybe either speeding up (if the velocity is also negative) or slowing down (if the velocity is positive).

Students who make a reverse error of drawing a positive acceleration for motion up and negative acceleration for motion down seem to link the direction of the acceleration with the direction of the motion. Then, students also have difficulties in distinguishing among different types of motion graphs. They often tried to draw the graphs ($x-t$, $v-t$, $a-t$) that have basically the same shape.

McDermott et al. (1987) and Beichner (1994) found similarities in their research where students have difficulties in terms of area, slope, height and variable confusion in the kinematics graphs. According to the research, the students considered the graphs as photographic situation. It is not seen as mathematical representation but rather a duplication of the motion event. Beichner (1994) identified from the test he conducted that students mostly have confusion with regards to slope/height and area of the graph. Students have difficulty determining the slope of line or the appropriate tangent line if it does not go through zero. They always perform slope calculations or inappropriately use axis values when area calculations are required.

CONCLUSIONS

The existence of alternative conceptions among students is known for a fact from the vast literature in science education (Pfundt & Duit, 1994). However, the main problem is not their existence but rather their persistence. New instructional strategies based on conceptual change must be instigated in physics classroom to promote deep understanding of concepts among students. Traditional instructions are mostly ineffective and new ones must be planned and carried out carefully as inappropriate instructions might added more to the students' alternative conceptions.

Mayer (2008) proposed several steps teachers can do to provoke conceptual change among students. The steps are based on the classical approach by Kuhn's paradigm shift and Posner's assimilation and accommodation. First, students have to consciously notice and understand they have ideas that are different from scientist's views. Then, students have to assimilate more information and try to fit it to the already existing schemes or ideas.

The next step is for students to think through all the argumentation in their own words and reorganize their thought. Finally, students have to work towards obtaining fluency in the newly acquired and understood concepts so this concept can be a building block for more advanced concepts. However, these processes cannot be done if students don't have the motivation. The processes might be slow but worthwhile.

Teachers should emphasize on the quality of their students' understandings rather than just surface learning or their test scores. Conceptual understanding is vital in learning physics and it should be a focus of teachers' interest in teaching. Teachers should opt for depth rather than breadth when teaching physics concepts and call attention to the process of teaching rather than just the content. Students who understand the process are better prepared to acquire science content on their own. Teachers should not just consider themselves teachers but also students for learning.

Martens & Crosier (1994) explored the usefulness of a conceptual change approach to learning by examining the relationship between pedagogical experiences provided by in science education course and pre-service elementary teachers' changing concepts about teaching and learning science. They found that the science education course structured to promote conceptual change provided pre-service elementary teachers pedagogical experiences that would change their concepts about science teaching and learning.

From the study, teachers become more self-reflective in their pedagogy and more successful in terms of promoting conceptual understanding of their students. Yip (1998) suggested that teacher education programs should aim at equipping prospective teachers with the following knowledge and skills:

- a. Literature studies of students' misconceptions in science. This knowledge will help teachers to develop awareness and understanding of the nature and sources of students' misconceptions, which is the first step in designing suitable instructional strategies.
- b. Methods for diagnosing misconceptions held by students before and after instruction. This information will allow teachers to monitor students' learning problems and provide feedback on the effectiveness of the teaching strategies used.
- c. Designing instructional strategies that tackle student' misconceptions. This involves planning and structuring curriculum materials and learning activities using constructivist approach that aims at promoting conceptual change and development such as the use of examples and analogies, cognitive conflicts, concept maps, demonstrations and student activities (Clement, 1993; White & Gunstone, 1992).
- d. Reviewing selected areas of subject matter in which teachers have conceptual problems. Teacher education courses should provide learning experiences for teachers to strengthen their understanding on certain difficult concepts of the school curriculum.

Eventually, physics teachers must asked themselves how far they will go for their students to have the acceptable conceptual understanding, not just for passing the exams and finishing the syllabus, but to ensure that students have a 'noble' scientific literacy and becoming avid thinkers in perceiving the world around them. Discovering, identifying and changing the alternative conceptions in physics are hard and challenging for teachers as it is their responsibilities to be aware of students' conceptions.

However, this can be accomplished easily if teachers and student work together in an active learning environment through conceptual change approaches. Thus, this study hopefully can help teachers, including students, get hold of several ideas in improving learning and understanding in physics and ultimately achieving meaningful learning.

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