CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

Energy is generally regarded as an important concept in the Malaysian school science curriculum. At the Grade 5 primary school level, children are introduced to different sources of electrical energy and the transfer of electrical energy to other forms of energy (Kementerian Pendidikan Malaysia, 1993). At the secondary school level, energy is taught in the Form One topics 'Forms and Sources of Energy' and 'Heat and its Transformation' (Kementerian Pendidikan Malaysia, 1990). The concept of energy is then progressively dealt with in the Form Two topic 'Food and the Release of Energy' (Kementerian Pendidikan Malaysia, 1990) and in the Form Three topic 'Electricity and Electromagnetism' (Kementerian Pendidikan Malaysia, 1989).

Furthermore, at the Form Four level, the arts stream students are taught the energy concept in the topic 'Energy and Chemical Changes' in their KBSM Science syllabus (Kementerian Pendidikan Malaysia, 1990), while their science stream counterparts are taught the concept in the topic 'Work and Energy' in their Form Four KBSM Physics syllabus (Kementerian Pendidikan Malaysia, 1991). The energy concept is dealt with in further detail at the Form Six level for the science stream students in the topic

'Work, Power and Energy' in their STPM Physics syllabus (Majlis Peperiksaan Malaysia, 1995).

Though the term 'energy' is frequently encountered in our everyday discourse, the formal study of the concept of energy, its forms, conservation and degradation, poses difficulties for many secondary students. According to Warren (1983, 1986), energy is an advanced and abstract concept. Thus, difficulties in the understanding of this concept are expected. One of the probable reasons for the difficulties faced, according to Solomon (1985), could be due to the negative formulation of the concept as something which can neither be created nor destroyed. This formulation contradicts with the everyday experience where things used as fuels to provide energy are used up and have to be replaced. Furthermore, the aspect of conservation of energy as taught in school, is not utilized in the everyday use of the word 'energy'.

Empirical investigations about learning the energy concept clearly indicate that learning the conservation aspect of energy causes the students greater difficulties than learning the conversion aspect (Duit, 1981). The difficulties are further aggravated by the non-conformity in the nomenclature of the energy-related concepts (Taber, 1989). For instance, the gravitational potential energy, the potential energy and the strain potential are the different terms found in books used to represent gravitational potential energy, whereas in some books the term 'potential' is used in chemical potential energy to mean chemical energy stored in batteries and food.

2.1 Research on Students' Frameworks of Energy

Children who have not been exposed to any formal lessons on energy, often pick up ideas about energy concept through daily conversations with friends and adults. These ideas are assimilated by them as prior knowledge of energy. This prior knowledge of energy often hinders students from acquiring the accurate energy conceptions during formal lessons. This fact is supported by Driver and Warrington's (1985) study which reported on students' lack of efficiency in the applications of principle of conservation of energy. Moreover, Watts (1983) and Duit (1984) had also noted the lack of differentiation between the concept of energy and the concept of force among students.

Thus, many studies had been done to obtain information on students' prior knowledge of energy (Watts, 1983; Solomon, 1983a, 1983b; Bliss & Ogborn, 1985; Finegold & Trumper, 1989; Lijnse, 1990; Boyes, 1990; Trumper, 1993; Nicholls & Ogborn, 1993; Trumper & Gorsky, 1993 and Trumper 1997) in the hope that based on the students' prior knowledge, new strategies for more effective teaching of the energy concept could be developed.

Watts' (1983) study on ideas of energy of about 40 secondary students of age between 14 to 18 years old around Greater London area was used as a benchmark study by many researchers. His subjects comprised of third-year (General Science), fourth- and fifth-years (O-level and CSE Physics) and sixth form (A-level Physics) students. They were interviewed using the

interview-about-instances approach introduced by Osborne and Gilbert (1980a, 1980b) which made use of pictures of instances.

During the interview, these students were asked to decide if the pictured instances illustrated their conceptions of energy and to explain their response. Their responses were then analysed and categorized into seven alternative frameworks based on certain patterns which was observed in their responses. These alternative frameworks, according to Watts, were ideas and meanings for words which were not simply isolated misconceptions, but were part of a complex structure which provided sensible and coherent explanations of the world from students' point of view.

