

**LEARNING PROGRESSION OF ENERGY IN
SECONDARY SCHOOL PHYSICS**



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**FACULTY OF PSYCHOLOGY AND EDUCATION
UNIVERSITY MALAYSIA SABAH
2016**

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SECONDARY SCHOOL PHYSICS**



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**THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR
THE DEGREE OF MASTER OF EDUCATION**

**FACULTY OF PSYCHOLOGY AND EDUCATION
UNIVERSITY MALAYSIA SABAH
2016**

DECLARATION

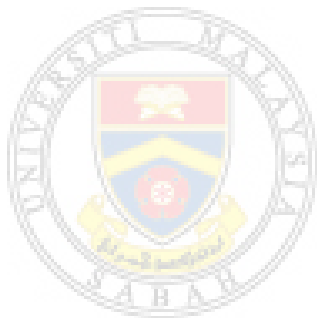
I hereby declare that the material in this thesis is my own except for quotations, except equations, summaries and references, which have been duly acknowledged.

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Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis.

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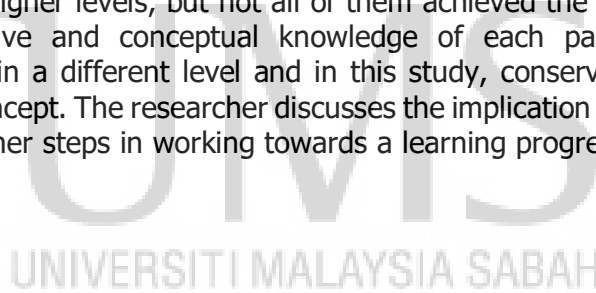
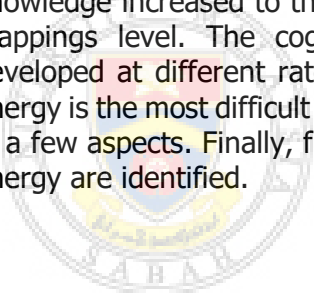
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7 September 2016

ABSTRACT

This study reported results on short-term learning progression of energy in secondary school physics. Energy concept is one of the most important ideas in all of science and useful for predicting and explaining phenomena in every scientific discipline. There are differences in how the energy concept is used across different disciplines. This matter triggers the alternative conceptions of energy not only among children, but students at university and society. This study employs a method called developmental maieutics in order to achieve the research objectives and to answer the research questions. All participants involved in two semi-structured interview sessions before and after the instructional intervention of energy concepts. There are five different situations of daily activities used as interview tools (interview-about-instance). Each interview transcribed and analysed. The cognitive level and energy concept development were analysed from both of the interviews. The development of cognitive was analysed based on Dawson-Tunik's cognitive development, while the energy concept is based on the sequence which starts from the forms and sources of energy, transformation of energy, energy transfer, and conservation of energy. The results triangulated with the reflection. Overall, all participants' conceptual knowledge increased to the higher levels, but not all of them achieved the abstract mappings level. The cognitive and conceptual knowledge of each participant developed at different rates in a different level and in this study, conservation of energy is the most difficult concept. The researcher discusses the implication of result in a few aspects. Finally, further steps in working towards a learning progression of energy are identified.



