Science and Mathematic Education Centre

Students' Use Of Formal And Informal Knowledge About Energy And The Human Body

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ABSTRACT

During the past three decades, much research has occurred into students' conceptions as well as factors influencing them and how the conceptions are formed. This study reports on students' conceptions involving energy and the human body. Initially, a number of student conceptions within the overarching area of energy and the human body were identified by developing and administering questionnaires to 610 students ranging from Year 8 through to Year 12. Students' responses to the questionnaire items resulted in previously identified conceptions as well as a number of unreported ones. The unreported notions included: carbohydrates are different to sugars; energy is needed for organs to function; fats and their role in energy storage; the eye and ear do not convert energy but transfer it to the brain; sweat cools the skin due to contact with air; objects need energy to start moving but not to move; and aspects of respiration and digestion. Conceptions such as the particulate nature of energy, energy's usefulness, conservation and transfer of energy, role of digestion and respiration, sources of energy were associated with previously identified notions which were derived from both informal and formal learning situations. But, it was not possible to distinguish which source knowledge was derived from.

From these notions, a series of possible pathways for conceptual development within the area of energy and the human body were described. Further analysis of the data indicated a number of ontological changes that can occur as the student-cohort became older. These ontological changes included a decline in the notion of energy being particulate to being non-particulate and not being described, through to being involved in the chemical bonds of molecules, the role and processes of digestion, the number of energy types and energy sources and how the eye and ear function. All these conceptions changed with student age and became more scientifically acceptable in their nature as students' formal education increased.

Based upon the findings of the above questionnaires, a diagnostic paper and pencil instrument set of 20 items based upon a modified two tier multiple-choice format was developed to identify student held conceptions on energy and the human body. Subsequently, an interventionist strategy was designed and implemented to help students avoid the development of misconceptions as they construct acceptable concepts related to digestion and to respiration. This strategy follows the passage of food from its ingestion through to the absorbed foods conversion into ATP for use by the body.

The findings of this study are to be of use to science teachers worldwide, not only in Western Australia as the findings of this thesis are relevant to educators of students in Years 8 to 12. The findings are related to energy in general but specifically to the students' own body. These findings relate directly to an intrinsically interesting feature, the student's own body. Another outcome of these misconception findings are two instruments which are likely to be of value to educators of Years 8 to 12 students. These are a diagnostic instrument designed to identify a number of alternative conceptions

learners may hold and secondly a lesson sequence dealing with digestion and respiration and the role these have in the conversion and transfer of energy in the body.

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CHAPTER 1

OVERVIEW

1.1 INTRODUCTION

This study is concerned with the identification and analysis of children's notions of energy and the human body that incorporate the areas of energy intake, conversions, usage and losses. This chapter begins by briefly introducing constructivism and its many guises, then presents a brief comment on conceptual change theory and goes on to discuss ontology and the changes which may occur within an ontological position. The introduction locates this research within current educational research and theory and relates to the research already carried out into the notions that children hold with regard to energy use and their body. Following this overview of the work into constructivism, alternative conceptions and conceptual change and growth, the research problem is stated and focussed as a number of research questions.

The research questions provide the basis for the structure of the research that comprises a number of stages written as four separate studies. Each study stands on its own but they all support each other, with each study addressing one research question derived from the research problem. A rationale is provided for the study, setting this study within the realm of international research which has been developing over the past 40 years. The chapter concludes with a discussion of the limitations of the study and the research problem.

1.2 CONSTRUCTIVISM

Since the early 1970s, much research has been carried out into the study of the notions that children hold; these notions include both alternative conceptions and those that are in agreement with conceptions held by scientists. This research into alternative conceptions has been guided by constructivist views as expressed by many philosophers of education and psychology and by numerous researchers. While constructivism can most probably be traced back to the Greek philosophers such as Plato and Socrates, it is only in the last 30 or so years that constructivism has become a recognised theory or paradigm of learning. Over the proceeding years since the early 1970s, a number of forms of constructivism with different emphases on what is important in the learning processes have been variously described. The major subdivisions of constructivism are the radical constructivism of von Glassersfeld (1981, 1985, 1989), the social constructivism of Vygotsky (1986) and later Driver (1989) with a number of other constructivist forms including information processing, social constructionism, cybernetic systems, socio-constructivism and critical constructivism.

All of the various sub-paradigms of constructivism reject the old notion of the learner coming to a formal classroom lesson as either a *tabula rasa* or with no unacceptable prior knowledge that cannot be changed easily with good lesson planning. Central to all these sub-paradigms of constructivism is the notion that the learner becomes actively engaged with new data from the environment. It is through this interaction with and reaction to the new data that the process of learning proceeds. As a consequence of previous interactions, children bring notions with them that have been developed during their everyday active involvement with their environment and society. The pre-existing notions of the phenomena, that students are studying in a formal learning situation, are more often than not at odds with the scientifically acceptable concepts. For example, many students believe energy can be created or destroyed and is used up (Lijnse, 1990; Ross, 1991; Solomon, 1982, 1983b), there is good and bad energy (Arzi, 1988), only living things can possess energy, (vitalism) (Barak, Gorodetsky & Chipman, 1997; Gilbert & Watts, 1983; Solomon, 1986) the duality in meaning of the term ‘conservation of energy’ (Carr & Kirkwood, 1988; Heilman, 1989), and no understanding of the conservation of energy (Duit & Haeussler, 1994; Gayford, 1986b; Goldring & Osborne, 1994).

A major area of study in recent times has been that of students’ misconceptions or alternative notions, with many researchers looking into various areas of science that children study at school. With learners of all ages, from preschool through to graduate students and practicing teachers and in many science disciplines, research has identified consistent evidence of learners’ conceptions that are frequently at odds with those of scientists. This study of alternative notions has resulted in a large body of research being reported, with for example, Duit (2002) listing some 3300 reports of research in this area.

1.3 ALTERNATIVE NOTIONS

Alternative notions come under a variety of names which include such terms as misconceptions (Lawson & Thomson, 1988; Novak, 1988), alternative conceptions (Gilbert and Swift, 1985), children's science (Osborne and Freyberg, 1985), alternative frameworks (Driver & Easley, 1978), preconceptions (Clement, Brown, Zietsman, 1989; Hashweh, 1986), student's informal knowledge (Driver, Asoko, Leach, Mortimer & Scott, 1994a), intuitive conceptions (di Sessa, 1993), prescientific conceptions (Good, 1991) and a number of other names. As yet, there is no consensus on one acceptable term to account for the concepts that children bring with them to a formal learning situation, although there appears to be a trend towards the use of the term 'alternative conceptions' to be the overarching name for alternative notions to those which are scientifically acceptable.

In this thesis, I shall refer to three notions as alternative conceptions, misconceptions and preconceptions with the following meanings. *Alternative conceptions* are those notions held by an individual which are at variance to those currently acceptable to science, while *misconceptions* are a student's conceptions that arise as a result of instruction but which do not match the currently scientifically acceptable conceptions. *Preconceptions* are conceptions developed through the students' interactions with their environment prior to formal learning. The last two types of conceptions form a subset of a larger group of alternative conceptions as shown in Figure 1.1. The larger group of alternative conceptions would also include those conceptions which are undergoing modification. All or many of these notions may be retained despite teaching, as was found, for example, by Dreyfus and Jungwirth (1989).

Associated with research findings on students' alternative conceptions research in science is the need to implement teaching strategies so that learners are more easily able to adjust their conceptual frameworks to become better aligned to those currently held by science. Research in this area has led to much study of how people learn and adjust currently held notions (see Duit, 2002).

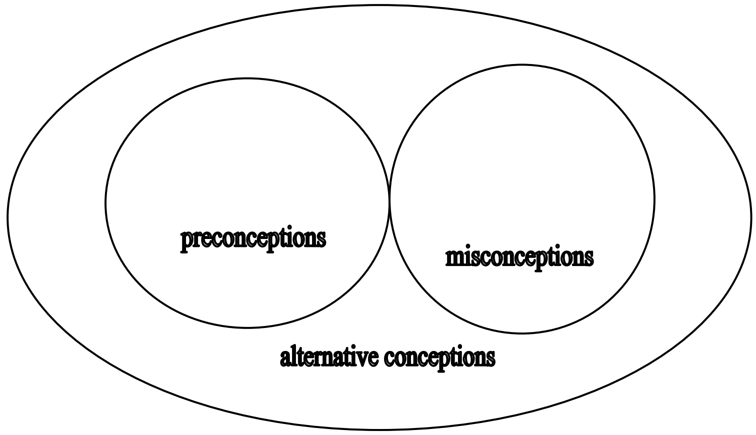

Figure 1.1 The relationship between various types of students' conceptions.

1.4 CONCEPTUAL CHANGE

A number of factors can influence conceptual change by making the current concept appear less fruitful, plausible and intelligible (Hewson, 1981). Over a number of years, researchers have raised various factors which they claim influence change, for example, formal education and everyday experiences and language. Within the formal education setting, factors such as the classroom environment, the teaching methods employed, the situations and materials used during lessons all impinge upon the acceptance or rejection of the new information. But, the overarching factor is the student's prior conceptions since these influence the reception, encoding and processing of data and its subsequent incorporation into the mental framework of the learner. Pintrich, Marx and Boyle (1993) claimed motivation and contextual factors were also involved in influencing conceptual change. Treagust (1996) and Tyson, Venville, Harrison and Treagust (1997) combined a number of influencing factors to arrive at their multi-dimensional framework of conceptual change where the influencing factors are placed into three categories consisting of ontology, epistemology and social/affective. These latter authors claim that these factors need to be examined during the time that students learn a concept so that researchers can obtain a full appreciation of the conceptual change that has occurred.

Further to these factors is the degree of change which occurs. Various researchers have reported conceptual change as small in size or weak revisions (Posner, Strike, Hewson &

Gertzog, 1982; Strike & Posner, 1992), by the addition or accretion of new material (Posner *et al.*, 1982; White,1996) and the revision of a specific theory (Vosniadou, 1994) all of which are said to involve an evolutionary change. Large changes or strong restructuring (Carey, 1985), revision at the framework level (Vosniadou, 1994) and changing ontological categories (Chi, Slotta & de Leeuw, 1993) are said to be revolutionary. There are numerous names for the different degrees of conceptual change with only a few named here; a comparative summary of these various terms are shown in Tyson *et al.* (1997). Debate is still taking place over which of these degrees of conceptual change takes place or if it is a combination of both evolutionary and revolutionary change. Shymansky and his co-workers reported a saw-tooth pattern of change whereby there is a slow but certain change taking place which is punctuated by regression to old held views (Shymansky, Yore, Treagust, Thiele, Harrison, Waldrip, Stocklmayer & Venville, 1997). Still other researchers have discussed conceptual change in terms of ontological and epistemological changes. For example, researchers such as Carey (1985), Chi *et al.* (1993), Mariani and Ogborn (1995) discussed ontological change while diSessa (1993), Kaper (2000), Posner *et al.* (1982), Strike and Posner (1992) and Tytler (2000), to name a few, have discussed epistemological change. These ontological changes will be discussed in more detail in Section 2.14.7 and 2.15 followed by epistemological change in section 2.16.

