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Transforming Physics Content into Content Physics for Instruction through the Model of Educational Reconstruction (MER)

Azlinah Ispal[1*], Mohd. Zaki Ishak[2]

[1]SMK Bugaya II, WDT 69, 91308, Semporna, Sabah, Malaysia.
Email: g-86242765@moe-dl.edu.my
[2]Faculty of Psychology and Education, University Malaysia Sabah, 88400, Kota Kinabalu, Sabah, Malaysia.
Email: movolk@ums.edu.my

CORRESPONDING AUTHOR (*):
Azlinah Ispal
(g-86242765@moe-dl.edu.my)

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ABSTRACT

This study discusses how to transform physics content into instructional content using the Model of Educational Reconstruction (MER). The MER is a popular method of lesson design because it gives equal attention to the content of physics to be learned other than students' cognitive, affective, and learning processes. This model is from the German-*Didaktik* tradition, which is influenced by constructivism and is nearly unknown in Malaysia. According to this perspective, knowledge is derived through human reconstruction, and every young learner has intuitive knowledge prior to entering a formal classroom. As a result, in order to meet students' needs in a balanced manner, teachers must elementarize physics content and integrate it with students' alternative conceptions. This study focused on energy concepts to determine how effective MER is. With the complexity and difficulty of the dual meaning of energy, physics teachers must devise efficient teaching techniques to bridge the gap between energy in everyday language and scientific concepts. Thus, the researchers evaluated 15 significant papers to determine scientists' understanding of energy; interviewed 12 secondary school physics students to get their alternative conceptions; and re-analyzed 23 earlier studies on the same topic. This paper is exclusively on natural concepts and energy fundamentals, and it found physicists and students had a significant understanding gap. As a result, the contradiction in understanding of the energy concepts must be applied to the development of an energy lesson plan by narrowing the gap between physicists' and students' understanding.

Contribution/Originality: This study contributes to the methods for creating an energy lesson plan for secondary school physics. The instruction in the classroom begins with a balance of information from textbooks and everyday experience. This study shows how to transform this knowledge into a form that can be applied for formal instruction.

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1. Introduction

The idea of transforming physics content into content physics for instruction is originated from the constructivist epistemological orientation, which is stand by two facets: first, learning is viewed as students constructing their own knowledge from their experience and observation, but this knowledge is not seen as obstacles to learning, instead as points for guiding them to the physics knowledge to be learned (Driver & Easley, 1978); and second, physics knowledge is viewed as physicists' creation or personal expression of the physics knowledge "reconstruction" (Abd-El-Khalick & Lederman, 1998; Kattmann et al., 1996).

Transforming the original structure of physics content into structure for instruction have been long practiced by the *Bildung* and *Didaktik* mechanism, which is based on the German-*Didaktik* educational tradition. There is no accurate word to replace the phrase of *Bildung* and *Didaktik* in English words. As a brief, *Bildung* is seen as a process of self-improvement that has a wider meaning than schooling and it is concerned with the analytic process of transposing (or transforming) human knowledge into schooling knowledge, contributes to the formation of children or young learners. On the other hand, *Didaktik* (not didactics in English) refers to the "art of teaching" which always considers the questions of what to teach, how to teach it, and why it should be taught for the teaching of a content knowledge. The principles of education discussed here is the one that was not well-known in the Anglo-American curriculum tradition (Westbury et al., 2000), and an extremely unfamiliar educational tradition in Malaysia (Azlinah, 2022).

Primarily, the aim of transforming the content structure of physics which is understood by physicists must be transformed into physics content structure for instruction is solely to make it easier to understand by students. This phrases may sound bizarre for curriculum tradition teachers or practitioners include in Malaysia, but again this is actually the "missing" step in our teaching method. Subsequently, the content of every subject matter is essential to distinguish as different structure of content may best be taught and learned in different ways. The theory of content portrays the content properties, predicts the teaching and learning procedures that are most effective for each sort.

The flourishing of research on understanding of the role of content in learning in the mid-1970s marked an uprising of research on understanding in alternative conceptions of natural phenomena and scientific principles. This uprising's first phase focused on considering students' beliefs. Only much later do the researchers begin to try, with varying degrees of success, to integrate these beliefs with accepted scientific conceptions. As a result, content properties must be considered as one of the variables in science education research, other than time, class size, resources, form of assessment, learners' abilities and motivations, and the teacher's methods and skills, as well as confidence in using them (White, 1994).

Physics distinguished from other science subjects by its content properties. According to Angell et al. (2004), students struggle with physics because they have to deal with a multitude of representations at the same time, such as experiments, formulas, calculations, diagrams, and conceptual explanations. Students also must be able to switch from graphical to numerical representations by themselves. From preschool to university, research on students' conceptions has revealed that the majority of students' preconceptions contradict with the nature of physics (Wandersee et al., 1994). This is

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why, the number of research on teaching and learning science shows that approximately 64% of studies are conducted in the domain of physics, 21% in the domain of biology, and 15% in the domain of chemistry (Duit, 2014).