ABSTRAK

PEMBELAJARAN TERPERINGKAT TENAGA DALAM FIZIK SEKOLAH MENENGAH

Kajian ini melaporkan dapatan tentang pembelajaran terperingkat jangka pendek bagi konsep tenaga dalam fizik sekolah menengah. Konsep tenaga merupakan salah satu idea paling penting dalam semua bidang sains dan sangat berguna dalam menjangka dan menerangkan fenomena dalam setiap disiplin saintifik. Terdapat perbezaan bagaimana konsep tenaga digunakan merentasi pelbagai disiplin. Hal ini telah mencetuskan konsep-konsep alternatif terhadap tenaga bukan sahaja dalam kalangan kanak-kanak malah pelajar-pelajar di universiti dan masyarakat. Kajian ini menggunakan pendekatan kaedah yang dipanggil perkembangan maieutics untuk mencapai objektif-objektif kajian dan menjawab soalan-soalan kajian tentang bagaimana pelajar mengembangkan kefahaman dalam konsep tenaga. Semua peserta kajian terlibat dalam dua sesi temu bual separa-berstruktur sebelum dan selepas intervensi pengajaran. Terdapat lima jenis situasi yang berbeza dalam aktiviti harian dijadikan bahan temu bual (temu bual-tentang-contoh). Setiap temubual disalin dan dianalisis. Perkembangan tahap kognitif dan konsep tenaga dianalisis daripada kedua-dua temu bual tersebut. Perkembangan kognitif dianalisis berdasarkan perkembangan kognitif Dawson-Tunik, manakala konsep tenaga berdasarkan jujukan yang bermula dari bentuk dan sumber tenaga, perubahan tenaga, perpindahan tenaga, dan keabadian tenaga. Hasil kajian ditriangulasi dengan refleksi. Secara keseluruhan, semua peserta kajian menunjukkan peningkatan pengetahuan dalam kognitif dan konsepsi ke tahap yang lebih tinggi, tetapi tidak semua daripada mereka mencapai tahap pemetaan abstrak. Perkembangan pengetahuan kognitif dan konsepsi setiap peserta kajian meningkat dengan kadar yang berbeza dalam aras yang berbeza dan di dalam kajian ini, konsep keabadian tenaga merupakan konsep yang paling sukar. Penyelidik membincangkan implikasi dapatan kajian dalam pelbagai aspek. Akhir sekali, langkah seterusnya dalam pembelajaran terperingkat konsep tenaga telah dapat dikenalpasti.

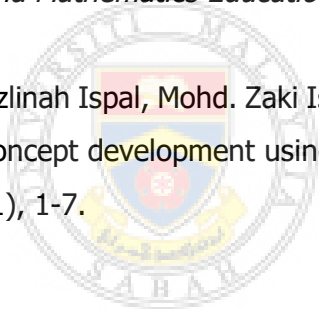
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AWARD

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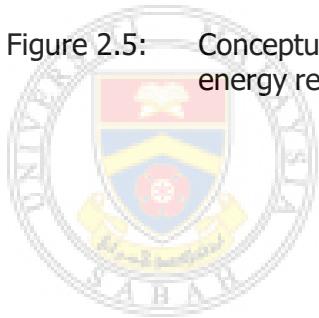
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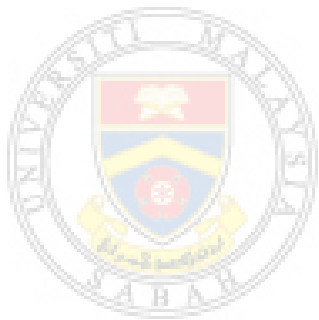


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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The Malaysian aspiration to be an industrialized society can be said as highly depending on science and technology. The Malaysian science curriculum comprises three core science subjects and four elective science subjects. The core subjects are Sciences at primary, lower secondary and upper secondary school levels. Elective science subjects are offered at upper secondary school level and consist of Biology, Chemistry, Physics, and Additional Science. As articulated in the Malaysia Education Blueprint 2013 – 2025, Pre-School to Post-Secondary School, education in Malaysia is an on-going effort towards developing the potential of individuals in a holistic and integrated manner, who are knowledgeable, thinking critically and creatively.

In today's society, we are confronted with a wide range of energy usage issues such as electrical devices, hybrid or traditional cars, renewable energy and fossil. We need to understand what energy is and how it can be used wisely to reduce costs and pollution. In a school context, energy ideas are central to understanding the life, earth, and physical science (Herrmann-Abell & DeBoer, 2011). The term 'energy' has different meanings in everyday contexts. In a classroom, students often cannot link the term energy that they have learnt in physics to the term energy that they have learnt in biology or chemistry. On the other hand, they talk about energy being 'conserved' in physics, in biology 90% of energy 'lost' during the transfers between trophic levels while energy is often discussed as a 'flow' from natural sources to users in chemistry (Eisenkraft *et al.*, 2014). In addition, energy is already a part of the students' everyday language and experience (Lijnse, 1990; Trumper, 1990). It is not surprising to note that energy is a difficult concept for students to understand (Liu & McKeough, 2005; Neumann *et al.*, 2013).