The identification of alternative notions and research in conceptual change has led onto investigating ways of teaching such that students' alternative notions can become better aligned to the current views held by science. Work carried out by a number of researchers has dealt with strategies which have been tried and tested for their efficacy in changing student preconceptions. Some strategies have proved successful, for example those by Grayson (1994), Osborne *et al.* (1993) and Trumper (1990a & b, 1991), while others have been unsuccessful, for example, tests by Dreyfus *et al.* (1989) and Gorrell, Tricou and Graham (1991). Gorrell *et al.* carried out an interventionist-strategy with two post-tests and found that while the initial post-test results showed that adjustment of conceptions had occurred, the second post-test showed these adjustments were not necessarily held over the longer term. The degree of retainment of new concepts in Gorrell *et al.'s* study was dependent upon the methods employed to facilitate the student's development of the new material. Such researchers as Gorrell *et al.* (1991), Hewson (1985), Solomon (1983b), Shymansky *et al.* (1997) and Trumper (1993b) have described delayed post-test situations where they found that students did retain their scientifically acceptable concepts. Gorrell *et al.* and Shymansky both found when students are actively involved in creating their own knowledge, they did better remember this material than material that they were not actively involved in generating. Hewson and Solomon found that students will revert to their life-domain concepts unless there is ample practice of the new science concepts.

1.5 PURPOSE OF THE STUDY

Consequently, the purpose of this study is to identify the conceptions held by students aged 12 to 17 years with respect to energy and its relationship to the human body and to observe how these conceptions change over time by collecting and analysing data from different year levels. From these data, a two-tier diagnostic instrument was developed and tested to identify alternative conceptions held by students. The research also deals with the development and trialing of an interventionist strategy for two aspects identified as having frequently held student alternative conceptions.

1.6 OBJECTIVES AND RESEARCH PROBLEMS

Four objectives were created to address the purpose of the study and were further refined to create a series of specific research questions.

1.6.1 Objective 1

To develop a series of questionnaires to help identify both scientifically acceptable and unacceptable notions held by students (in Years 8 through to 12) with respect to energy and the human body and the underpinning reasons for these held notions.

Research Questions

i What commonly held scientifically acceptable and non-scientific notions about energy are held by students both in a general sense and more specifically in relationship to the human body?

ii Are biological energy conceptions related to general energy conceptions as reported in the literature or are they specific to biology and the human body?

iii What are the underpinning reasons for the notions held?

1.6.2 Objective 2

To investigate how student held energy notions and their underpinning reasons as related to the human body change over time and in what manner they change.

Research Questions

i What held notions about energy use and the human body change over time and how do these notions change?

ii How do the underpinning reasons in held notions change?

iii Are the concept changes observed evolutionary or revolutionary in nature?

iv What is the manner of the changes (in notions) which do occur?

1.6.3 Objective 3

To develop a series of two-tier true/false diagnostic items for use by teachers and students as an aid in helping identify student held notions and their underpinning reasons about energy and the human body.

Research Questions

i Can a series of two tier true/false items be developed to identify the most commonly held notions of energy as related to the human body which are held by students in Years 8 through to 12 (and if so develop a series of two-tier true/false diagnostic items)?

ii Will the diagnostic items identify notions and the underpinning reasons for these notions (and if necessary modify the diagnostic items as necessary to achieve this outcome)?

iii Are the two-tier true/false diagnostic items effective in describing the notions held by students and the underpinning reasons for these held notions?

1.6.4 Objective 4

To develop an interventionist strategy for use by teachers and students, in Year 8 to Year 12, which may help overcome identified conceptual problems and to test the effectiveness of this interventionist strategy in helping students adjust their notions.

Research Questions

i Can an interventionist strategy for teacher and student use be developed which will help overcome problematic notions held by students? (Or strategies to avoid using as they may lead to unacceptable notions).

ii Are the interventionist strategies effective in leading to the development of acceptable concepts by students?

iii Can the interventionist strategies be modified as necessary so they are made more effective?

1.7 OVERVIEW OF METHODOLOGY FOR THE IDENTIFICATION OF MISCONCEPTIONS

A pilot study designed to identify areas that created problems for students in their conceptions on energy and their bodies was carried out. Concurrently, a number of interviews based on ‘interviews-about-instances’ (Carr, 1996; Osborne & Freyberg, 1985) were held to ascertain (and to probe deeper than possible in a written questionnaire) notions that students held in relation to energy and the human body. From this information, a series of items consisting of a statement with a true/false response followed by an open-ended reason for giving the true or false was developed and administered to 616 students from Years 8 through to Year 12. The data collected from these questionnaires were used to identify alternative conceptions held by students and how these conceptions changed over time.

A series of short interviews were held to clarify the meanings of specific terms given by respondents in the written responses to the questionnaire items because of the use of everyday language with respect to energy and its conflict of meaning to that of science. These interviews were an endeavour to reduce any potential errors by the researcher in the interpretation of the meaning of terminology used by the subjects.

1.8 DATA ANALYSIS

While a number of student-held notions and how these notions change with age were identified, students' ability to transfer information from one situation to another was indirectly discussed. The area of study in this thesis covers a number of topics in the non-biology areas of science such as physics and chemistry; these topics are rarely related to the student and his/her own body and situation in formal lessons. Examples of these topics include evaporation, cellular respiration, energy transformations, energy conservation and bond energy. Research has shown for example, that most learning is within a specific context and the concepts held by a student would, once identified, reveal the ability of students to transfer concepts out of their learnt context(s) to new ones (Driver *et al.*, 1994a; Garnett, Garnett & Hackling, 1995; Linder, 1993; Mortimer, 1995). To the reader of this research, it will become clear how much transfer of information and knowledge has occurred with the subjects of this study as well as what knowledge is held by the students. This knowledge and its transfer can be seen for example in the areas of evaporation and its cooling effect, food and its relationship to energy intake and subsequent use and the involvement of cellular respiration in supplying energy to the body.

1.9 OVERVIEW OF METHODOLOGY IN THE CREATION OF A TWO TIER DIAGNOSTIC INSTRUMENT

With the concepts held by students on energy and the human body identified, a set of modified two-tier items was developed. These diagnostic items were developed as a result of the findings which came about from a close examination of the major facets of energy intake, use, transformations and losses by the human body and a study into aspects of these energy areas. The diagnostic instrument is a modified two-tier multiple choice instrument specifically developed for this research but which followed the format developed by Mann (1994, 2000) which was a modification of the two tier multiple choice question format as developed by Treagust (1986, 1996).

1.10 CREATION OF INTERVENTIONIST STRATEGY

Also from the alternative conceptions identified, a series of teaching strategies were created which, it was hoped, would lead to students developing more scientifically acceptable concepts involving energy and the human body. These strategies concentrated on one concept which was considered important and relevant to the Year 8 to 10 students and which fits into the Western Australian Curriculum. This strategy was also relevant to certain science subjects such as Human Biology and certain Senior Science topics available in Years 11 and 12 in the State of Western Australia.

1.11 RATIONALE

Energy is an area of study with everyday exposure for people of all ages. This exposure happens in a number of different contexts and meanings, many of which have alternative meanings to those currently acceptable to science. Some examples of these everyday uses are 'energy food', 'run out of energy', 'energy consumption', 'burn up energy' and 'energy conservation'. To the student, these variations in meaning lead to conceptions of the term energy which are scientifically naive (Goldring & Osborne, 1994; Posner, Strike, Hewson & Gertzog, 1982) and may be in conflict with those held by science (Duit, 1987; Lijnse, 1990; Watts, 1983). This described situation may lead to confusion, conflicts and difficulties with learning at school when the term energy is used in its scientific context. Because of this potential for conflict between in-school and out-of-school notions of energy, it is imperative that teachers be familiar with student-held notions on energy upon commencement of a lesson sequence (see for example, Ausubel, 1968; Trumper, 1991; Ward, 1983). In this way, potential conflicts and appropriate starting points can be planned for in a teaching sequence such that the student can be presented with material which will facilitate the development of high quality cognitive representations of the broad concept of energy.

A search of the literature in the bibliography source of Duit (2002) reveals much of the research involving energy-related education carried out to date has been in the area of physics (. 40%), with a smaller percentage in chemistry (31%) and only a very small volume in biology (14%). These percentages are approximate as there are "about 6 000 entries" (Duit, 2002, p.1). The vast majority of work in biological energy has involved the study of respiration and/or photosynthesis, with a small number of papers covering a range of other areas.

Lucas (1995) made a call for more research to be carried out in the field of alternative conceptions held by children in the area of biology claiming that there had been little work carried out in biology that was published in English and what was published was restricted to a small number of concepts. Lucas pointed out that the existing research examined very small aspects of these biological concepts rather than bringing together parts of a larger research area of biology such as photosynthesis and its role in the environment stating that:

> I suggest that a progressive research programme is needed, where the sub-themes to be examined are part of a deliberate map of a larger theme. Indeed, … the essential point is to go beyond accumulations of more and more isolated studies… (p. 198)

The research that forms this thesis is a partial response to this call because the research has focussed on integrating conceptions related to energy and the human body as held by secondary school students. There is a paucity of research carried out on energy and its relationship to the human body.

Prior to formal school exposure to energy in the physics and chemistry contexts, most students are informally exposed to energy and nutrition, exercise and weight control, to nominate a few areas. A wide range of energy conceptions related to other aspects of life are commonly used, for example, the energy crisis, conservation or preserving of energy resources and energy at home. It is this exposure to the relationships between energy and the individual's self that guides the young person's formulation of early concepts of energy which may be naive or alternative to those acceptable to science. Gayford (1986) points out that energy education is taught in three different fashions at school depending upon which subject context - physics, chemistry or biology - energy is being covered. This variability in context is despite energy being of equal importance and relevance in all three subject contexts.

Many educators assume that students have scientifically acceptable notions of energy, but it is never stated what these conceptions are - just that they exist. More importantly, it is frequently assumed no scientifically unacceptable notions exist or are held, or if they are that these conceptions can be easily changed. There is ample research reported in such bibliographies as Pfundt and Duit (1998) and Duit (2002) which illustrate that these assumptions are very far from the truth. In fact all learners bring with them to formal education many conceptions they have developed throughout their lives prior to formal education.

Many debates have occurred in the literature on how, when and what to teach for the concept of energy in a physics context (Duit, 1987; Richmond, 1983; Solomon, 1984a, 1986; Trumper, 1991; Ward, 1983; Warren, 1982, 1983a; Watts, 1983) but no such debate exists for biology. In comparison to energy in physics and chemistry, no concerted effort has been made to identify student notions held about energy in relation to the human body and how these notions develop.

As discussed by Piaget in his work, children when young are interested in themselves first and then start to expand their sphere of interest finally to the world. That is, children first develop notions of what goes on within and immediately influencing themself before expanding their cognitive horizons. Any naive conceptions developed early may create learning challenges as the child gets older, especially if not carefully attended to during early formal lessons. Consequently, it is necessary to identify if students concurrently hold more than one conception about energy in biology as proposed by Trumper (1991) and Solomon (1983a & b), to name a few researchers. In other words, do students hold one conception for everyday living and another for school, or more specifically for science classes? Of equal interest in this research is the development of any changes in these held conceptions over time and if any of the changes are evolutionary (gradual) or revolutionary (large) or within this continuum as suggested by Duit (1995).

1.12 SIGNIFICANCE

This thesis is different to past research into energy in that it deals with energy within the context of the human body. This context requires students to not only have an understanding of the relevant underlying science concepts but also to be able to apply or transfer this knowledge from one contextual area across to another area. This contextual transfer is usually not referred to during formal learning situations. While covering energy in their classes, many teachers do not relate aspects of energy to the student's own experiences with their body but rather use examples which only relate to physical science situations which the student may have experienced. For example, the cooling effect of evaporation is rarely related to sweating, or chemical energy in the bonds of molecules related to food energy, or energy transformations related to the eye or ear.

When investigating the area of energy and the human body, it appears necessary to not only conduct research into the existence of alternative conceptions and their underpinning reasons, but also to look at those factors which influence conceptual change. Knowledge of these factors will help teachers better facilitate conceptual change by a learner and will help identify factors which influence concept formation over time. To this end, the multi-dimensional framework proposed by Treagust (1996) and Tyson *et al.* (1997) can be used to aid in the understanding of human energy and conceptual change by attempting to identify which factors influence conceptual change and how the relative influence of these factors change with student age. This information contributes more material to the increasing database of information on the process of conceptual change from an ontological perspective and improves our understanding of the conceptual change process in general and more specifically in the area of human biology and energy.