In many cases, these frameworks of energy were obtained from the usage of the term 'energy' in loose descriptive and interpretative network of ideas regarding the instances shown to the students in the energy cards. According to Watts, sometimes the term 'energy' was synonymously used with terms like 'force' or 'power'.

Without arranging in any particular order, the first alternative framework identified by Watts (1983) was the Human Centred Framework. This framework included description of energy which was either very anthropocentric or anthropomorphic. That is, energy was either associated mainly with human beings or objects were treated as if they had human attributes. An example of the Human Centred Energy Framework with the anthropocentric description of energy was obtained from the instance on a person pushing a box up a hill, as quoted by Watts (1983, p. 214) :

> "The person's got a lot of energy in that one ... I mean he can push it the whole way up to the top of the hill ..., but er, once the box is up there it can't *do* anything so the box definitely hasn't got any energy ... whereas the person can walk away back down."

Another example on the Human Centred Framework of energy with the anthropomorphic description given by Watts (1983, p. 214) is :

> "The two reacting chemicals have energy *in* them ... I mean they don't go round talking to things ....But I mean they've got energy in them ... so I suppose in their own sort of way they're living."

The second framework identified by Watts was classified as the Depository Framework of energy. This category of responses included students' views about some objects having energy (and rechargeable), some needing energy (and simply expending what they get) and yet others neutral (and whose activities were somehow normal or natural). From this point of view, energy was regarded as a causal agent, a source of activity based on energy stored within certain objects. An example of a student's transcript with the Depository Framework provided by Watts (1983, p. 214) is :

> "Water ... if we didn't have water ..., water is the source of energy ... we need it to survive ... (later) ... water has got something to do with this for (power station). I think it is powering the generators."

The third framework of energy identified by Watts was that energy was an 'ingredient'. In this framework energy was not necessarily a causal agent, but a 'reactive' one. It is a dormant ingredient within objects or situations that need some 'trigger' to release it. An illustration cited by Watts (1983, p. 214) for this framework is :

> "There is energy *in* things ... it's there but it needs another energy to ... sort of ... another form of energy to make it come out ... it's like a seed, it's got energy inside it to grow but it needs the sun ... well, one chemical needs another chemical to make it react."

The fourth framework of energy obtained by Watts was that energy was an 'obvious activity'. To many of the students he interviewed, outward displays of activity were the sole means of identifying energy. In fact, the activities themselves were called energy. Movement of any kind was also widely given as a reason for energy being involved. Examples of responses for this framework as cited by Watts are (1983, p. 215) :

> "The sledge is creating energy by moving fast."
>
> "Examples of energy are a burning fire, a ringing phone, chemical frothing ... people running that sort of thing."

The fifth framework identified by Watts was one which regarded energy as a product. This framework carried the suggestion that energy was not an ingredient or a process but a by-product of the situation. Here, energy

was treated as relatively short-lived product that was generated, was active and then disappeared or faded, clearly showing that energy was non-conserved. One example of a student's response belonging to this category as cited by Watts (1983, p. 215) is :

> "Some chemicals might change ... in which case they'll release some of their energy and produce heat ... in this vapour here."

The sixth framework identified by Watts was that energy was functional. Many of the students interviewed by Watts saw energy as a very general kind of fuel, with some limitations. Firstly, energy was more or less restricted to technical appliances and secondly, it was not essential to all processes but was mainly associated with those that made life more comfortable. An example cited by Watts (1983, p. 215) for this framework is :

> "Energy is something that can *do* something for us ... say like gas or something ... (later) ... energy has got to make something else work ... like if it was electrical it would make something like that tape recorder work."

The seventh framework categorized by Watts was the Flow-transfer Framework of energy. In this framework energy was seen as being 'put in', 'given', 'transported', 'conducted' and so on. An illustration cited by Watts (1983, p. 216) for this category of framework is :

> "energy comes out from both leads ... (battery) ... because you never get a circuit without the other one ... it comes out of the negative end ... from around the circuit encountering the bulb on the way where it can transfer some of the energy. The energy is *on* the electrons as they travel round."