As a consequence, there has been a shift in physics education research about the lesson, practicing the teaching methods, and evaluating teaching and learning environments. As a result, the complexity of physics content should be treated equally with its instructional content (Fensham, 2001). This is consistent with science education research that examines how individuals learn and teach on a micro level (e.g., a single session or a single topic sequence) (Kariotoglou & Tselfes, 2000). This research trend also known as the teaching-leaning-sequence that will lead to a missing level of detecting and grasping what happens in scientific classrooms in terms of content-specific interactions between teaching and learning processes, and then attempting to explain them using instructional theory (Lijnse, 2000). This kind of study is balanced as it considers both the teaching methods and the students' concerns, as well as the content knowledge itself.

Speaking about balancing or knotting between three elements in this research trend; i.e., teaching methods, students' prior knowledge, and the content knowledge being taught, brought us to discovery the ability of the Model of Educational Reconstruction (MER)—a model that leads researchers or teachers to a meeting point between physicists' knowledge and students' prior knowledge as an aid for designing physics lessons. This model is based on the German-*Didaktik* tradition, and it aims to eliminate a popular myth among teachers: that instructional content must be "simpler" than physics content in order to match students' understanding by reducing the original structure of physics content. Regrettably, this procedure misses the point entirely. Kattmann et al. (1996) say that to close the conceptual gap between students and physicists, the content of instruction must be much more complicated than the content of physics.

We conducted a study on the concept of energy to see how effective and capable the idea of MER is. With the complexity and difficulty of the dual meaning of energy, physics teachers and physics education researchers must devise efficient teaching techniques to bridge the gap between energy in everyday language and scientific concepts as this problem does not only occur in other countries, but secondary school physics students in Malaysia are no exception to having the same difficulty (Azlinah, 2016; Fah et al., 2012; Karpudewan & Ponniah, 2016; Lay et al., 2013; Tan, 1999). Despite the fact that energy is a difficult topic to teach and study, it is always considered a minor topic in physics and scientific curricula (Goldring & Osborne, 1994; Loverude et al., 2002; Rizaki & Kokkatos, 2013; Warren, 1982).

2. Theoretical Background

2.1. Model of Educational Reconstruction

The Model of Educational Reconstruction (MER) is quite popular as a method of planning instruction by teachers and curriculum developers by giving equal attention to the physics content to be learned and students' cognitive and affective variables, including their learning processes (Duit et al., 2012). The MER is based on the *Bildungs*- and *Didaktik*-frameworks of the German-*Didaktik* education tradition (Westbury et al., 2000). This model established by Kattmann et al. (1996) provides a framework for developing and verifying teaching-learning-sequences that aims to bring together the

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German hermeneutic tradition on scientific content and constructivist teaching and learning methodologies. The MER offers useful insights for avoiding one-sided approaches that focus solely on the physics subject structure or the perspectives, abilities, and needs of students. As noted previously, the model's most valuable aspect is the close interaction between its three components: (1) subject matter clarification and analysis; (2) teaching and learning research; and (3) design of the teaching and learning environment. In particular, the MER is distinguished by the fact that, on the one hand, the physics content structure serves as a reference point for understanding students' knowledge, while on the other hand, students' knowledge serves as a reference point for improving understanding of the physics content for instruction.

The MER is also built on a constructivist epistemological framework (Duit & Treagust, 1998, 2003) where there are two key facets of epistemological orientation: first, learning is viewed as students constructing their own knowledge on the grounds of already existing knowledge, but this knowledge is not seen as obstacles to learning, instead as points of departure for guiding them to the physics knowledge to be achieved (Driver & Easley, 1978); and second, physics knowledge is regarded as physicists' creation (Abd-El-Khalick & Lederman, 1998). In other words, physics is a personal reconstruction of the physicist's knowledge expression (Kattmann et al., 1996).

2.2. The MER Structure

2.2.1. Component (1): Subject Matter Clarification and Analysis

Traditionally, physics content primarily denotes physics concepts and principles. However, recent views of scientific literacy (Bybee, 2014) claim that physics processes, view of the nature of physics and views of the relevance of physics in daily life and society should be given substantial attention in physics instruction (Osborne et al., 2003; McComas, 1998). All these "additional" issues are included in the process of MER.

Therefore, what is commonly called the physics content is seen as the consensus of a particular physics community. Every presentation of this consensus, including the presentations in the leading textbooks, is viewed as an idiosyncratic reconstruction of the authors informed by the specific aims they explicitly or implicitly hold. Thus, academic textbooks are regarded as descriptions of concepts, principles and theories and not as accounts of reality itself. Certainly, in most cases the scientific knowledge is of higher inter-subjective validity than everyday knowledge but it is still a system of mental constructs. Clearly, these considerations also hold for issues of physics processes and the nature of physics (issues about physics).