The ontological categories of Chi *et al.* (1994), Harre (Harre,1986 quoted in Monk, 1995) and Vosniadou (1998) were used to gain an understanding human energy and conceptual change by attempting to identify which aspects of the initially held concepts change over time with respect to the ontological categories in which they are placed. After collecting data on notions held by students at different ages, a picture of these notions and their underpinning reasons emerged. From this pattern of change, the changes were ascertained as being either evolutionary or revolutionary in nature and the student ages at which changes to student held conceptions occur was revealed.

The need to identify the changes to notions over time is important to both teachers and curriculum developers. By understanding how concepts and their underpinning reasons change, a research base or set of findings will be available which can be used to help guide the creation of a more applicable curriculum in energy. This development is even more important for those writers of integrated curricula because these courses seek to create links across areas of study. The data collected in this study are intended to provide information on some of these cross-links and can be applied by teachers when designing their curriculum for the new syllabus titled *Curriculum Framework of Western Australia* (1998).

The diagnostic instrument developed to reveal the conceptions that students hold will be made available for teachers (and their students) to help in the identification of both scientifically acceptable and unacceptable notions already held by the students and also the major underpinning reasons for each of these notions. This knowledge will enable teachers to more specifically formulate learning sequences for their individual classes, which can better address unacceptable notions, and/or the underpinning reasons for the notions. Whilst helping teachers, this knowledge can also be used by students to help adjust their alternative conceptions. This instrument consists of 20 two-tier true/false items.

Having identified the conception of energy held by students of different ages, suggestions for an interventionist strategy utilisable by the classroom practitioner was made after this strategy was trialed with a Year 9 class. This strategy, if effective, can help teachers create lessons that better guide students to develop more scientifically acceptable notions of digestion, energy in food and respiration. This strategy was developed to help mainly Year 8 to 10 science students but also could be applicable to specific areas/topics in specific subject areas in Years 11 and 12.

A new curriculum is in the process of being implemented in Western Australia as of 1995 when trials were commenced in many schools. This new curriculum titled *Curriculum Framework* was legislated in 1997 and is to be fully implemented by 2004. There is no specific teaching or content objectives prescribed, rather a set of broadly worded outcomes is decreed. It is these outcomes which are to be completed during a child’s formal education commencing in pre-school and continuing through to Year 12. Teachers are assumed to have the necessary background knowledge to fully implement the set of overarching statements and outcomes in their class(es). (Further discussion on the *Curriculum Framework* is found in Chapter 3.)

Many practicing teachers in the primary level of formal education and teachers in high schools who are teaching outside their subject specialties have little science background and would most likely hold naive and or alternative conceptions themselves (as do many trained high school science teachers). This lack of accurate science knowledge by teachers has been reported by a number of researchers such as Baird, Fensham, Gunstone and White (1987), Barak, Gorodetsky and Chipman (1997), Gayford (1986b) and Kaper and Goedhart (2000) when they have been studying both pre-service and practicing teachers. While improved or more accurate knowledge can be gained through the use of reference texts, many teachers do not have time to use these reference sources and instead rely on their prior knowledge and so pass on (unintentionally) scientifically unacceptable conceptions. To this end, it is important that teachers become aware of both the scientifically correct and alternative conceptions held by both themselves and their students.

The research reported here could be used as an aid in helping teachers identify both their own and their students’ alternative conceptions and so go a little way towards bridging the gap to help teachers gain more accurate, scientifically acceptable knowledge. With this knowledge teachers should be able to better implement the *Curriculum Framework* and reduce the perpetuation of incorrect conceptions and further go some way towards adjusting their own and their students’ misconceptions.

A study of cross-age conceptions held by students about energy and themselves would benefit not only the teachers but also their students and society in general. This study would also raise awareness of energy and its relationship to the human body in teachers and researchers and help answer the plea of Lucas (1995) for more research in biology conceptions.

In this new *Curriculum Framework* as set up by the government of Western Australia, (Curriculum Council, 1997) one strand of the Science Learning Area Statement is devoted solely to energy and is titled ‘Energy and Change’. This curriculum framework is derived from the National Framework which also has an energy strand. In the Energy and Change strand there are no specific objectives or outcomes, only a general statement indicating the formal coverage of energy. This statement is subdivided into a set of eight Level Statements. How this Strand and the different Levels are attended to in a school situation is up to the school or the individual teacher. However, these Levels are supplemented by a set of indicators to help a teacher determine the level at which a student is working; as a back-up, there is a set of examples of student work titled *Outcomes and Standards Framework: Science Work Samples* (Education Department 1998). A teacher can use these work samples as a guide in determining the attainment of a level for an outcome by a student. Many of the examples utilised as work samples and as indicators of attainment relate to energy as it pertains to physics, with few examples related to human energy use. (Further discussion on this occurs in Chapter 3.)

1.13 SUMMARY OF CHAPTER AND STRUCTURE OF THESIS

This study focuses on student-held conceptions with respect to energy and the human body. Firstly the identification of student conceptions about energy and their own body will be discussed. From these conceptions, a discussion on how they change over time will be carried out and be followed by the development and testing of a diagnostic instrument which could be used to identify student conceptions and their underpinning reasons. The research is also designed to discover the ability of students to transfer concepts across science domains. Further, an interventionist strategy to change one of the reasons for a commonly held conception on energy and food is created and its efficacy investigated.

This chapter discussed the background to the study and places the context of this research into the field of student-held conceptions and how they change with age. The large quantity of research into energy as a section of physics was established and the need for investigations into conceptions on energy and the human body established and briefly an overview of conceptual change was introduced. The applicability of the findings from this study was then established with respect to the implementation of the new *Curriculum Framework* in Western Australia. A series of research objectives and questions, which have guided this study, were articulated. These research questions provide the basis of the following investigations and analyses of the data collected.

Chapter 2 reviews the literature pertinent to student notions, examines the role of language in conception formation and the interpretation of data collected when examining learners' conceptions, conceptual change theories, in particular ontological change. Chapter 3 analyses the new curriculum currently being phased into the state of Western Australia and places this research and its relevance to the new curriculum and its implementation. Chapter 4 describes the research methodology, which led to the identification of student conceptions used in the development of the two-tier diagnostic instrument designed to aid in the identification of student held conceptions.

Chapter 5 presents the analysis of the data on student conceptions and the underpinning reasons for these conceptions and links this information to the information already reported on in the literature. Chapter 6 presents a cross section examination of the conceptual changes with respect to student age and ontological categories in the conceptions identified from the data analysed in Chapter 5. Chapter 7 outlines the development and subsequent testing of a diagnostic instrument which could be used by teachers and students to identify student held notions with respect to energy and their body. Chapter 8 discusses the development and application and evaluation of an interventionist strategy designed to assist students to adjust their notions with respect to energy in food and the body's absorption of this energy source. Chapter 9 discusses the findings of this study, highlights the practical implications and limitations of the study, and provides recommendations for future research into student notions of energy and strategies to help re-direct these notions towards more scientifically acceptable concepts and finally offers some concluding comment.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

A review of the literature that relates to student conceptual knowledge identifies numerous works covering differing aspects of students' pre-instructional conceptions. This literature base came about as a result of the call by Ausubel (1968) to start any education program from where the students already possess knowledge. Work in this area of educational research started in earnest during the 1970s and a ground swell of research followed, particularly in the area of student misconceptions. This search for student knowledge raised the question of not only what do students know but how accurate is this knowledge. Research that followed was concerned with how the inaccurate knowledge could be changed to become more scientifically acceptable. From this field of constructivism and alternative conceptions research, interest spread to finding the reasons why learners have these notions and how teachers can change these notions into more scientifically acceptable ones. This application of the research into the classroom led to the quest to discover the mental and psychological changes that accompany the learning processes as learners readjust their mental frameworks to accommodate new information. The field of conceptual change was born and this has further branched into a number of sub-fields such as how students change epistemological and ontological aspects of their mental constructs and the influences that affect the development or resistance to change of new concepts.

The major purpose of this study was to examine students' conceptions with regard to energy, but more specifically energy and their body. Much research work has been carried out on energy but with the majority in the field of physics. Hence, the intention of this study was to examine student notions with regard to their own body (biology) and to examine how these conceptions are similar or different to those applied in the area of physics where most of the topic of energy is taught. Other areas of interest in this study were to determine whether or not the information about energy (as taught in physics) is transferred to other domains where it is applicable and to investigate how these student notions changed with student age.

This chapter is divided into four major subdivisions; firstly, a study of the research carried out so far into notions that students bring with them to class, secondly, a look at the role language plays in concept formation, thirdly, a look at conceptual development, and finally a brief comment is made on ontological and epistemological changes as they relate to this study.

The first subdivision of this literature review examines research associated with student notions with particular attention paid to energy and the human body. Initially, this review is from a semi-historical perspective where much of the work has been centred around the field of physics (Section 2.2.1 & 2.2.2) and why there is a need to study how students transfer their knowledge from this domain to that of biology (Sections 2.2.3). From this position, the review examines the commonly held notions of energy (Sections 2.2.3) and how these notions can be placed into a number of categories which reflect the notions frequently held by students across various ages and educational experiences (Sections 2.2.3.1 to 2.2.3.3). Section 2.2.4 deals with the confusion that surrounds the meaning of a term such as energy due to its everyday and scientific meanings. This conflict of meaning for the term energy leads into the second subdivision of the literature review, where the role of language in concept formation is covered (Sections 2.3).

The second sub-division is concerned with the role that language plays in concept formation (Section 2.3.1) and the way students use language to express or explain their concepts and the care needed when attempting to interpret the students' meaning of their concepts (Sections 2.3.4 and 2.3.5). The conflict of meaning between the everyday and scientific use of energy is discussed (Section 2.3.2), as is the duality of meaning between different domains of science. The need for teachers and researchers to accommodate students in their use of language when discussing science concepts in classes is pointed out in Sections 2.3. and an example illustrating this confusion presented in Section 2.3.6.

The next subdivision reviews the literature on conceptual development that is examined via a number of theories (Sections 2.4.1.1). From these theories, the degree of conceptual change is discussed (Section 2.4.1.2), followed by conceptual change (Section 2.4.1.3) and the difference between conceptual change and growth are indicated (Section 2.4.1.4 to 2.4.1.6). This discussion leads onto the final section of this review (Section 2.5) where ontological and epistemological change and how these have helped direct this piece of research into investigating some ontological changes in student alternative notions are discussed.

This review of the literature helps place this research into the fields of study in alternative conceptions and conceptual change and shows how past research has helped in directing this piece of research (Section 2.6).

2.2 PAST RESEARCH INTO STUDENT CONCEPTIONS

2.2.1 Research Carried out And Emphasis

There has been much research into the area of energy in education because of its pervasiveness across all the domains of science. Research into student knowledge of energy, both scientifically acceptable and unacceptable, has spanned at least the last three decades and parallels the work carried out into alternative notions and precedes that of research work into conceptual development which involves both conceptual change and conceptual growth. These areas of research are the result of the growth in constructivism as a referent to learning and the manner in which it has guided and directed much of the research in science education over the past two and a half decades. A look at a bibliography on educational research in science such as Duit (2002), or the electronic data base ERIC, reveals the research into energy has not only included that of alternative conceptions but also recommended teaching and learning strategies to adjust these misconceptions, various methods for diagnosing student held conceptions, and conceptual change and growth.