Historically, many researchers and educators did not agree for the teaching of energy in early education (Rizaki & Kokkatos, 2013). For example, Warren (1982) stated that the concept of energy should not be taught until students have attained a high level of abstract reasoning, whereas Solomon (1983) and Trumper (1993) hold the opinion that teaching of energy should start at the primary school as soon as possible. Understanding energy in modern society is only possible with a sound insight into key basic ideas about the energy concepts. The teaching of energy worldwide is associated with the interest of experts and non-experts in particular for confronting the environmental problem. As a result of the seriousness of this situation, the energy concept is among the 'big ideas' established as a general framework in international monitoring studies, like PISA and TIMSS as well as in Science Education Standards around the world (Mullis *et al.*, 2009). For that reason, the United Nations have established a 'Decade of Education for Sustainable Energy Development' from 2005 to 2014 (Rizaki & Kokkatos, 2013) and continue as 'Decade of Sustainable Energy for All, 2014-2024' (United Nation, 2014).

Lehrmann (1973) argued that the traditional approach to introduce the energy concepts was via force and work, however Papadouris, Constantinou, and Kyratsi (2008) claimed that this approach cannot be accepted by another field of sciences. While a biologist uses energy to describe the relationships between organisms in an ecosystem for the atmosphere's warmth (Chabalengula, Sanders, & Mumba, 2012), a chemist interprets chemical reactions by tracking energy changes; a geologist uses the conservation of energy to build models that describe plate tectonics; a cosmologist relies on energy conservation when deducing the shape and structure of the universe; a particle physicist relies heavily on the idea that energy is conserved during interactions between subatomic particles and a dietician tracks the energy requirements of human body to help treat a diabetic patient. Thus, Richard Feynman goes on to say that, "It is important to realise that in physics today, we have no knowledge what energy is", (Feynman *et al.*, 2011).

What students should know about the energy concepts are the most important question to discuss among scientists, science education researcher and teachers. Science teachers confront a complicated prospect when teaching students about energy. A teacher has to choose on how to present the concepts of energy in

his/her discipline-centred classroom, but the concepts are still correct to the nature of energy. The failure of students in understanding the energy concepts does not only exist in the lower or upper secondary schools (Goldring & Osborne, 1994) but also occurs at the university level (Loverude, Kautz, & Heron, 2002).

After analysing all these situations, Neumann *et al.* (2013) carried out an empirical study towards a learning progression of energy. They developed a new measurement instrument, the *energy concept assessment*, and used it to investigate students' progression in understanding the energy concept in three different grade levels, Grades 6, 8 and 10. Ideally, learning progression is capable of describing how students develop a more expert understanding of a big idea of science such as energy over abroad (Smith *et al.*, 2006) and provides teachers with a framework for assessing the students' level of understanding of a core concept (Duschl, Maeng, & Sezen, 2011). Subsequently, learning progression is intended as a means to align content, instruction and assessment in order to provide students with the opportunity to develop a deeper understanding of the particular concept (Stevens, Delgado, & Krajcik, 2010).

1.2 Problem Statement

Science education researchers have indicated that there are serious difficulties in understanding energy and its related concepts among students of all ages (Bécu-Robinault & Tiberghien, 1998; Liu, Ebenezer, & Fraser 2002; Saglam-Arslan, 2010). For example, a high percentage of lower sixth form students do not understand the key concepts of energy, and little correlation has been found between their abilities and the application of qualitative knowledge and quantitative reasoning (Goldring & Osborne, 1994). Another essential point, Cheong *et al.* (2015) found that Bruneian students' understanding of alternative energy is low based on their two-tier instrument to diagnose students' understanding and alternative conception about alternative energy among Years 10 and 11 in Brunei.

Since energy are both a disciplinary core idea and a crosscutting concept (Eisenkraft *et al.*, 2014), students have to learn about energy in the contexts of biology, chemistry, physics, and the earth and environmental science.

Simultaneously, they recognised that the energy of living systems (e.g. human and various organisms) and non-living systems (e.g. car, heat, nuclear) are the same. Due to these, students have been found to have alternative conceptions about energy concepts, and these refer to students' inappropriate conceptions that are not in tandem with the ones understood by the worldwide scientific community (Anderson, 2007). Students use the term energy in everyday lives well before learning about it in school and come to develop an intuition about it that may or may not map onto a scientific view of energy. If these alternative conceptions are not challenged, they can interfere with the development of new understanding (Duit & Treagust, 2003; Duit, Treagust, & Widodo, 2013).