Clarification of subject matter also known as *elementarisierung* draws on content analyses of leading textbooks and key publications on the topic under inspection but also may take into account its historical development. The German term, *elementarisierung*, is actually relatively tough to translate, and no exact English term with a similar meaning. Thus, English-speaking researchers have commercialised the term *elementarization* to represent the concept of *elementarisierung* in their writings (Kattmann et al., 1996). Ironically, *elementarization* also is not an English word either but its meaning closes to the process of subject matter clarification process.

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2.2.2. Component (2): Research on Teaching and Learning

This component comprises empirical studies on various aspects of the specific learning environment. The method of this component's research on students' perspectives, including prior knowledge and affective variables like interests, self-concepts, and attitudes, is particularly essential. Previous research has shown that students' surprising and seemingly different conceptions of physics content can provide alternative conceptions of physics content, allowing for a deeper understanding (Duit et al., 1997; Kattmann, 2001). There are many studies on research on teaching and learning, as well as the role of instructional methods, experiments, and other instructional tools. It is important to do research on how teachers see and think about physics content and how students learn.

2.2.3. Component (3): Development and Evaluation of Instruction

Concerns the design of instructional materials, learning activities, and teaching and learning sequences. The design of learning supporting environments is at the heart of this component. The design is, first of all, structured by the specific needs and learning capabilities of the students to achieve the goals set. Various empirical methods are employed to evaluate the materials and activities designed, such as interview with students and teachers, e.g. on their views of the value of the designed items, questionnaires on the development of students' cognitive and affective variables, and also analyses of video-documented instructional practice. Development of instructional materials and activities as well as research on various issues of teaching and learning science are intimately linked (Komorek & Duit, 2004).

This component focuses on the creation of learning-supporting environments, including instructional materials, learning activities, and teaching and learning sequences. To achieve the set goals, the design is first and foremost structured by the specific needs and learning capabilities of the students. Interviews with students and teachers, for example, on their views of the value of the designed items; questionnaires on the development of students' cognitive and affective variables; and analyses of video-documented instructional practise are all used to evaluate the materials and activities designed. Teaching and learning science research, as well as the development of instructional materials and activities, are inextricably linked (Komorek & Duit, 2004).

The three components do not strictly follow one another, but they do influence one another. As a result, the process must be carried out iteratively, step by step. During the development of a method of instruction, it may become apparent that certain aspects of subject matter clarification are missing or that a new focal point is required. Furthermore, additional research into students' prior knowledge may be required to cover domains that were previously overlooked. Because inadequate and inadmissible references are corrected by the iteration itself, the iterative method can be expected to result in the students' prior knowledge and the clarification of physics content being reliably and appropriately referred to one another. As a result, the parts of the figure (a triangle) must be arranged in a specific order (see Figure 1).

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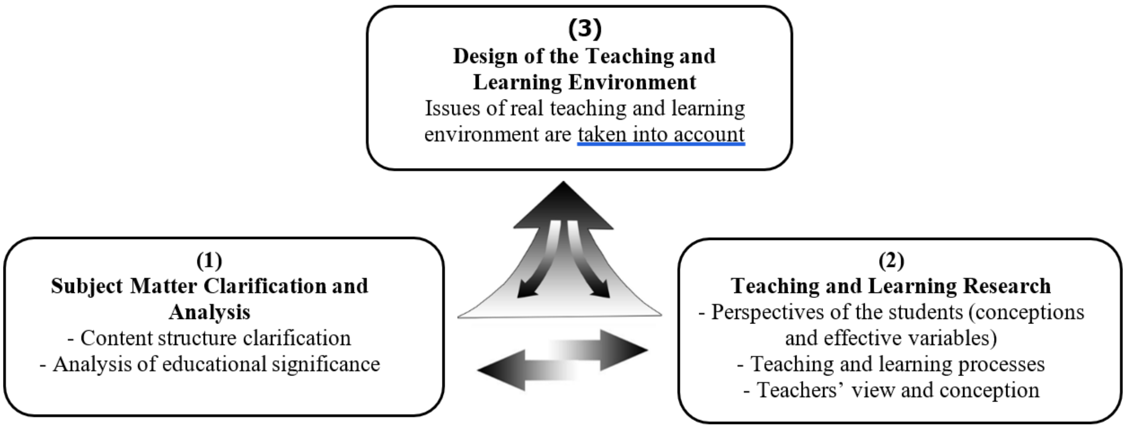
Figure 1: Model of Educational Reconstruction



2.4. The Concept of Energy Understood by Physicists

2.4.1. The History and The Nature of Energy

The word "energy" comes from the ancient Greek word, which is written as *ενέργεια* and means activity or life and has been used in many different ways over the years. Previously, energy was not considered a scientific or technological concept. It is strange that the term "energy" was used in everyday conversation long before it became a scientific term. However, despite the fact that the concept of energy has existed for centuries, it was not until the late 1800s that it was given scientific recognition. People who use this word in ways that are inconsistent with what it means in science are roundly criticised by scientists.