Since its inception in the 1970s, conceptions research has covered a diverse range of learners' ages from the two year olds of Ault, Novak and Gowin (1988) and four year olds of Gelman (1988) through to undergraduates (Barak *et al.* 1997; Boyes & Stanisstreet, 1991a; Lavoie, 1997; Novick, 1976) as well as newly graduated students and experienced teachers (Barak *et al.* 1997; Hashweh, 1996a & b; Kaper & Goedhart, 2000; Kirkwood, Carr and McChesney.1986; Kruger, 1990, 1992; Yip, 1998). Some findings show that held conceptions persist throughout life despite contrary formal education covering that notion (Dreyfus & Jungwirth, 1989; Duit, 1994; Finegold & Trumper, 1989; Pedro, 2000) while other findings using pre- and post-test studies reveal learner's concepts can be changed (Grayson, 1994; Osborne, Black, Meadows & Smith, 1993; Trumper, 1990b, 1991). Still other researchers found the learners will even concurrently hold a number of different conceptions related to the same concept (Bliss Ogborn, 1994; Garnett, Garnett and Hackling, 1995; Gunstone, 1994a) and that they use these various notions as they see their relevance to the current situation (Solomon 1983b). One study by Gorrell, Tricou and Graham (1991) found that testing immediately after instruction gave an indication of modified concepts but a later test showed the students had reverted to their earlier conceptions. This finding was supported by similar findings from such researchers as Hewson (1985), Solomon (1983b), Shymansky *et al.* (1997) and Trumper (1997a).

This field of alternative notions research (with all its various names) has involved a vast quantity of research being reported. For example, Duit (2002), which is not an all-inclusive bibliography but has some 6000 references cited from English and German language sources. Of this work, 186 articles are related to energy in some way. Table 2.1 shows a summary of some of the work reported in Duit (2002) which involved the concept of energy across a range of science subject areas.

Table 2.1: Energy research carried out in science and the field of conceptual research from Duit (2002)

Subject	Percentage Research Work Reported	Percentage All Alternative Notions	Number of Alternative Notions on Energy
00000000Ph00 ysics	40	25	71
Chemistry	31	2	3
Biology	14	3	1
Earth Sciences	14	0	0

The data shown in Table 2.1 reflect the subject areas of research interest and emphases in the work carried out in science education with respect to energy. Pfundt and Duit

(1998) and later Duit (2002) are frequently referred to in the literature as the representative bibliographies on science education research. As such, this bibliography reflects the research work carried out to date. Work in the area of conceptual change has occurred in all science domains but, the quantity is small and results in percentages of the overall work on conceptions and science being very small (approximately 1.5%) and as such these percentages have been left out of Table 2.1.

The percentage of work in each subject area shows how much of the research work has been carried out in the area of Physics and that there is far less in Chemistry and even less in the area of the Biology and less in the Earth and Astronomical Sciences than the former two science domains. This is because in most teaching situations such as lesson programming and curricula, energy is separated out as an individual area of study and is commonly regarded as belonging to the domain of Physics. There is infrequent coverage of energy, as an area of study in its own right, outside of the physics context. When energy is taught in non-physics domains, it is as a section of a larger topic of study or interest and so is more an incidental than the key point. For example, study on the energy of chemical reactions is rarely seen in either chemistry or biology. In chemistry lessons, heat energy as shown by a change of temperature and is used to indicate when a chemical reaction has occurred but no teaching occurs as to the reason why there is a gain in heat. In human biology, ingestion, digestion and absorption of food is not seen as being energy related but are taught as the process of getting food into the body so it can be used by the body or more specifically the cells. That is, food consumption is rarely related to energy intake. In ecology studies, this is why food chains and food webs are created, to show the transfer or 'flow' of energy through an ecosystem but this flow is mentioned and then students concentrate on what eats what but not to gain energy.

The energy studies reported by researchers in the domain of biology in general are mainly concerned with photosynthesis, respiration, and ecology with little work carried out with respect to energy and the human body. Much of the work in this latter area has been, on the whole, part of a larger study into some aspect(s) of energy not specifically related to the human body (for example, Gilbert & Watts, 1983; Kruger, 1990; Ross, 1991; Simpson & Arnold 1982a & b; Yip, 1998). Little work has been directed solely to the study of energy as it relates to the human body and has concentrated in the fields of general respiration (Lavoie, 1997; Simpson & Arnold, 1982b), sight and the path of light (Boyes & Stanisstreet, 1991b; Collis, Jones, Sprod, Watson & Fraser, 1998; Guesne, 1985; Osborne, Black & Meadows, 1993), hearing (Boyes & Stanisstreet, 1991b), food as an energy source (Arzi, 1988; Duit & Haeussler, 1994; Francis & Hill, 1992) and other sources of energy (Boyes & Stanisstreet, 1991b; Carr, Kirkwood, Newman & Birdwhistell, 1987).

This current research (reported on in the following Chapters of this thesis) is involved in the study of energy and how students relate it to the human body. Here the energy concepts are taken out of the context specific to the physics domain and studied in relation to its involvement with the human body and so is connected to the different discipline area of biology. That is, in most cases energy is taught in a physics context and rarely related to the human body as for example, the use of food as an energy source, evaporation for cooling the body, energy conversions by the eye and ear to name a few situations and contexts. Much of what is being investigated and reported on in this thesis is based on information being taught to students in a formal situation, which rarely relates this material directly to the human body with students left to make their own connections between the class situation and their body. This transfer of knowledge can lead to mis-connections and/or inappropriate connections if any connection is made at all. Often these connections are made only when a question is asked at some later time and in a novel situation (for the student) where the student must make rapid connections between the formally taught information (should they remember it) and this new situation.

Further, the material may have been taught in such a fashion as to not cover that aspect of the concept. The role of evaporation is one such example, where it is taught as a separation or purifying technique in chemistry or as a way water can enter the atmosphere (as part of the water cycle) and as a contrasting process to water molecule movements when a liquid boils. It is infrequent that the cooling effect of evaporation is attended to in formal situations and even less frequently that the cooling effect is related to sweating and body temperature regulation.

An illustration of the position that energy holds in the research into student-held notions being concentrated in the domain of physics is seen in the debate which was carried out in the literature of the early 1980s. This debate centred on what to teach and when to teach energy in physics. No such debate on energy has occurred to my knowledge in the other science domains.

2.2.2 Debate In The 1980s On Physics Education

During the 1980s, a debate on when and what to teach students about energy occurred. This debate was held through the journals *European Journal of Science Education* and *Physics Education*. This debate arose from the research work carried out during the late 70s and early 80s on the identification of learners' notions with respect to energy. As a consequence of these findings, subsequent recommendations for the teaching of energy in the classroom were suggested. Sexl (1981) made a number of recommendations on what he considered should be included in teaching physics and in particular the concept of energy. It was this article which sparked a vigorous debate over what and when to teach energy in physics. In the same issue of the *European Journal of Science Education*, Duit (1981) commented on energy conservation in a response to Sexl when he claimed energy conservation is formed very late in a child's development and as such it should not be attempted until later in a child's education and then be introduced in a less formal manner than that proposed by Sexl. Later in the same journal, Warren (1982) made a plea for the term energy not to be used at all in the early phases of physics education, and in the more advanced stages of a physics education that energy be firmly based on the concept of work.

In 1982 and 1983 another debate arose over articles presented by Schmid and Richmond (1982) in the journal *Physics Education*. In a general letter, Warren (1983a) rebutted both these authors on their articles when he claimed energy should first be taught as a definition and teaching should then proceed using this definition as a base to be developed further. In their response, Schmid and Richmond indicated that they considered the teaching of energy differently to Warren since they saw energy as needing to be taught in the context of everyday life and not in an academic or theoretical manner. Later in the same year, Warren (1983b) elaborated further on the ideas presented in his brief letter when he wrote a paper that developed his idea further.

Watts (1983) joined the debate when he discussed alternative views on energy which he had found during his research program. He discussed his findings in light of seven frameworks based upon how students view energy. Solomon (1984a) pointed out that Watts' frameworks are based on his interpretation of the meaning of words that his subjects had used during the interviews and that he had not looked at the real students' meanings. Rather, he had interpreted the words' meanings in light of their scientific usage while ignoring the fact that many words are subject to change due to their multiplicity of everyday meanings and that they have entirely different meanings depending upon the situation in which they are used.

Warren (1983a & b), on the other hand, claimed that physics should be taught with formal definitions being given, laws stated and measurements taken that can be interpreted in terms of these laws. He argued that the teaching of energy (in particular) should be based upon a solid knowledge in a number of related areas (e.g. work and force) before energy is taught since, these are the basic concepts upon which energy can be developed. This supported his earlier arguments found in *Physics Education* and discussed earlier. In the same journal three years later, Solomon (1986) discussed how physics should be taught: not in a theoretical manner but be based on a "groundwork of practical physical experiences and an exploration of the variety of meanings available in the language." (p. 154).

While Solomon and Warren approach the teaching of physics from different positions which reflect the age of their students, they still want energy in a physics context to be based on first hand experiences - Solomon in the outside world and Warren in the laboratory. Duit (1987) recommended that energy should be taught to younger students as a quasi-material phenomenon. This was at odds with Warren and gave some support to Solomon when Duit pointed out that young pupils could not grasp abstract notions such as energy and hence should be taught energy as a concrete material and then later this notion be adjusted to reflect the more accurate concept of energy as a mathematical formulation.

The 1980s saw an interest in the teaching of concepts to best avoid the formation of misconceptions or to adjust these conceptual problems and these debates reflected this concern. While the concern is still present, the thrust has now been directed towards facilitating conceptual growth and conceptual change while still attempting to reduce misconceptions which may arise as a result of instructional procedures.

At no stage during this 1980s debate did the role of energy in biology or chemistry enter the discussion. Rather, the debate centred entirely on energy belonging to and being taught in the domain of physics. This is a further indication of where much of the research into energy (and education) was centred and was most likely a result of energy being categorised as belonging predominantly in the domain of Physics.

2.2.3 Common Views On Energy

A number of views on energy can be taken depending upon the position of the commentator. Three such views will be briefly introduced in the following sections.

2.2.3.1 Researcher Views of Energy

A number of researchers have divided the concept of energy up into sub-divisions based upon the groupings of students' concepts that the researchers have identified. These sub-divisions can be employed when developing a teaching program on energy or to help in classifying student concepts. Upon examination of these categories, we see they cover the (mis)conceptions observed by the researchers discussed earlier. For example, Watts (1983) created seven frameworks into which students are likely to have problems in their conceptions of energy. These frameworks are i) human centred energy; ii) a 'depository' model of energy; iii) energy is an 'ingredient'; iv) energy is an 'obvious' activity; v) energy is a product; vi) energy is functional and vii) flow-transfer model of energy.

Gayford (1986b) discussed the fact that many biology students do not study physical science and in particular physics or energy and that energy is rarely covered adequately in the biology class and because of this students find the concept of energy difficult to comprehend. Hence most students bring with them misconceptions formed earlier in their lives. From this poor coverage of energy while studying biology in a formal educational situation, Gayford proposed the following four models of energy which she saw as being most relevant in the biology context. The models were 1) the depository model; 2) energy is a product or bi-product of a situation or process; 3) flow-transfer model and 4) energy is an ingredient. These four models (or as Watts (1983) called them - frameworks) were derived from the seven frameworks of Watts and are used by students at the same and different times depending upon the situation being explained.

Many studies since 1983 have reinforced the Watts' framework of energy notions, in particular the anthropocentric (Framework 1), vitalistic aspect of category 4, flow model (Framework 7) and energy as being functional (Framework 6). In general, most of the research studies reported on energy misconceptions can have their findings placed into one or more of the frameworks of Watts (1983) or as it was modified by Trumper (1990a) and Lijnse (1990).