Solomon (1983b) however, in her investigation on everyday meanings of energy did not use the interview methodology. Instead, she used the word-association methodology on 914 first, second and third-year students (equivalent to Malaysian Form One, Form Two and Form Three students) of two mixed comprehensive schools for the first part of her study. In this part of her study, these 914 students were asked to make few sentences using the term energy. Their responses were then analyzed according to living and non-living associations. From the analysis, she found that students' associations with energy could be subdivided into four overlapping categories. The first category consisted of views which saw energy as vital in life. In the second category energy was related to activity. In the third category energy was seen as a cause for machines to work. In the fourth category, energy was viewed from a global and political perspective pertaining to its shortage and the future. The second and third categories seemed to be similar to the Obvious Activity and Functional Frameworks identified by Watts (1983).

In the second part of her study, Solomon showed four sentences to 128 fourth-year students from the two comprehensive schools. Two of these sentences were correct and the other two were wrong from the scientific

point of view. The students were asked to decide whether any of these sentences were wrong. This part of her study was meant to forecast students' ability to discriminate between the scientific and non-scientific knowledge. Results showed that lower ability students were better at recalling than the high ability students. In her conclusion for the findings, Solomon found that students' out-of-school knowledge about energy was very different from scientific knowledge. It is pertinent to note that she did not categorize students' knowledge into categories as what Watts (1983) had done because she considered the process not suitable for large group of students. According to her, the categorization of students' knowledge as what Watts had done was more applicable for studies which were situation-bound.

In another of her study, Solomon (1983a) examined the energy conceptions of 59 students aged between fourteen to fifteen years old from three fourth-year classes in one comprehensive school. These students had already covered exactly the same elementary work on energy. Their conceptions of energy were studied by means of discussions, tests and examinations. At the initial stage of the study, the students were all subjected to a formal instruction on constructing energy chain. After that they were all immediately given a test and later an examination. One of the three groups was given the examination immediately after the test, while the other two groups were given the examination two and a half months later. Analysis of the results proved that her two hypotheses were right, that is,

firstly, due to lapse of time, students selected preferentially the life-world structure of energy if no further reinforcement of symbolic knowledge was provided. Secondly, successful moving over and back from one domain of knowledge to another was more difficult than continuous operation in one domain of knowledge.

Bliss and Ogborn (1985), using questionnaire methodology on seventeen thirteen-year-old girls, studied their ideas about whether or not energy was needed in certain situations. They found that animacy, which was similar to Watts' version of the Human Centred Framework, as the most salient feature of energy. In fact, they also commented that the students tended to show multiple frameworks rather than one single framework. However, they did not elaborate on what these multiple frameworks were. In addition, they also found difficulty in interpreting some frameworks from the data obtained from the questionnaire. Finally, they commented that the frameworks ought to be seen in a developmental perspective.

Finegold and Trumper (1989) had also contributed to the research on students' ideas on energy. During their pilot study stage, they used a written-response to task sort of interview-about-instance methodology to study the alternative explanatory frameworks of energy of 175 Grade 9 to Grade 11 Israel secondary school students. These students' frameworks were categorized into categories similar to those of Watts' (1983). Their list of categories of frameworks were :

(i) Anthropocentric : associating energy with human beings,

(iia) Depository : some objects have and expend energy,

(iib) Active deposit : energy causing or needed for things to happen,

(iii) Ingredient : energy as dormant in objects and release by a trigger,

(iv) Activity : in which energy is an obvious activity,

(v) Product : energy as a product of a process or a situation,

(vi) Functional : energy as a 'kind of fuel',

(viia) Transfer : energy as 'something' transferred in an interaction or process, and

(viib) An Accepted Scientific Concept : when two systems interact, that is, when a process takes place, something which we call energy is transferred from one system to another.

Later, at their case study stage, Finegold and Trumper (1989) used in-depth discussions with 35 students from the same school (some with and some without physics background). From this stage of study, they discovered that the Anthropocentric, Active Deposit and Product frameworks were frameworks shown by many students. However, they did not provide numerical statistics on how many students actually manifested the three frameworks. In their conclusion, Finegold and Trumper (1989) suggested that it was possible to develop these alternative frameworks held by students into a framework which was acceptable to the scientific community.