The problem with the term's historical connotation is actually quite similar to the problem with the term's scientific definition. The common idea of human strength and vitality is that for people to run fast, jump high, or push hard, their bodies must be able to change chemical potential energy into different forms. Although energy is a scientific concept that applies to all living things, students frequently believe that it only applies to living things when they first begin science classes in elementary school. If they believe that energy is only associated with living organisms, it can be difficult to gain a more complete understanding of the subject.

As a result, Tobin et al. (2012) recommended that the nature of energy be incorporated as a key learning goal for teaching energy, particularly in physics, in order to increase students' understanding. This includes: (1) energy exists in many forms, but it is a single substance; (2) the two main types of energy are kinetic energy and potential energy. On a microscopic level, chemical, thermal, and electrical energy are all manifestations of these two types of energy; (3) when energy is moved or changed, the systems involved must change in some way; (4) energy is not the same as matter. There may not be a flow of matter between systems, but energy can be traded between them. (5) It should be found out why energy ideas are important and how they can be used to understand engineering, technology, and social issues.

Also, Nordine (2016) says that the United States created the Next Generation Science Standards (NGSS) to start a multi-state effort to create new education standards that are rich in content and practise, organised in a way that makes sense across disciplines and

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grades, and give all students a science education that meets international benchmarks. The NGSS formulates the five big ideas on energy concepts in an attempt to help students think consistently about energy-related phenomena across disciplines. The five big ideas about energy are as follows: (1) energy exists in a variety of forms; (2) energy can be transformed; (3) energy can be transferred between systems and objects; (4) energy is conserved; and (5) all macroscopic processes consume energy.

2.4.2. Energy as a Crosscutting Concept

There are several different definitions of "energy" in everyday situations (Gyberg & Lee, 2010). According to Millar (2014), there are two ideas about energy: first, energy is widely understood as an abstract, mathematical concept, and it is difficult to define energy or even explain clearly what we mean by the word; and second, the word energy is widely used in everyday conversations, with a meaning that is less accurate than its scientific meaning. As one of the most significant concepts in science, the term "energy" can be used to predict and explain phenomena across all disciplines. As a result, each subject's instruction fails to offer students the methods they need to connect their concepts about energy from one field to another. Students face unique challenges when learning about energy because it is a fundamentally abstract concept with precise scientific applications. They also use the word "energy" in everyday conversation before they learn about it in school. This gives them a different idea of what energy is that may or may not be the same as what scientists know about it.

The term "energy" is used differently in different branches of science. As a result, when it comes to educating students about energy, teachers face a difficult task. That is, teachers are now expected to teach not only about energy as a disciplinary concept, but also clearly about energy as a cross-disciplinary analytical framework. While scientists rarely make these crosscutting connections in their daily work, science teachers are requesting that their students be taught in a way that makes these linkages evident. To meet the challenge of teaching energy in new ways, teachers need help from science and science education research groups on how to talk about energy in the classroom.

2.4.3. Energy as a Disciplinary Core Concept

As previously said, a good definition of energy is difficult to come by. However, "the ability to do work" or "the capacity to cause a change" are two frequent definitions of energy. Conversely, they have flaws and are difficult to define in a way that students can understand (e.g., Chai et al., 2006). Worse, it may send the message to students that only objects with the ability to act on their own, such as moving living beings, have energy. According to Watts (1983), many students already struggle with this alternative idea, so the physics teacher should think twice before introducing a term that strengthens this idea even more.

As a result, teachers have to introduce the fundamental concept of energy, which refers to all processes that involve energy as a general way to teach energy concepts. Understanding the importance of energy in relation to nature, technology, and society is critical, particularly when it comes to energy supply challenges (Duit, 2014). Before constructing the efficient energy instruction, it is necessary to analyse the fundamental concept. The fundamental concept of energy must consist of five major concepts: energy form and sources, energy transformation, energy transfer, energy conservation, and energy degradation (Constantinou & Papadouris, 2012; Dawson-Tunik, 2006; Lee & Liu,

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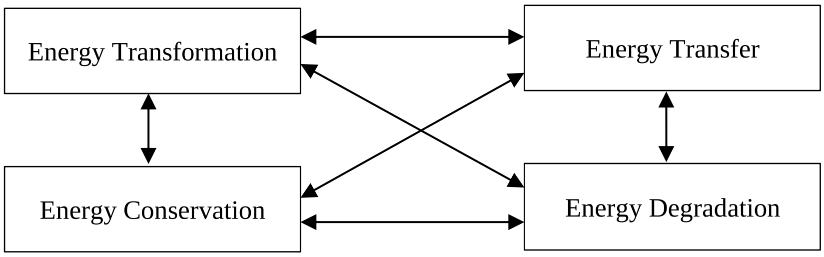
2010; Liu & McKeough, 2005; Neumann et al., 2013; Nordine et al., 2010) and their relations are illustrated in Figure 2.