In his study on students' beliefs about energy, Trumper (1990a) also found the need to modify some of the frameworks of Watts (1983). He subdivided Framework 2 (Depository Model) into two subcategories of active and passive deposits and also sub-divided Framework 7 into two subcategories of the flow transfer model and the scientifically acceptable one of interacting systems. He also broadened the definition of Framework 5 to include energy as a product of a process as well as a bi-product.

Lijnse (1990) objected to some of Watts' (1983) seven frameworks since he found students had a set of 'flexible' ideas of energy which he claimed formed the 'natural thinking' proposed by Guidoni (1985). Since students need to base their new learning on past experiences and knowledge (flexible ideas), Lijnse proposes starting a lesson sequence with 'life-world' situations and then developing these life-world situations into quantifiable situations (the descriptive phase). This descriptive phase is followed by the development of the 'real' or theoretical concepts of physics. Once the theoretical concepts have been introduced students should go back to the descriptive phase to re-examine these in light of the theoretical concepts developed. This procedure for a teaching program in energy is sequential and circular.

Duit and Haeussler (1994) proposed a quadriga or four basic aspects of energy that were created from a study of energy from a scientist's point of view rather than from student-held conceptions. These aspects are 1) energy transformation; 2) energy transport; 3) energy conservation and 4) energy degradation. Duit and Haeussler (1994) proposed these four aspects of energy to develop an approach to the teaching of energy. This approach to dividing energy into four aspects was very similar to that of Lijnse (1990) while the methods for covering energy in a formal education setting were different. Duit and Haeussler propose the use of all four aspects of energy from the start of a teaching program while Lijnse suggested the teaching program follow his suggested sequence discussed above.

While Duit and Haeussler and Lijnse both developed teaching sequences to better help students develop the concept of energy than past teaching programs, a number of researchers have reported their findings on student-held notions of the concept of energy and how they confirm these various categorisations. From these findings of the various researchers, it appears they have the concept of energy subdivided into similar categories but differ in their approach and the reasons for their subdivisions.

2.2.3.2 Students' Views of Energy

A large number of educational researchers have reported on the notions learners hold with respect to energy. Many of these notions are consistent across a range of age groups. This can be seen in the brief discussion just held on the different groupings of the student frameworks of energy reported by such researchers as Watts, Grayford, Trumper, Duit and Haeussler and Lijnse.

2.2.3.3 Materialistic View of Energy

A number of researchers have reported findings of students of all ages who viewed energy as being a material substance (Ault, Novak & Gowin, 1988; Bliss, 1995; Erickson, 1989; Watts, 1983) or energy as a discrete thing (Solomon, 1985; Kirkwood *et al*., 1986; Lijnse, 1990). This material nature of energy manifests itself through implications of energy being particulate, being an ingredient of materials (Lijnse, 1990) and in its flowing from one situation to another flowing is used rather than being transferred as a physicist would describe the process (Driver *et al*., 1994b; Duit *et al*., 1994; Finegold & Trumper, 1989; Gayford, 1986a; Leach , Driver, Scott & Wood-

Robinson, 1995; Trumper, 1990a). Duit *et al*. (1994) found a number of students who thought energy was a material like 'thing' which is obtained from the food during the process of digestion.

The notion of material energy is also reflected in the way that many people, including science teachers, refer to energy during general conversation and in the teachers' case during lessons where they frequently refer to the flow or movement of energy. For example, energy flows through a food chain or moves from one body to another one. This use of language can lead to the notion of energy being seen as a fluid and having substance-like properties. The link between energy and its 'flowing' when energy transfer takes place are discussed by Carr *et al.* (1987), Duit (1987) and Lijnse (1990). Duit *et al.* (1994) suggested the use of 'energy flow' was satisfactory when teaching energy if the view of energy being an indestructible entity is taught and held by the students.

Further to Lijnse (1990) finding energy as an ingredient, he also found it was seen as the product of an action such as movement and was released so it could be used or consumed. This has been supported by a number of other researchers (Duit *et al.* 1994; Finegold & Trumper, 1989). This material nature of energy can be used to explain a range of other notions such as energy being created and destroyed when it is used (Brook & Wells, 1988; Gayford, 1986a & b) or converted into other unnamed things (Jennison & Reiss, 1991). Even the term 'used' implies a material like property.

The material nature of energy may be a result of people of all ages having difficulty with abstract phenomena and their desire to give the abstract phenomena concrete properties (Duit, 1987). Collis *et al.* (1998) discuss their notion of cognitive operation and claim people have a set of modes of cognitive functioning of which the third is 'concrete symbolic'. They argue that learners develop the five modes sequentially and at different stages of their life and that once developed these modes are all used even at the same time. Both of these explanations help explain why so much research has revealed the material nature of energy conception.

2.2.4 Confusion Of Terms Within Energy

Watts and a number of other writers in their debate during the 1980s discussed the fact that students need to be taught force and work before energy. This they claimed would reduce the problem of confusing these three terms. Further, researchers since then have reported on learner confusion between a variety of terms and energy. A summary of these confusing terms can be found in Table 2.2.

One possible reason for this confusion arises from the everyday observations involving these concepts where they all are linked in some way to energy and observations of their effects are similar to those of energy. Attendant to this is the everyday use of many of these terms, for example, we do not say turn on the energy (so the light will come on), we say turn on the power, where power and electrical energy are synonymous. This confusion of words and duality of meaning will be developed further in Sections 2.3.6 where the conservation of energy and the material nature of energy are discussed.

Table 2.2: Table showing the scientific terms frequently confused with energy and the researchers reporting these confusions.

Confused Term/Word	Researcher
voltage	Goldring and Osborne (1994)
Force, voltage and electric current	Gilbert and Watts (1983)
Force	Kruger (1990), Kruger Palacio & Summers (1992), Barak *et al.* (1997)
Force work and power	Ault, Novak and Godwin (1988), Duit (1984)
Heat and temperature	Erickson (1989), Harrison, Grayson and Treagust (1999)
Power	Goldring and Osborne (1994)
Heat	Jennison and Reiss (1991)
Force power	De Bueger-van der Borght (1989)

2.2.5 Energy Sources For The Human Body

Arzi (1988) found many learners had no idea how food gave the body energy, just that there was a link. A similar finding was reported by de Bueger van-der Borght (1989), Frances *et al.* (1992), and Simpson *et al.* (1982a). Baird *et al.* (1987) found glucose was seen to be a form of energy while Yip (1998) found protein is not thought to be an energy source.

These research findings, show that a number of students have misconceptions about energy sources which the body can use to supply the energy it needs to function. Table 2.3 shows a variety of alternative energy sources which students think the body uses for its energy requirements. Many students do have some notion that food is involved as an energy source for the body, just how the body obtains or gets its energy to function is unclear.

2.3 ENERGY AND LANGUAGE

Preconceptions are those conceptions that an individual has developed through their interactions with their environment prior to formal learning. These preconceptions have helped the individual successfully interpret phenomena and to become an active participant within society. Over time, these concepts have been refined as new data have become available to the individual and the poor fit of old concepts or ‘dissatisfaction’ has

Table 2.3: Table showing alternative sources of energy and researcher(s) reporting it.

Energy Source	Researcher
produced through the process of digestion	Gayford (1986b) Ross (1991) Duit *et al.* (1994)
the air/oxygen	Solomon (1985) Carr *et al.* (1987) Boyes and Stanisstreet (1991)
sleep	Carr *et al.* (1987) Boyes and Stanisstreet (1991a)
water	Carr *et al.* (1987) Boyes and Stanisstreet (1991a) Lavoie (1997)

required their subsequent modification so as to adequately explain the new data and to become ‘fruitful’ (Hewson & Hewson, 1989). As a consequence of this active learning through engagement, the concept(s) become(s) part of the learner’s cognitive framework since it has proved to be intelligible, fruitful and plausible to the individual (Hewson *et al.* 1989). Because of this continued success the concept is resistant to change and that concept may often be reinforced by society via the meaning derived from the language in common use (Trumper, 1990b; Warren, Ballenger, Rosebury & Hudicourt-Barnes, 2001). The development of these preconceptions is a result of the interactions between the individual and other members of society and its culture. These interactions are generally through the use of language and from these interactions the formation of conceptions will reflect the words used and the manner in which they are used.

2.3.1 Language And Concept Formation

Language influences both the way a concept is developed by a learner and the way in which it is recalled or stated since language forms an active part of a learner's conceptual ecology. When the learner is working with that notion it is often through some form of social interaction between the learner and or a teacher and/or other people (often other students). The language being used through the verbal messages of the learning situation will help formulate the context in which that concept will be formed or adjusted. While the language used will help set the context in which a concept is developed if that language is at odds with the learner's conceptual ecology of the concept then the notion may be rejected, ignored or misconstrued by the learner. Similarly, the language aspect of a concept's ecology and the current situation in which hat concept is being dealt with will influence the way that notion is recalled or stated (Strike & Posner, 1992).

Energy is an all-pervasive phenomenon not only in science but also in everyday living. We are exposed to it all the time through the electronic and print media as well as everyday conversation and actions. This frequent contact with the term energy has resulted in a common language framework within which we are immersed. As a consequence of its common usage, energy has developed a whole set of meanings in everyday life that are in conflict with the meanings assigned to these words by science (Kruger, 1990; Warren, 1983b). The common use meanings of energy are continually being reinforced during everyday conversation where the meanings are more flexible in contrast to the specific meanings assigned by science.

From their everyday situations, people develop their preconceptions of energy. For example, we hear of 'burning energy', 'use up energy', 'conserve energy', 'waste energy', 'save energy' and numerous other terms. These everyday meanings lead to conceptions which are scientifically naive (Goldring & Osborne, 1984; Posner, Strike, Hewson & Gertzog, 1982) and may be in conflict with those held by science (Duit, 1987; Lijnse, 1990; Watts, 1983). This link to everyday language also makes for the high resilience of many concepts as found by such researchers as Trumper (1990b) and Warren *et al.* (2001). Often these everyday conceptions are at odds with the more specific meanings developed by science and the misuse of everyday language in a scientific situation has been reported on by a large number of authors. What is taught in the class is not reinforced out of class and in fact is undermined.

Duit (1984) and later Warren *et al.* (2001) discuss the role that language plays in the formation of conceptions involving energy when they claimed them to be due to the 'colloquial' use of language. Duit (1981) discusses the colloquial use of the words energy and work and its effects in a formal learning situation when he states that " these notions are greatly influenced by the use of this word by the mass media" (p. 296). This comment was later reinforced by Duit and Huessler (1994) when they discussed the role of language and stated that students do not use science language in unfamiliar situations. They are more familiar with the everyday meanings and find these easier to use than the newer scientific meanings of the words.

A number of researchers have discussed the role of the learner's native language in assisting in the formation of alternative conceptions (Duit, 1984; Muralidhar, 1991; Grayson, 1994; Warren *et al.* 2001). Some languages do not have the same types of concept formation problems due to the precision and structure of the language (Atwater, 1996; Urevba 1984; Warren *et al.* 2001). The construction of sentences and the meaning of words are such that alternative meanings are not as easy to form from the way a term is used as is the case with English where there is a certain looseness of meaning ascribed to words and phrases. Warren *et al.* (2001) point out some languages do not function well or cater for abstract, technical information transmission nor for rational argument. Duit (1981) indicated he could not claim all the conceptual differences that he found (between the two groups of students) were due to language alone but may also be due to other cultural differences. In 1998, he further commented that the social and material setting of the learning environment might influence learning.