Lijnse (1990) also carried out an investigation to identify 97 sixteen-year-old students' prior conceptions of energy. These students had only been

taught the introductory level of energy. For the purpose of the study, these students were required to answer open-ended questionnaire. According to Lijnse, though this method of asking questions forced students to explore more actively and deeply what a stimulus word such as energy was to them, it also had its drawback. Students were not always inclined to give long and full descriptions. However, analysis of the results from Lijnse's study yielded the following frameworks of energy which were similar to that of Watts' (1983) study :

(i) human centred energy,

(ii) depository model of energy,

(iii) energy as an ingredient or as a product,

(iv) energy as an obvious activity,

(v) energy is functional and

(vi) energy as some kind of fluid.

In addition, an interesting finding from the study was that elements of several frameworks often appeared in the answers of the same students, that is, students showed single and multiple frameworks of energy. Lijnse reported that 5% of the subjects showed four different frameworks, 22% showed three different frameworks, 48% showed two different frameworks, 22% showed one framework and 3% showed none. This was an interesting finding which was not found in other studies pertaining to students' alternative frameworks of energy.

Another group of researchers, Nicholls and Ogborn (1993) , used a questionnaire which required written responses, to map six primary pupils' and twelve secondary students' ideas about energy in their pilot stage of the study. However, they found that the questionnaire could not survey the necessary variety of kinds of entity and aspects of energy which they needed to cover. Thus, during their actual study stage, they used only a 'yes' or 'no' answer questionnaire on a class of 32 fourth-year primary juniors aged between ten and eleven years old and another class of 19 third-year secondary school girls, aged between thirteen and fourteen years old from a selected grammar school. Results from their study showed that the students manifested two dimensions of thinking which underlay the energy conception. One dimension was a source-user distinction, with natural phenomena and fuels seen as sources, and living things and energy-using devices seen as users. The second, more complex dimension was a distinction between acting alone versus being used to act. And in conclusion, they found that the strongest basic notion of energy was energy as a source of action.

Trumper and Gorsky (1993) had carried out research pertaining to the influence of alternative frameworks, cognitive levels and closed-mindedness on the learning of the energy concept on 60 grade nine students from a rural regional high school in Israel. One part of their study attempted to establish the relationship between the students' alternative frameworks of energy held prior to instruction and their cognitive levels.

To determine the students' alternative frameworks, a written questionnaire was administered to these students. The students were asked to choose three out of eight pictures in which the energy concept was most clearly evident and to explain their choice. The classification of frameworks was based on the definition provided by Finegold and Trumper (1989) and Watts (1983) as listed earlier (see page 22).

To assess the students' cognitive levels, the Video-taped Group Test (VTGT) developed by Shemesh and Lazarowitz (cited by Trumper & Gorsky, 1993) was used. This test comprised twelve tasks and assessed the following formal reasoning patterns : Control of variables and proportional, probabilistic, combinatorical, and correlational reasoning. Based on the scores obtained from the test students were clustered into the preformal (concrete and transitional) and formal cognitive levels.

Part of the results showed that seven frameworks were identified from their study. These frameworks were the Cause, Product, Anthropocentric, Flow-transfer, Transformation, Depository and Activity Frameworks. It should be noted that the Transformation Framework was the new term used by Trumper and Gorsky (1993) to replace 'An accepted scientific concept' used in Trumper's (1989) study. Similarly, the term 'Cause' was used by Trumper and Gorsky to replace 'Active Deposit' used in Finegold and Trumper's study. From the statistics provided in Trumper and Gorsky's (1993) study, the Cause, Product and Anthropocentric Frameworks were more frequently used by the students.

In another study by Trumper (1997), one of his purposes was to determine the alternative frameworks of energy of 608 pre-service trainee teachers in Israel. To do so, a written questionnaire was also administered to these students. These students were also asked to choose three out of eight pictures involving the concept of energy and to explain their choice in two or three sentences using the word 'energy'.