Figure 2: Fundamental Concept of Energy



3. Research Methods

This study was carried out in a secondary school located in Kota Kinabalu, North Borneo, also known as Sabah in Malaysia. The constructivism paradigm is used in this study, and the qualitative approach is based on the hermeneutical phenomenology, which was established by Martin Heidegger, who has transformed radically Edmund Husserl's transcendental phenomenology. According to this epistemology, "content physics" is a "language of thought" that exists in the mind of a physicist. As a result, data for this study were gathered through a clarification of scientific sources as well as the prior knowledge of a group of secondary school physics students (16 years old) through document analysis, semi-structured interviews and written responses.

We created teaching activities in nature to simulate classroom energy lessons. The content of energy concepts that was to be taught to students has been *elementarized*, and its historical evolution has been considered through qualitative content analysis. This is required since textbooks often offer professional knowledge in an abstract and condensed manner, and the linguistic terms are also confusing to students (Komorek & Kattmann, 2008). Similarly, we positioned the local context to ensure that students' and teachers' curriculum are intelligibility, plausibility and fruitful (Carey, 1991; Chi, 2009; Posner et al., 1982; Strike & Posner, 1992). This is similar to the German tradition of Bildung, which is the analytical process of transferring human knowledge (cultural legacy) into knowledge for schooling as according to MER, physics content needs to be clarified before it can be approved as instructional content. The curriculum tradition does not recognise these principles (Westbury et al., 2000).

Therefore, subject matter clarification and analysis (Components (1) of the MER), followed by research on teaching and learning (Components (2) of the MER), were used in the process of transforming content physics into content physics for instruction. The first step is known as *elementarizing* the content of physics, and the second is taking into account what students already know. Figure 3 illustrates the phases. All data is gathered and analysed by qualitative content analysis (QCA) (e.g., Gropengießer, 2007, cited in Grusche, 2017) and metaphor analysis (MA) (e.g., Schmit, 2005). Both QCA and MA are applied to perform a more in-depth analysis of the physicists' and students' concepts in terms of meaning-making for creating content physics for instruction based on MER.

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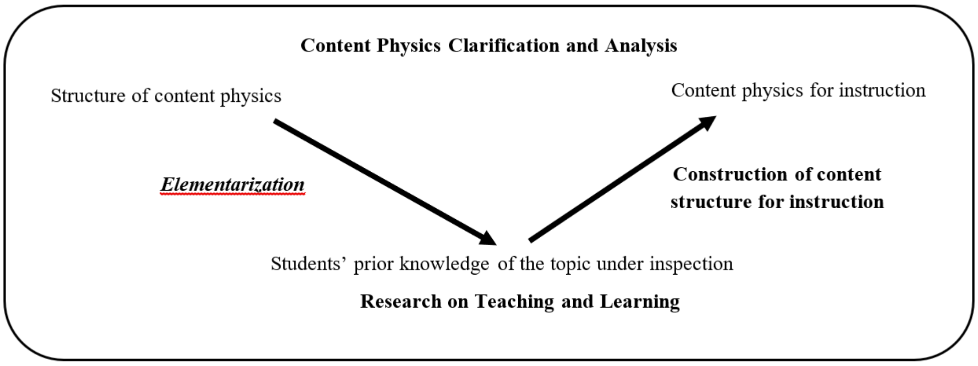
Figure 3: Steps for Content Structure for Instruction



3.1. Elementarization

The *elementarization* of physicists' conceptions of energy concepts from 15 scientific sources such as physics textbook and major publications related on energy concepts in an attempt to clarify and analysis the physics content structure in terms of the history, the nature of concepts and the metaphor used by the authors to represent their knowledge of energy concepts.

3.2. Students' Prior Knowledge

The analysis of students' prior knowledge of energy concepts was gathered from two sessions of semi-structured interviews and the reanalysis of 23 empirical past studies. This phase provided an overview of a number of notable alternative conceptions of energy concepts that are popular among students. The concepts of energy focus on the concept of energy transformation, energy transfer, energy conservation, energy degradation, and alternative or misconceptions of energy. The metaphor used by participants to represent their knowledge of energy concepts was also analysed.

4. Results

4.1. The Concept of Energy Understood by Physicists

The *elementarization* of the physics content found from 15 publications include textbooks and research papers on energy concepts refers to the fundamental concept of energy includes: energy form and sources, energy transformation, energy transfer, energy conservation, and energy degradation, as shown in Table 1. This critical analysis of energy concepts that are understood is necessary because usually their ideas are presented in an abstract and condensed manner. The presentation of the concept of energy in textbooks is sometimes difficult to understand due to the confusion of linguistic expressions, especially when the same word exists in everyday conversation but carries different meanings (Komorek & Kattmann, 2008).