Kruger (1990) also discussed the role of the many social meanings of energy and how these are at odds with those meanings given by science and how this creates difficulties in the minds of learners when distinguishing between the scientific and everyday meanings of terms. Both Lijnse (1990) and Trumper (1990b) reinforce this multiplicity of meaning when they talk of the pragmatic use of energy in Physics when Trumper explained how students' early concepts arise through socialisation and how these concepts are inappropriate to the formal education setting. This formation of incorrect notions and connections between notions can also arise from misunderstandings due to word usage during formal lessons and the multiplicity of meanings ascribed to such words as energy and work (Jennison *et al.* 1991).

Duit (1981) commented upon the colloquial use of the words energy and work and how they affect each other and how the everyday use of these words affects their use and development. Solomon (1983b) refers to the 'socialised use' of the term conservation of energy and how this affects the way people refer to it. (Further discussion on this term occurs in Section 2.3.6.) Kruger (1990) goes further by pointing out that social meaning makes it difficult for learners to distinguish the science and everyday meaning of words and this is echoed by Boyes *et al.* (1991a). But, Solomon (1983a) argues that teachers should not attempt to extinguish everyday meaning as it is essential for the learner's communication in general society. Solomon (1983a, 1983b) and a number of other authors argue that teaching should try to link everyday meanings to those of science so students can operate effectively in both worlds (Duit, 1987, 1994; Duit & Haeussler, 1994; Lijnse, 1991; Trumper, 1990b). While agreeing with these researchers, Veiga, Pereira and Maskill (1989) make the suggestion that teachers find it very difficult to discuss experimental results of energy in a class situation without resorting to everyday language to facilitate easy dialogue. (They go on to suggest a number of ways to cope with this situation.) This may further add to the learner's confusion that could in turn lead rejection of the domain's use of the term.

Fensham, Gunstone and White, (1994) showed how science formulates its language when they write "When scientists decide to confer into a word a particular, more exact definition this is an act of construction from the world of experience significant to science" (p. 154). They then go on to state "in the process described above, science has often reinterpreted experience and as a result the words of science have changed their meaning." (p. 155). The precise science meaning of words and terms is developed and used by a number of scientists and is continually refined by the culture of science and in particular the western culture of science since much research is reported in this language (Solomon, 1986). This precision of meaning contrasts to the development of everyday language meaning where there may be a number of meanings ascribed to a word depending upon the situation in which it is used and leads to the “rubbery” meaning of Duit (1981). It is this contrast in exactness of meaning which students must learn to use in a science class as it is expected of them by the teachers. The scientific word(s) will be useful as long the majority can communicate through a shared meaning even if it is vague in its definition to many of the population.

The everyday reference to energy has led to a language developing which has meanings that are in conflict with the more precise meanings attributed them by science. Even the different domains of science have different terms that are used to describe situations (Gayford, 1986b; Kirkwood *et al.* 1986; Lucas, 1995; Solomon, 1984 b). For example, energy flow in biology means much the same things as energy transfer in physics and chemistry. The duality of meaning can be demonstrated through the use of energy conservation where energy conservation in science refers to the oft-quoted adage of ‘energy cannot be created or destroyed’ while in everyday parlance it refers to the endeavour to reduce energy consumption and so prolong the supplies of fossil fuels.

2.3.2 Language And The Duality Of Meaning

The duality of language that children face along with the notions associated with each word’s usage can and does create conflict within the individual. This conflict leads at best for the science teacher, to the retention (by the students) of both meanings and the appropriate use of the scientific meaning at school when called upon as discussed in the expert versus novice use of language by Driver *et al.* (1994a). More often, the child will forget or reject the scientific meaning of the term and revert to the common language meaning, especially over time when the former meaning is not frequently used. It is more convenient and less stressful to use the common meaning as it is part of everyday life and as such this meaning is continually reinforced by society.

This confusion, due to the multiple meanings of terminology, is especially relevant in science classes dealing with energy where energy is often introduced to students with the definition of *Energy* = *Work done*. The use of this definition assumes the learner to have a scientific meaning of work, which is highly unlikely due to its common language use and meaning. At the same time, many science teachers (especially in the past) have assumed learners have a scientifically acceptable understanding of energy and proceed to teach energy based on this assumption.

In her introduction to the seven articles in the special edition of the *Journal of Research in Science Education* dealing with language and culture in science education, Lynch (2001) sums up the importance of language and culture when she says of science education 'language and culture' cannot be separated from 'learning content' (p. 623). While this comment was intended for science teaching in a classroom, it applies equally to everyday learning and the role of language in the classroom situation is further discussed in section 2.3.3 and Section 2.3.4.

2.3.3 Subject Area Differences In Language Use

So a child in school faces at least two languages at any one time. But there may also be an additional language problem caused by the different disciplines of science and how these disciplines use words to explain the same phenomena. This is discussed by Gayford (1986b), Kirkwood *et al.* (1986), Lucas (1995) and Solomon (1984a & b) who have all indicated there is a difference in the use of terms between the various subject domains of science. Gayford discusses the different use of energy terms in Physics and Biology when he talks about the flow of energy in biology compared to the energy transfer of physics while in chemistry energy is mostly associated with the heat of chemical reactions. Barak (1997) discusses the way physics, chemistry and biology teachers all talk about energy in different fashions and how these various usages can lead to misconceptions developing. For example, physicists talk about energy transferring from one body to another while biologists talk about energy flowing; physicists and chemists talk about energy transformations while biologists use change in energy forms. Kirkwood *et al.* (1986) say "differing disciplines hold differing concepts of energy" (p. 178) and sum this problem up when they say there are "clear suggestions of very different frameworks with links, (not always strong), to the discipline of academic training" (p. 179). Kruger (1990) concurred when he made the observation that “ Science educators at all levels would find it hard to agree upon a universally acceptable and applicable explanation of the nature of energy and the biologists (or chemists) view of the concept is unlikely to be identical to that of the physicist” (p. 90).

These comments reflect similar arguments to those on the influence of culture and language meaning in that how we are taught a concept will influence how we conceive it to be. Each subject has its own language as reflected in Barak’s (1997) comment of “different views (and some misconceptions) of energy may be due to vocabulary used in biology to describe energy” (p. 28) and thus from a student’s point of view confer different meanings on a phenomenon such as energy.

In her study of learners relating science to everyday situations, Arzi (1988) showed that the learners did not relate the energy as it was taught in class to everyday situations even though they had been exposed to it in formal science lessons. This outcome would indicate, as do studies into energy notions, that learners use the common meaning of terms rather than the scientific meaning. Other researchers have reported similar findings as exemplified in the discussion on energy conservation (Section 2.3.6).

This multiplicity of scientific language uses increases over time as different specialist subject teachers teach the child general science and as different science disciplines are covered. It is little wonder students will continually revert to the common usage language (which is reinforced by everyday use both in and out of school) with all the language conflict which occurs during formal education.

2.3.4 Language Use In Class

The various uses of language between subject areas can only further aid in confusing the students when they face the problem of multiple word meanings. This could help explain the persistence of learners in using the everyday terminology, which at least has a consistent, if somewhat flexible meaning, and has proven successful more often than not when used in general communication.

Driver *et al.* (1994b) point out that scientists often use everyday language to communicate ideas but in appropriate situations use the scientifically acceptable language. They understand the difference between both usages and can freely switch their expectations and language usage. Young or inexperienced learners and many other people cannot carry out this duality of language but only use the everyday language because of its frequent use and ingrained nature. Similarly Viennot (1979) showed how the experienced teachers in her study reverted to the 'intuitive physics' when under pressure.

A consequence of the confusion that results from language usage is the way that students use words to suit situations resulting in the students frequently interchanging words. In their study on electricity, Gilbert and Watts (1983) reported their subjects interchanged the following words, energy, force, voltage and electric current in their responses. Baird *et al.* (1987) has also reported this with learners mixing types of energy with both motion and stored energy, while mixing of heat and energy was reported by Jennison *et al.* (1991) and Goldring *et al.* (1994). The latter noted power and voltage mix-ups while de Bueger-van Borght (1989) reported confusion over the use of energy, power and force. These common-meaning terms have resulted in misconceptions being reported in the literature (see Table 2.2). All of these terms have everyday usage that reflects their interchangeability when in common use and students use these familiar terms in the formal science situation with adverse results.

It is little wonder that with science having precise word meanings which are in conflict with many everyday or common use that people will develop or retain inappropriate notions of meanings about phenomena studied in science at school. It becomes very confusing. This language meaning along with each individual's unique interpretation of the world can help explain how alternative notions develop. It is these alternative notions about energy and the human body which students have developed that this study is investigating.

2.3.5 Language Interpretation And Research

The use of everyday language in responses to researchers' questions needs care in interpretation to ensure the learner's meaning is used and not that of the researcher. This was an issue raised by Solomon (1984a) when she criticised Watts' seven frameworks (Watts, 1983) in the energy debate of the 1980s. Although as indicated in the discussion on language and the way students use words in class, it is usually the common usage meaning which is applied in a response given by a student.

Lijnse (1990) makes the point that researchers must interpret student language from ‘life-world’ meaning and relate this to the scientific meaning. Warren *et al.* (2001) support this assertion when they argue the interpretation of children’s explanations must be carefully carried out as their descriptions may conceal scientific knowledge which they have difficulty explaining through the use of true scientific language but can do so through the use of their everyday or natural language. In her letter on Watt’s discussion on student frameworks of energy, Solomon (1984a) and later Lijnse (1990), point out that teachers and researchers need to interpret student language from the students’ ‘life-world’ meaning. To do otherwise is to misinterpret information. When analysing student language, researchers often have the expectation of their subjects using the scientific meaning in responses. That interpretation of meaning (or student responses) must be foremost in researcher’s minds when analysing interviews, class discourse and written work should be obvious from this discussion.

2.3.6 Two Examples of Dual Meanings of Terms

The problems created through the multiple meanings of words and terms in every day living becomes even more of a problem when science has precise definitions for commonly used terms. This is exemplified by the term conservation of energy and the way people refer to the material nature of energy.

2.3.6.1 Conservation Of Energy

An example of the confusion created by language is the use of the term conservation of energy. In everyday language, conservation of energy refers to saving or not wasting fuel while in science the First Law of Thermodynamics claims that energy can only be converted into other forms of energy but not destroyed or converted.

Saving fossil fuels or reducing energy use is the manner in which energy conservation is commonly used in the mass media (Brook & Wells, 1988). During the 1980s, a number of articles were written in USA education journals about the conservation of energy (Duggan, 1983; Koballa, 1989; Lawrenz, 1988; Lawrenz & Dantchik, 1985). All of these articles were referring to energy savings and/or the reduction of its use. This is an example of the conflict of terminology that is found even in journals on science education where the everyday use is mixed up with the scientific meaning. These articles were written after the energy crisis of the1970s and reflected societal concerns about potential energy (specifically fossil fuel) shortages.

A problem can be seen in the two definitions of this term and confusion could and does arise due to the duality of meaning. These two meanings are disparate and the energy saving meaning is the everyday meaning and often accompanied by terms such as loss of energy or energy use and waste energy. This confusion can be greatest in students who are still in the formative stages of developing the exact meaning of science terminology. This latter notion runs contrary to the general observation where a supply of fuel (often referred to as energy) does run out (Ross, 1991; Solomon, 1983b). This duality of meaning will aid in confusing the early learning process and help the student retain the everyday meaning or become very confused and reject the new science meaning.

Carr *et al.* (1988) found the scientific meaning being substituted for this fuel-saving notion a major concern in the 1980s in New Zealand with other researchers reporting similar results (Goldring & Osborne, 1994; Heilman, 1989; Jennison & Reiss, 1991). Some researchers have found that learners do not see energy conservation within a strict scientific context even after having the scientific aspects and meaning covered in class (Duit, 1981; Solomon, 1982, 1983b). (More discussion of the duality of terms will occur in the section on Energy and Language Section 2.3.2.).