The trainee teachers' conceptions of energy were analyzed according to the frameworks defined by Watts (1983), together with the 'Cause' and the broaden 'Product' framework defined by Trumper (1989, 1990a). From the analysis of the students' responses, Trumper found that students' conceptions could be categorized into eight frameworks. These frameworks were the Cause, Anthropocentric, Product, Depository, Transformation, Ingredient, Flow-transfer and Functitonal Frameworks. He also reported that these students used mainly four alternative frameworks, namely, the Cause, Anthropocentric, Product and Depository Frameworks to describe the pictures they chose. However he did not define the term 'mainly'.

2.1.1 A Summary of the Review of Literature

From the above review of the nine studies, it was found that studies done by Watts (1983), Finegold and Trumper (1989), Lijnse (1990), Trumper and Gorsky (1993) and Trumper (1997) yielded more relevant findings pertaining to the students' conceptions of energy which were related to the present study.

Watts'(1983) study allowed him to construct a list of seven energy frameworks manifested by the students. Whereas Finegold and Trumper's (1989) study, in addition to providing a list of frameworks of energy manifested by the students, was able to add information on the frameworks of energy (that is, the Anthropocentric, Active Deposit and Product Frameworks) which were manifested by many students. They were able to obtain this information through in-depth discussions with only 35 students. However, it should be noted that among the frameworks of energy defined by Finegold and Trumper, two of them were slightly different from those of Watts (1983).

In Finegold and Trumper's (1989) study, the Depository and Active Deposit Frameworks have the following meanings. To them the Depository Framework was manifested if something was mentioned as having energy and expending it. This is actually the first half of Watts' definition of the Depository Framework. The Active Deposit Framework was manifested when energy was mentioned as a cause or needed for something to happen. This is the second half of Watts' definition for the Depository Framework. According to Watts (1983) the Depository Framework involves seeing energy as a causal agent or source of activity based on the energy stored. The additional category of frameworks reported by Finegold and Trumper was the accepted scientific concept, which was not in Watt's list of frameworks of energy.

Trumper and Gorsky (1993) who used the written questionnaire methodology was able to identify three frameworks of energy frequently used by the junior high schools students in Israel, that is the Cause, Anthropocentric and Product Frameworks. These three frameworks were actually similar to Watts' Depository, Anthropocentric and Product Frameworks.

A recent study by Trumper (1997) showed that elementary school trainee teachers mainly held the Cause, Anthropocentric, Product and the Depository Frameworks of energy. These four frameworks were in fact also in line with Watts' Depository, Anthropocentric and the Product Frameworks. The Depository Framework defined by Watts (1983) had been subdivided into two categories by Finegold and Trumper (1989), that is, the Depository and the Active Deposit Framework. The later was also named as the Cause Framework in Trumper and Gorsky's (1993) study.

Lijnse (1990) also found an inventory of students' frameworks of energy. However, in addition to the inventory, she also reported specifically on the percentage of students showing single, double, triple and even four frameworks of energy. This was possible for Lijnse as the open-ended quesitionnaire was used for data collection. However, in Lijnse's (1990) case, the categorization of the framework also differed slightly from that of Watts (1983). She had all the seven frameworks of energy which Watts had. But she grouped the Ingredient and Product Frameworks as one framework, whereas Watts split these into two separate groups.

Bliss and Ogborn (1985) who used the questionnaire methodology was able to find animacy, which was similar to Watts' Human Centred Framework, as the most salient feature of energy framework existing among students and that there was also a tendency for students to show multiple frameworks. Unfortunately, she did not provide any detailed picture of the multiple frameworks of energy manifested by the students, neither did she provide details of the list of frameworks found.

Similarly, Nicholls and Ogborn (1993) who used a 'yes' or 'no' questionnaire was only able to obtain two dimensions of thinking pertaining to energy. They were the 'user-source' dimension which was similar to Watts' Depository Framework, and 'acting alone versus being used to act' dimension which was similar to Watts' Obvious Activity Framework. They also reported that the source of action was the strongest basic notion of energy among the students.

Study by Solomon (1983b) which made use of the word-association methodology found some overlapping categories of views of energy held by students. Of these views, only two of them, that is, the views that energy was related to activity and a cause for machines to work were similar to Watts' Obvious Activity and Functional Frameworks.