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Table 1: Physicits' Understanding of Energy Concepts

Energy Concepts	Physicists' Understanding
The nature of energy	Energy is the capacity of a system to do work. Energy = changeability. Can flow, be carried, lost, stored, or contributed to a system. Emerge in various forms. Energy is not a substance. Energy is commonly considered as a mathematical concept in physics. An abstract concept. Energy comes in a variety of forms. Energy can be transformed. Energy can be transferred between systems and objects. Energy is conserved. All macroscopic processes expend energy. Cross-cutting concepts Core concepts
Energy sources	The sun, rain, coal, uranium, and hydrogen provide us energy nature appears unconcerned. "Power sources" such as wind, gasoline, batteries, food etc. The exploration of alternative energy sources is necessary. Malaysia has abundant fossil and renewable energy resources and has successfully managed the country's energy demand. Pupils will then collect information about energy sources (such as the sun, food, wind, gasoline, and batteries). The sun being the main source of energy. The various types and sources of energy.
Energy form	Energy is a variable state quantity. Energy can exist in many forms. Kinetic energy, potential energy, thermal energy, gravitational potential energy, nuclear energy, elastic energy, electrical energy, chemical potential energy, chemical energy, sound energy, heat energy, light energy, gravitational potential energy, radiant energy, electrical potential energy, nuclear energy.
Energy transformation	Energy can be converted from one form into another. Energy can be transformed into another. Energy can be exchanged.
Energy transfer	Energy can be transferred from one system to another. Energy transferred by conduction, by mechanically, by electrically, by electromagnetic radiation, energy can flow. Energy has the ability to go long distances. Energy can travel between them. Equal to amount of work done. Thermal (internal energy) transferred. Energy can be carried. Heat is defined as energy transferred.
Energy conservation and degradation	The total amount of energy in the system remains the same unless energy is added to or released from the system. The quantity of reduction must be equal to the amount of growth,

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Energy Concepts	Physicists' Understanding
	and vice versa. It can be neither created nor destroyed but can be transferred from one form into another, which simply states that the quantity of positive and negative electrical charges remains constant. Energy is fundamentally the same. Energy can be stored. Constant quantity of energy. Recognise the importance of maximising efficiency of devices in conserving resources.

4.2. Analysis of Student's Prior Knowledge of Energy Concepts

The prior knowledge of students was discovered through two series of semi-structured interviews and written responses from students, with a three-month gap between the first and second interviews. Qualitatively, 24 transcripts of interviews with 12 participants were analysed using qualitative content analysis and metaphor analysis (see Table 2). Reviewing students' previous knowledge was not done to replace it with scientifically valid concepts, but to connect it to scientific ideas so that students can see and understand the different points of view (Duit & Häußler, 1994).

Table 2: Students' Understanding of Energy Concepts

Energy Concepts	Student's Prior Understanding
Energy form and energy resource	Renewable energy resources and non-renewable energy resources. Types of energy such as kinetic energy, potential energy, heat energy, sound energy, wave energy, chemical energy. The meaning of energy forms or energy resource seem interchangeable. Energy resources as forms of energy such as coal, hydro, wind, oxygen and pressure. Form of energy such as friction energy, gravity energy, energy push and pull, pressure energy, absorbing energy, and photosynthesis energy. Energy as power, weight, work and electrical charge. Energy is associated with living Energy is associated with living things is different with energy in non-living things. Energy is not involved in certain activity. Energy is physical entity. Energy is related to brain activity and paranormal believe.
Energy transformation and energy transfer	The meaning of transformation and transfer are always interchangeable. The concept of energy transformation and energy transfer become challenging caused by the language. The concepts of energy transfer defined as the changing of energy forms in a system. The concept of energy transformed/transferred as energy is able to produce or generate other form of energy in a system. Energy is also seen as a product of any activities Energy transfer slightly similar to the scientific definition that is energy is transferred from one location to another.

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	The participants conceptualised energy transferred like a fluid which can flow between two places. Energy can be transferred through medium such as wire. Energy like a gas and when it transferred, the energy tries to fulfil the empty space of the system. The area of intersection described energy transfer where the amount of initial energy being transferred is less than 100%. He stated that only the source of energy can be transferred. The analogies of energy transformation/transfer: ball collision analogy, moving the house analogy, water supply analogy, marble collision analogy.
Energy conservation and energy degradation	Energy as a conserved quantity in a close system, where energy can neither be created nor destroyed, energy only can be transformed and/or transferred from one form to another. Energy as an entity that can be stored in a system such as chemical energy in a battery, potential energy in human and fuel. Energy conservation means energy saving. Some energy can finish if it is used regularly or in a long period such as battery and energy in human when he or she become tired. Energy will loss to environment as a new form of energy or into something unknown but still exist. Energy and heat will loss to environment. When the torchlight is switching off, the light energy and heat will turn back into electrical energy or chemical energy inside battery. Energy can be created or generated in various ways. Using solar technology to generate electrical from sunlight. Energy slowly disappears as heat energy.

By reanalysing previous research on students' conceptions of energy, the researchers were able to compare and contrast the findings of previous studies with the empirical studies conducted in this study to see if there were any similarities or differences. Furthermore, it appeared to be interested in seeing the pattern of students' mental representations of the energy concept, which included both alternative and scientific conceptions of the energy concept. This is significant because it allows the researchers to create instructional settings that respect students' prior knowledge, as suggested by the constructivist approach to teaching and learning. The results of the reanalysis of students' conceptions of energy concepts are shown in Table 3.