The lack of the scientific use of energy conservation by students has been directly reported by a number of researchers such as Baird *et al.* (1987), Duit *et al.* (1994), Kruger (1990), Lijnse (1990), Ross (1991), Solomon (1982) and Trumper (1997b). Ross (1991) found his students thought that not only was energy used up and destroyed but matter is destroyed when it is converted into energy thereby combining the material nature of energy with another notion that matter can be destroyed or created.

During his participation in the 1980s debate, Warren (1983b) stated that 'Conservation of energy is increasingly used as an absurd malapropism for saving fuel.' (p. 209). Here he had failed to come to terms with the current (and at the time increasingly popular) use of the term conservation of energy, instead only viewing it from the Physics domain.

There has been much research into learners' alternative conceptions involving energy conservation as defined by the First Law of Thermodynamics. Albert (1978) found learners think energy can be created or destroyed. This finding has been repeated by a number of other researchers such as Solomon (1982, 1983a, 1987), Gayford (1986b), Baird *et al.* (1987), Goldring *et al.* (1994), Kessidou & Duit (1993), Duit (1994) and Trumper (1997a) to name a few. Other researchers have made findings consistent with this but have not referred directly to the conservation factor. For example, Gilbert and Watts (1983) found that students thought that energy to be rechargeable through food and rest. Solomon (1983a) found that students thought energy builds up with exercise and in a 1985 report she found energy was considered to be produced when a fuel is burnt while Finegold and Trumper's (1989) students indicated energy was made by some process such as during activity. Baird *et al.* (1987) found energy was created as mass (of food) is destroyed during bodily reactions and Lijnse (1990) found a similar conception of energy being destroyed as it is used.

As an aid to help students come to terms with this dual meaning of conservation of energy, Duit *et al.* (1994) proposed that the conservation of energy (scientific meaning) be one section of their quadriga of energy which should be taught as part of the concept of energy. By participating in this quadriga process of learning, students will come to appreciate the scientific meaning of conservation of energy while still appreciating its everyday meaning which Trumper (1990b) claims will never be extinguished due to its value in everyday conversation.

Barak *et al.* (1997) found that biology students had difficulty with the conservation of energy but he did show students had some intuitive knowledge based on the First Law of Thermodynamics which was also reported by Solomon (1983a) and Kesidou and Duit (1993). This difficulty appears to be related to the trouble that students had in identifying the initial and final energy forms in each situation.

The lack of energy conservation when the body is gaining energy for use or when using it has been directly reported by a number of researchers (Baird *et al*. 1987; Ross, 1991; Solomon, 1983a). While not directly commenting upon conservation, Duit *et al.* (1994) found that energy from food may be produced through the process of digestion. A number of other researchers have reported finding energy is a material like 'thing' which is obtained from the food but their subjects had no idea how food 'gave' the body energy, just that there was a link (de Bueger van-der Borght, 1989; Frances *et al*. 1992; Simpson *et al*. 1982a). These findings are further evidence of the lack of understanding of the scientifically acceptable notion of energy conservation.

Another commonly used term that conflicts with the science meaning of energy conservation is that of 'using up energy'. The First Law of Thermodynamics contradicts the everyday meaning of this phrase. Intuition dictates that energy does run out since we need to add petrol to a car or gas to a heater plus in the classroom it is very difficult to demonstrate this phenomena without some fudging of results. It must also be remembered that the First Law of Thermodynamics refers to a closed system and this compounds the difficulty of teaching energy conservation in a classroom. In everyday life, this phrase is used frequently to mean utilisable energy is becoming low while its scientific meaning is that energy is being converted from one form to another which may not be useful in the situation. This conversion and subsequent disappearance of useful energy is the reason for framework 5 of Watts (1983). The concept of energy being unavailable or used up has been reported by a number of researchers including Albert (1978), Ault, Novak and Gowin (1988), Solomon (1982, 1983a), Trumper (1997b) and Watts (1983)

With these discoveries of the poor understanding of the scientific conception of energy conservation across a range of ages and countries, it is little wonder that in the debate of the 80s, a number of people advocated teaching energy with both a real life focus and from an elementary starting point. From these points on the conservation of energy, a course could and should develop concepts of energy which are real to students via their everyday experiences and so aid in the development of more acceptable conceptions of energy. The end of such a course of study, be it one course or a series of smaller sub-courses, should be the ability to use energy terminology in the appropriate way in any situation which would most likely be similar to the expert's use of multiple languages where each use is appropriate to the situation (Solomon, 1983c, 1984b, 1985; 1993; Veiga, 1989; Warren *et al*. 2001).

2.3.6.2 Energy and Activity

The notion that energy is activity or is only present when activity occurs is a commonly reported phenomenon and is found in all age groups (Bliss, 1985; Brook & Wells, 1988; Jennison & Reiss, 1991; Lijnse, 1990; Nicholls & Ogborn, 1993; Solomon 1982). This energy and activity link is not the acceptable notion that activity requires energy, rather that energy is only present when activity or change occurs. This is different to the 'depository' framework of Finegold *et al.* (1989) and other researchers who found the energy is found within the object.

This confusion could arise in a similar manner to that of the conservation of energy and other misconceptions on energy sources referred to in Table 2.2. Observations of situations involving energy all have some form of activity or change present. For a human to be active requires the expenditure of energy and leads to a decrease or loss of useful energy. So to the young mind, when other objects undergo change, energy must be involved (as a form of activity to cause the change) and so it is lost as well since energy needs to be continually supplied to the situation.

2.4 CONCEPTUAL DEVELOPMENT

2.4.1 Constructivism and Conceptual Development

Researchers with a constructivist orientation consider knowledge as internally coherent systems built up from the individual's own experiences for their own purposes to cope with the world. Therefore, knowledge is instrumental in that it provides mechanisms for observations, predictions and to explain phenomena. This knowledge enables individuals to engage in successful or unsuccessful ways when dealing with objects and events. If these dealings are unsuccessful, then because of the dissatisfaction with the current concept, the cognitive structures held that have proved unfruitful and/or implausible and/or unintelligible will either be changed, rejected or a new concept formed in light of this experience. This altering of the knowledge scheme was originally called conceptual change by Posner *et al.* (1982). A concept has been variously defined by a number of authors; for example, Novak (1996) defined a concept as "a perceived regularity in events or objects designated by a label (usually a word)" (p. 32). This definition can be related to the way a concept is thought to form through active interaction with phenomena as described by constructivist ideas.

2.4.2 Conceptual Change

Conceptual change is the general term used to describe the learning that changes one's knowledge base or structure as a result of the interaction between a person's current conceptions and new information recently obtained from a new interaction with the environment, that is, a change in the knowledge structure of a domain. This change occurs when there is dissatisfaction because the currently held knowledge does not prove fruitful, intelligible or plausible as Posner *et al.* (1982) and Strike and Posner (1992) point out. Conceptual change research has developed as a result of the study into misconceptions or alternative notions, which burgeoned during the 1980s and arose as an outgrowth of constructivist epistemology where all knowledge is seen as being the result of active learning in which the learner interacts with the phenomena to formulate individual conceptions. The question arose as to how people form their concepts and how these concepts change over time.

Much of the work on conceptual change has been a result of the seminal paper of Posner *et al.* (1982) where they introduced the term conceptual change as being the cognitive restructuring or the accommodation of Piaget (1972) or the science revolution of Kuhn (1970). Here conceptual change involved a restructuring or re-ordering of the knowledge scheme that already existed. The change may range from strong to weak but never the less there is a change in the learner's mental scheme.

Posner *et al.* established the first theory of conceptual change when in 1982 they endeavoured to explain how people's concepts change from one set to another; the former being incompatible with the latter (Posner *et al*. 1982). They saw change as being large with many forward and backward steps and direction changes along the way. In this theory, two types of conceptual change were proposed – assimilation, which describes where students use existing concepts to deal with new phenomena, and accommodation where the student must replace or reorganise currently held central concepts. For the latter to occur, four conditions must be met: the concept must prove fruitful, intelligible, and plausible and there must be dissatisfaction with the currently held conception(s).

This theory was later modified by Strike and Posner (1992) when, in response to criticism, they introduced the role of social interaction and the central role of conceptual ecology into the theory and "that all parts of the conceptual ecology are dynamic and in constant interaction and development" (p. 160). These researchers state that one aspect of conceptual ecology is that of language and the way in which it can influence the way a student views the concept and its context and also how the learner will recall that notion (see Section 2.3.1). Other factors, which play a role in conceptual change, are the social and motivational factors present in the learning environment.

Since the initial theory's formulation, a number of other writers have developed various theories to explain conceptual change. For example, Chi *et al*. (1994); Carey (1985); Hewson and Hewson (1984); Nussbaum (1998); Pintrich *et al.* (1993); Thagard (1991); and Vosniadou (1994) each has a different emphasis in what affects change and how the change occurs and the type of change that takes place. A summary of some of these theories is presented in Table 2.4.

While these theories have different emphases, there is general agreement in what is proposed. Development, which may be large and has been variously called the accommodation (Posner *et al.*), conceptual exchange (Hewson *et al.*), strong restructuring (Carey), or revision at the framework level (Vosniadou). If the change is small it has been labelled assimilation or accretion by Posner *et al.*, conceptual capture by Hewson *et al.* weak restructuring by Carey, or the revision at theory level by Vosniadou. While it is confusing to use these different terms, they all have essentially a similar meaning but reflect the different approach of the theorist.

2.4.3 Degrees of Conceptual Change

With theoreticians using different terms for various degrees of change (and different factors influencing change) what they define as change varies in the degree of the

Table 2.4: Summary of some theories of conceptual change and growth

Theorist	Emphasis or focus	Type(s) of change	Special Terms Used
Posner *et al.* (1982) Strike and Posner (1992)	Epistemological perspective of change. Background of central ideas that organise learning and it is these ideas which change.	Radical with reversal, direction changes mistakes etc.	Accommodation Assimilation Accretion
Hewson and Hewson (1984)	Conflict between concepts.	Maintenance of original conception with gradual incorporation of the new	Conceptual capture Conceptual exchange
Vosniadou (1994) and Vosniadou and Brewer (1987)	Specific theories embedded in global framework theory which consists of entrenched ontological and epistemological presuppositions. Low emphasis on epistemological perspective.	Change is continuous.	Revision at specific theory level Revision at framework level
Thagard (1991)	Concepts are complex structures which are placed into hierarchies. Revision of beliefs.	Large (strong) and small (weak) changes.	Belief revision via addition (at various levels)
Carey (1985)	Low emphasis on epistemological perspective	Change is gradual and generally small and related to specific domains.	Weak and strong restructuring
Pintrich *et al.* (1993)	On affective influences in aiding change.		
Chi *et al.* (1994)	Nature of science content is dominant feature that influences change in ontological categories (of matter, procedures and mental state).	Change involves shifts in domains and may be different between domains.	Membership change Ontological categories
White (1996)	Content of instruction topic and student ability to interact with it, eg, social acceptance, types of knowledge embedded in, experiences of learner.	Not discussed as relates to an instructional model.	Relate various aspects of a topic to methods of instruction
Dykstra (1992)	Link instruction to conceptual maps of students. Focus on what seems to be changing and what induces this conceptual change.	Change ranges from gradual (differentiation & class restructuring) to significant (reconceptualisation)	Differentiation Class restructuring Reconceptualisation

Note: Table 2.4 is a modification of a table from Tyson *et al.* (1997).

change which can be evolutionary or revolutionary. Revolutionary change is a major shift in the knowledge base or in the case of evolutionary change there is a small adjustment to the knowledge scheme.