A variety of quantitative and qualitative methods have been employed to identify the alternative conceptions of energy (e.g. Dawson-Tunik & Stein, 2004; Neumann *et al.*, 2013). Students' pre-existing knowledge acts as a very important role in further learning. In a related review of literature, misconception, misunderstanding, preconception, alternative framework, children science, spontaneous knowledge and naïve theory were defined and these terms have the same meaning (Calik & Ayas, 2005). Despite this terminology, in this study, the term 'alternative conception' is being used to figure out students' inappropriate understanding of energy based on the explanation made by Watts (1983)—personal and idiosyncratic ideas about energy, which are not simply just isolated misconceptions, but are parts, of a complex structure which provides a sensible and coherent explanation of the world from the students' point of view.

Students have to learn about energy even though "we have no knowledge of what energy is". Liu and McKeough (2005) proposed the hierarchically ordered conception of energy; this sequence is: perceiving energy as activities or abilities to do work; identifying different energy sources and forms; understanding the nature and processes of energy transfer; recognizing energy degradation; and realizing energy conservation. Several researchers have reported a positive relation between the adequacy of students' scientific conceptions and level of cognitive development (Trumper, 1993). Consequently, an understanding of how scientific concepts are learned should be at the centre of the emerging cooperative efforts between

cognitive scientists and educator (e.g. Dawson-Tunik & Stein, 2004, Saglam-Arslan, 2010).

The initial ideas of students bring into the classroom in the hope of building bridges between 'alternative conception' and 'scientific conception' knowledge state (Chi & Slotta, 1993; diSessa 1996; Slotta *et al.*, 1995). Considering the energy as a central of scientific disciplines including biology, chemistry, and physics, it can be assumed that these conceptions have been the main particular focus of many studies (e.g. Solomon, 1983; Trumper, 1993). Then, how is the student is able to understand a lesson aimed at presenting the scientific conception if the initial ideas may be very different? Thus, the relation between the conceptions of energy and cognitive development of students is to be studied in this study.

On the other hand, the disappointing results of international monitoring studies such as the Trends in International Mathematics and Science Study (TIMSS) have fuelled another general debate on the need for a sufficient level of scientific literacy and the necessity to improve the quality of science instruction in school (Duit, 2007). In Malaysia, through the book of Malaysia Education Blueprint 2013-2025, the results of TIMSS become a benchmark for learning mathematics and science for national education development. Malaysia's ranking for Science subject in TIMSS 2011 fell by an ever greater margin, from 21st in 2007 to 32nd (Ministry of Education, 2012). This result raises concerns at all levels, including teachers, administrators, the ministry and parents. Based on the TIMSS frameworks (Mullis *et al.*, 2009), the most important concept evaluated in science domain is energy. Notwithstanding, energy concepts are too imperative to understand by students in Malaysia.

1.3 The Aim of the Study

The aim of this study is to elaborate the development of cognitive and conceptual understanding of energy concepts in Form Four (16 years old) secondary school students. This study is based on the framework of short-term learning progression that is prevalent visually and verbally articulates how learning will typically move toward increased understanding for most students. To achieve this aim, the study will attempt to describe how students understand the energy concepts in physics that

are consistent with physical science standard in the Malaysian Science Curriculum and Malaysian Physics Curriculum along the four strands: forms and sources of energy; transformation of energy; energy transfer; degradation and conservation of energy (Curriculum Development Centre, 2005f; 2006g).

This study is undertaken based on a number of the underlying reasons. Firstly, there is a growing interest of learning progression over the several decades. For example, Duschl, Schweingruber, and Shouse (2007) define a learning progression as “a sequence of successively more sophisticated ways of thinking about a topic over a period of time”. Researchers have addressed learning progressions for many topics or skills (e.g. Lee & Liu, 2010; Plummer & Krajcik 2010; Songer & Gotwals, 2012). Moreover, learning progression may be interpreted in many ways; progressions may be viewed both as ideas evolving over the long-term or in the short-term (Alonzo & Steedle, 2009; Corcoran *et al.*, 2009) and function vertically across grades/years or horizontally within a school year (Dusch, Maeng, & Sezen, 2011). Consequently, this study is expected to contribute other findings and enhances the literature for further work towards learning progression of energy.