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Table 3: Analysis of Misconception of Energy Held by Students from the Previous Study

Sources / Misconception	Barak et al. (1997)	Bliss & Ogborn (1985)	Boyes et al. (1991)	Chabalengula et al. (2012)	Driver et al. (1994)	Duit (1984, 2014)	Ellse (1988)	Fetherston (1994)	Goldring & Osborne (1994)	Kesidou & Duit (1993)	Kruger *et al.* (1992)	Krummel et al. (2007)	Lijnse (1990)	Mak & Young (1987)	Mann (2003)	Sağlam-Arslan & Kurnaz (2009)	Sanders (1993)	Solomon (1992)	Svedholm & Lindeman (2013)	Trumper (1997a, 1997b)	Watts (1983)
Energy is involved or found in living organism only (or human only)	/	/			/	/		/		/	/		/		/				/	/	/
Energy is not involved in non-moving object (e.g., statue)		/		/		/															/
Energy is different in living and non-living thing	/											/	/					/			
Energy is (only) present if there is movement		/				/		/		/	/	/	/	/				/		/	/
A causal agent stored in certain objects					/							/									/
Linked with force and movement					/													/		/	/
Energy is a general kind of fuel					/	/															/
Energy is a fluid, an ingredient or a product					/	/															/
Energy is force						/			/	/	/					/		/	/	/	
Energy is work						/										/					
Energy is electricity						/												/	/		
Energy is power						/			/							/		/			
Energy can flow												/									
Define energy in colloquial terms	/					/				/	/										
Students cannot explain the meaning of energy conservation	/			/		/			/	/			/		/					/	
Energy is an abstract accounting quantity						/															
Energy is the ability to do work						/	/		/												
Energy is the ability to cause changes						/															
Energy is the ability to produce heat						/	/		/			/		/							
The conceptualist and the materialist distinction						/					/										

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Misconception \ Sources	Barak et al. (1997)	Bliss & Ogborn (1985)	Boyes et al. (1991)	Chabalengula et al. (2012)	Driver et al. (1994)	Duit (1984, 2014)	Ellse (1988)	Fetherston (1994)	Goldring & Osborne (1994)	Kesidou & Duit (1993)	Kruger *et al.* (1992)	Krummel et al. (2007)	Lijnse (1990)	Mak & Young (1987)	Mann (2003)	Sağlam-Arslan & Kurnaz (2009)	Sanders (1993)	Solomon (1992)	Svedholm & Lindeman (2013)	Trumper (1997a, 1997b)	Watts (1983)
Energy is a substance-like quantity						/					/	/		/							/
A depository model of energy	/	/			/	/			/		/	/	/		/						/
Energy is functional						/															
Living things get their energy from resting			/					/							/						
Energy can be generated																					/
Students do not have proper information about energy forms						/															/
Energy conservation means energy saving									/												
Energy is conserved in the laboratory only									/												
Students generally fail to determine the unit of energy or power									/												
Energy is physical entity											/	/			/					/	
Energy associated to paranormal believes																			/		
Energy might have properties deriving from intuitive biology and psychology																			/		
Energy as a mental property																			/		
Energy might heal and poison																			/		
Energy as an animate being, such as telling, wanting, and hearing																			/		
Photosynthesis is the process provide plants with the energy				/													/				
Sun is the main source of energy				/													/				
Digestion is the process that provides animals with energy				/											/		/				
Plants obtain energy from soil and water				/																	
Mostly do not accept the idea of energy degradation																				/	

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The way to transform content physics into content physics for instruction through the phases of the clarification and analysis of energy concepts and the analysis of students' prior knowledge of energy concepts was triangulated to see the confrontation ideas from physicists and students. This confrontation idea is critical to helping physics teachers design energy concepts lessons based on the constructivist perspective of learning. Table 4 demonstrates the ideas' confrontation of the nature of energy.

Table 4: The Confrontation of Two Understanding Concepts of the Nature of Energy

Energy Concept	**Physicists' Understanding**	**Students' Understanding Scientific Conception**	**Alternative Conception**
The Nature of Energy	Changeability Work done Many forms Abstract Transferred Transformed Conserved Dissipated Cross-cutting Core	Involve in living and non-living things	Involve in living things only Energy in living things is different with energy in non-living things. No activity no energy Physical entity Brain activity Paranormal believe
Energy Sources	Renewable sources Non-renewable sources Alternative energy	Renewable energy Non-renewable energy	Form energy = source energy
Energy Form	Kinetic energy Potential energy Thermal energy Gravitational potential energy Nuclear energy Elastic energy Electrical energy Chemical energy Sound energy Light energy Radiant energy Nuclear energy	Kinetic energy Potential energy Sound energy Chemical energy Nuclear energy Electrical energy Light energy	Heat energy Wave energy Coal energy Hydro energy Wind energy Oxygen energy Pressure energy Friction energy Gravity energy Push and pull energy Absorbing energy Photosynthesis energy Power energy Weight energy Work energy Electrical charge energy
Energy Transformation	Converted Transformed Changed Exchanged	Energy can be transformed	Energy transformed = energy transferred Produce new energy Generate new energy Product of activity

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Energy Concept	Physicists' Understanding	Students' Understanding Scientific Conception	Alternative Conception
Energy Transfer	Transferred Flow Distance travel Work done Can be carried	Transferred through medium Less than 100% energy transfer before and after (in an inefficient system) Such as water supply	Transferred = changing of energy form Energy like a gas Transferred by fulfil the empty space Source of energy transferred Ball collision Moving the house Marble collision
Energy Conservation and Degradation	Amount conserved Equal Eternal Cannot be created Cannot be destroyed Can be stored Efficiency Save	Conserved quantity Can neither be created nor destroyed Can be transformed Can be transferred Can be stored Loss to environment Still exist Disappears as heat	Can be stored in human Can be stored in fuel Energy saving Can finish if used regularly Can finish if tired Turn back to original form of energy Can be created Can be generated Can be produced Used up Disappears as heat energy

5. Conclusion

As previously stated, MER is founded on a constructivist epistemological foundation (Duit & Treagust, 1998, 2003). This means that students construct their own knowledge based on prior knowledge (Driver & Easley, 1978), and content knowledge is regarded as a human creation (Abd-El-Khalick & Lederman, 1998). As a result, when planning a lesson, subject matter issues and student-related issues must be considered concurrently in order to produce an effective instruction method. According to MER's forefathers, Kattmann et al. (1996), the subject matter content issue is more of a personal reconstruction of the textbook authors than a delivery of scientific truth. Furthermore, they see material reconstruction for teaching purposes as a process that necessitates close collaboration between subject matter experts, content-area issues, referring instruction goals, and students' perspectives.

Many physics teachers believe that content physics for instruction must be “simpler” than content physics understood by physicists in order to match students' understanding. This is called “content reduction for instruction.” The procedure, however, this viewpoint misses the topic entirely. This problem can be avoided by using MER to prepare physics lessons. This is because MER has the unique ability to “transform” the content physics structure that physicists understand into a structure that students can easily understand. As a result, the content structure for instruction is not based on the structure or content of physics directly. Instead, it must be made methodologically with MER orientation in mind.

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Obviously, MER, which is based on a *Didaktik* approach, emphasize aspects of the relationship between teachers and students (the who), subject matter (the what), and instructional methods (the how) (Klette, 2007). Above all, *Didaktik* pioneers from the 15th century, such as Wolfgang Ratke, who defined *Didaktik* as the "art of teaching," and Johann Amos Comenius, who defined *Didaktik* as "teaching everything to everyone," explain that this models powerful because there is no biased concentration, regardless of whether the focus of teaching is student-centered or content-only. In MER, the interaction of these three elements is considered to be very harmonious. In the case of this study, the concept of energy is not viewed as a separate entity in the relationship between myself as a teacher and the researcher and my students as the research participants.

As in previous studies, the well-known concepts of energy, including energy forms, energy transformation, energy transfer, energy conservation, and energy degradation (e.g., Dawson-Tunik, 2006; Liu & McKeough, 2005; Nordine et al., 2010), has become the focus of students' conceptualisation. One fundamental design approach that applies to any physics topic is to expand on ideas and situations that students are already familiar with rather than try to replace them (Duit & Treagust, 2003; Posner et al., 1982). There are many problems and choices that students face every day in their personal and social lives that can be addressed in the context of an energy learning experience to help students better understand the scientific concept of energy and appreciate its brilliance (Millar, 2014). Through the lesson plan developed by using the MER as the guided, I was guided to be careful on few complicated terms need some consideration, such as:

Stored Energy: In the study, few students realised that the chemical liquid inside the lighter has the potential energy to burn. Although this interpretation is incorrect but this idea cannot be ignored because potential energy is commonly referred to as stored energy. The term "store" implies that energy is a substance that is inserted into atoms and held there until released. Science says molecules like methane is stored energy. This means that if we burn it, the atoms will break apart and form bonds with lower potential energy. Using these results, several students acquired understanding how chemical energy in dry cells can be used to power a toy train or a toy fan.

Energy Flow: Scientists use the word "energy flow" to describe energy transferred between systems because it is similar to fluid or air flow. We all know that fluids flow from one place to another, and that fluids prefer to spread out and fill their containers to the brim. Students in the study see energy transferred as a liquid flow. Using the term "flow" to represent energy transferred is not perfect, but it does help students use their fluid idea to support their understanding that energy missing from one place must appear somewhere. So energy is conserved.

Ethics Approval and Consent to Participate

The researchers used the research ethics provided by the Centre of Postgraduate Studies, Universiti Malaysia Sabah. All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional research committee.

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Conflict of Interests

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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