Secondly, prior knowledge had become one of the most important domains in science education research since the 1970s and thus affects the teaching and learning of energy (Duit, Treagust, & Widodo 2013). Students often held alternative conceptions that are incompatible with a scientific view (Anderson, 2007). Hence, the development of conceptual science is related to cognitive development (Dawson-Tunik & Stein, 2004; Trumper, 1993). Thus, this study is conducted for that reason, as a theoretical lens in an effort to interpret the process of how cognitive and conceptual knowledge developed with respect to the energy concepts.

Lastly, based on Millar (2014)'s definition, there are two worlds or concepts of energy: in science, energy is an abstract, mathematical idea. It is hard to define 'energy' or even to explain clearly what we meant by the word; and the word 'energy' is widely used in everyday contexts, including many in which appear 'scientific'—but with a meaning which is less precise than its scientific meaning, and in which differs from it in certain respects.

1.4 Research Objectives and Research Questions

This study investigates students' learning progression with respect to the concepts of energy in secondary school physics. The researcher intends to use the learning progression framework to describe how scientific knowledge such as energy concepts can evolve from students' ideas (which radically differ from scientist's) to a deep and productive understanding of a scientific theory over a period of time. The researcher attempts to answer the research question regarding the following objectives:

Objective 1:

To investigate students' cognitive level and their alternative conceptions of energy before the instructional interventions.

- i. What is the student's cognitive level of energy concepts before the instructional interventions?
- ii. What are the alternative conceptions of energy that were held by students before the instructional interventions?

Objective 2:

To investigate students' cognitive level and their conceptual development of energy after the instructional interventions.

- i. What is the student's cognitive level of energy concepts after the instructional interventions?
- ii. To what extent the conceptual development of energy of students after the instructional interventions?

1.5 Significance of the Study

As has been interpreted by the scholars in science education, learning progression is capable to describe how students developed a more expert understanding of a big idea of science over abroad (Smith *et al.*, 2006). Therefore, the researcher intends to contribute to a new perspective in learning progression research, such as the researcher using the qualitative approach to broaden the literature review, generally on learning progression research and particularly in learning progression of energy

research. This study may provide relevant information to the science education researchers, science teachers, and curriculum developers.

As the researcher mentioned earlier, the focus of the study is energy concepts. Research on students' conceptions revealed that students' ideas about energy before and also after formal class in school mainly reflect the use of energy in their life-world domain (Duit & Häußler, 1994). This situation will cause the inappropriate understanding of energy concepts. Therefore, this study will have implications to the participant's awareness of understanding of energy concepts, teaching and practice of science teachers and again to the curriculum developers.

1.6 Definition of the Terms

Here laid out the definition of the terms that have been used in this study:

i. Learning progression

Learning progression is a framework to see the progression of participants' understanding of energy, started from their alternative conceptions to the scientific conceptions over a period of time. In this study, the researcher viewed the progression in short-term period and involved the same year/grade of participants (Berland & McNeill, 2010).

ii. Development

Development refers to the participants' development of cognitive level and conceptual understanding of energy. There are six stages or levels of development (developmental maieutics) that have been used as an indicator (Dawson-Tunik & Stein, 2004).

iii. Instructional intervention

Instructional interventions that have been used in this study were based on qualitative and naturalistic approaches (Merriam, 2001). The instruction is about the energy concepts in physics. The instructions consisted of learning activities to gain understanding of energy concepts among participants.

iv. Writing exercises

Reflection in this study is to support the deepening of reflection through formative assessment to reflect the students understanding of energy concepts. The tools used for reflective is writing exercises (Coulson & Harvey, 2013).

1.7 Scope and limitation of the Study

This study focuses on the energy concepts in physics. The energy concepts are too wide and had brought different meanings in different perspectives. Some advanced concepts of energy such as renewable and non-renewable energy growing rapidly discussed worldwide and the related research on this concept is too broad. Therefore, the researcher is aware that the scope of energy concepts is in secondary school physics only. This study is based on the qualitative methodology; therefore, the researcher is aware that the main limitation of this study is that the findings or results cannot be extended to a wider population with the same degree of certainty with quantitative analysis.

1.8 Summary

This chapter describes the background of the study, the problem statement, aim of the study, the research question and objectives, significance of the study, definition of the terms and the scope and limitation of the study, which highlights the main essence of the study. The next chapter will present the review of relevant literature.