Posner *et al.* (1982) and Strike and Posner (1992) only have change as being a major revision or 'radical' with many false starts and changes of direction occurring during the process of change. Many of the researchers listed in Table 2.4 do not see conceptual change as radical but rather as being a gradual series of small changes that may ultimately end up as a big change (Vosniadou, 1994; Shymansky, 1997; Hashweh, 1986), while Duit (1995), Thagard (1991) and Tyson *et al.* (1997) see change as ranging from revolutionary through to evolutionary and go on to state that major change is best avoided in a classroom situation. They see change as being better if it is in small pieces.

2.4.4 Conceptual Growth

In comparison to conceptual change is the term conceptual growth discussed by Duit and Treagust (1995). A simple definition of conceptual growth could be an enlargement of the mental schemes by fitting new experiences into the already existing knowledge. In this definition there is no reconstruction or reordering of the mental scheme just its enlargement and development. This definition is in agreement with the evolutionary growth of Kuhn (1970) or the assimilation of Piaget (1972) and results in the accretion of new material into the cognitive framework of the individual as described by Posner *et al.* (1982).

Piaget (1972) discusses the notion that knowledge change involves both conceptual growth and conceptual change and that growth often follows change. Here the growth involves adding through the accretion of more data to the newly formulated concept. This growth will result in the development of a stronger mental scheme while change is the revision of that mental scheme.

2.4.5 Conceptual Improvement

Since both of the terms conceptual change and growth indicate a change in the knowledge scheme and vary in the degree of change (evolutionary or revolutionary), I propose a combination of the two terms under the umbrella of conceptual improvement. Here any alteration in the mental or knowledge scheme is a change to 'better fit' the new data into the conceptual framework or knowledge schemes of the individual. The degree of change then is a subdivision of the development or change overall in the concept. Shymansky *et al.* (1997) claim the process of growth is a 'saw tooth' process involving progression, regression and standing still during the overall growth process. This saw tooth progress facilitates the findings of Sadler (1998), with the punctuated changes in forward direction and the regressions to previously held notions noted by such researchers as Cleminson, 1990, Chi *et al.* 1994, Duit, 1994, Garnett *et al.* 1995, Geelan, 2000 and Solomon 1983a, and changes of direction of Strike and Posner (1992).

This conceptual improvement notion may be represented in Figure 2.1, which is a modification of a proposal by Tyson *et al.* (1997).

Here growth is the accretion or assimilation of more data into the knowledge scheme while change involves a revision or accommodation of the scheme with change being along a continuum from weak (evolution) change to strong (revolution) change.

I see the degree of change as being less relevant than that there has been a change in a concept as this is what surely is educationally important. I use the phrase 'conceptual development' to explain the types and degrees of change which may occur with a concept or a knowledge scheme change. The degree of change may vary depending upon the degree of dissatisfaction that occurs with that concept, and how much change is needed for the new material to be incorporated such that the new knowledge scheme proves fruitful, intelligible and plausible.

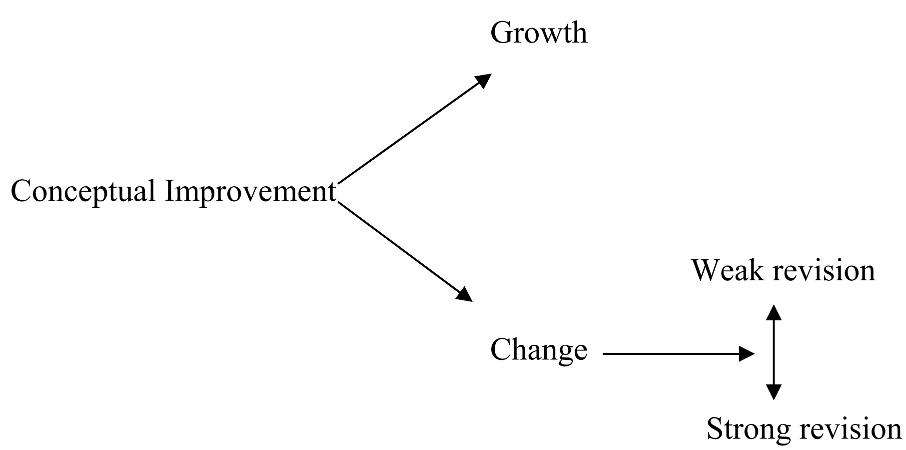

Figure 2.1: Degrees of conceptual improvement.

2.4.6 Conceptual Change Resistance

In the classroom situation, pre-instructional or preconceptions are resistant to change (Cleminson, 1990; Chi *et al.* 1994; Duit, 1994; Garnett *et al.* 1995; Geelan, 2000; Shymansky *et al.* 1997). In fact if these preconceptions are deep rooted they will not be changed as Duit says " There is no single study listed in the leading bibliographies of research on students' conception … in which a particular students' conception of the above deep rooted kind could be totally extinguished and replaced by a new idea … old ideas basically stay 'alive' in particular contexts" (Duit 1994 p. 8, quoted in Tyson *et al.* 1997). This is because in everyday life – the majority of any learner's life – these held conceptions have proved fruitful, intelligible and plausible and provide no dissatisfaction to the holder. Geelan (2000) echoes the findings of these authors when he points out that students rarely let go of their 'naive conceptions' and will jointly hold these along with the 'school science' concepts. This resistance to change is most probably due to the previous success of the preconceptions in the everyday or out of school world and the time and effort which has gone into their formation.

Students often switch between the competing concepts depending upon the circumstances or context (Bliss *et al.* 1994; Garnett *et al.* 1995; Gunstone, 1994a; Solomon, 1983b). This contextualisation will go some way to overcoming the dissatisfaction, which arises within differing contexts and results in the changing status of the different competing concepts. This is similar to the 'competing paradigms' of Lakatos (1970). In science classrooms it is necessary to encourage and develop a willingness to change these held concepts.

In this thesis, I will be looking at what preconceptions students hold and then at how and if these concepts change over time. The knowledge changes that occur may fit into a number of areas described by Tyson *et al.* (1997) of ontological, epistemological and social/affective domains. The changes in a knowledge concept may involve the continual placing of that concept into one of the ontological categories as described by Chi *et al.* (1994); viz matter, processes and mental states. These categories can be further subdivided into ontological kinds described by Bliss (1995) and Mariani and

Ogborn (1991, 1995) as "dynamic *vs* static, place like *vs* localised, cause *vs* effect and discrete *vs* continuous " (Bliss, 1995, p.160).

2.4.7 Ontological Conceptual Change

Various attempts were made during the1980s and 1990s to discover instructional methods that would facilitate conceptual change. Many of these methods were based upon the conceptual change model originally proposed by Posner *et al.* (1982). A range of researchers all of whom followed similar ideas to Posner *et al.* subsequently developed a number of models of conceptual change (see Table 2.4). These conceptual changes have mainly dealt with degrees of ontological change or shift as they were identified by pre- and post-instructional tests of various aspects of a concept. Few studies actually investigated epistemological changes, despite their claim to do so since they followed the same identification methods that failed to investigate the thinking involved in the changes observed.

The research into the changing of concepts resulted in a number of findings that often found a high degree of resistance to change by the learners, (for example, Cleminson, 1990; Chi *et al.* 1993, 1994; Duit, 1994; Garnett *et al.* 1995; Geelan, 2000; Shymansky *et al.* 1997; Slotta, Chi, Joram, 1995). A number of researchers have attempted to explain why there is this resistance to change. Chi *et al.* (1993) claim this resistance is due the change involving a category shift or to the lack of an ontological category in which to place the newly developing concept. Since either of these changes would require a mental framework change, this major change will require much effort and reinforcement by the learner to ensure the shift is satisfactorily made. The demand for the time and mental effort may be such that the learner does not fully complete this change and reversion to the older framework occurs especially if there is not the continual reinforcement of the new framework. Even if the change does occur, it is likely that the new framework will contain both the new and old concepts which will then be used in their appropriate contexts (Bliss *et al.* 1994; Garnett *et al.* 1995; Gunstone, 1994; Solomon, 1983b; Vosniadou, 1994; Vosniadou & Ioannides, 1998).

Despite these findings, some interventionist methods used to change conceptions have met with varying degrees of success. Gorrell *et al.* (1991) and Solomon (1983 b & c), for example, reported successful conceptual changes while a number of researchers such as Osborne *et al.* (1993) and Trumper and Gorsky (1993b) reported only limited success with their interventionist methods. It is highly likely these successful changes involve intra-category changes only. There are other reports of students holding dual concepts which are successfully used in the appropriate context (Bliss *et al.* 1994; Garnett *et al.* 1995; Gunstone, 1994a; Solomon, 1983b).

Chi *et al.* (1993, 1994) proposed a model of cognitive structural change which centred not on changing identified misconceptions as proposed by Posner *et al.* but rather centred on change(s) to the ontological category in which the concept is located. These authors proposed three major ontological categories which they called 'trees' and labelled them Matter, Process and Mental States. Process was a new category added by Chi *et al.* While, according to Chi *et al.*, the other two of these categories were from earlier researchers such as Sommers and Keil. To Chi *et al.* (1994), any conceptual change involved a change in the ontological tree as illustrated when they said "since re-assigning a concept from its initial tree into another tree is the crux of our notion of conceptual change" (p. 29). They go on to state that they are not sure as yet whether a change within a tree constitutes conceptual change. I contend this does constitute a change rather than growth if there is a shift across sub-categories rather than within them and that this change is a re-arrangement of the conceptual framework (albeit small) rather than a simple addition or accretion to the framework already in place. This change has come about due to a change to one or more of the defining, ontological or characteristic attributes that concept had been assigned.

This across category shift as a conceptual change is in line with the definition of conceptual change proposed by Vosniadou and Ioannides (1998). They defined conceptual change as involving "change in specific beliefs and presuppositions but also requires development of metacognitive awareness and the construction of theoretical frameworks with greater systematicity, coherence and explanatory power" (p. 1222). Vosniadou developed the notion of conceptual change to include not only ontological category changes but also epistemological shifts (Vosniadou, 1994). Her idea of conceptual change included a change to the presuppositions that formed part of the learner's cognitive framework (Vosniadou 1994, 1998).

Vosniadou and her coworker argue that a pre-instructional learner has developed a number of presuppositions that form the foundation of a learner's knowledge structure and organisation. These presuppositions are to do with the defining attributes of an ontological category as well as the nature of our knowledge that includes the nature of our knowing and learning and form the very basis of our knowledge structures. These presuppositions are different to the p-prims of diSessa (1993) in that some presuppositions form the basis of a learner's beliefs rather than being discrete as diSessa has his p-prims.

The definition of Vosniadou and Ioannides (1998) allows for conceptual change to include parallel and vertical shifts within a category or categories as the relevant knowledge presuppositions change. These specific knowledge presupposition shifts are easier to facilitate than ontological or epistemological presuppositions, as a change in the latter will affect the many knowledge structures based upon them. These smaller changes to concepts are still within the scope of the definitions of conceptual change of such authors as Duit and Treagust (1995), Posner *et al.* (1982) and Strike and Posner (1992).

Vosniadou sees the reassignment of concepts from one category to another as being difficult because she sees the changes as involving both ontological and epistemological presuppositions and not just the knowledge presuppositions. It is these presuppositions that underpin many other knowledge structures and to change one of these presuppositions has a domino effect on other knowledge structures. Much of the learner's prior experience has shown these other knowledge structures to be fruitful, intelligible and plausible and so result in conflict over the need to change these as well as the conflicting presupposition(s). Often the old and new conceptions or knowledge structures are retained and are then used in the appropriate contexts (Bliss *et al.* 1994; Garnett *et al.* 1995; Gunstone, 1994a; Solomon, 1983b).

2.5 ONTOLOGICAL AND EPISTEMOLOGICAL CATEGORISATION OF ENERGY

2.5.1 Ontological Changes and Energy

The particle nature of energy fits into the ontological category of Matter while the abstract notion would be classed as belonging in the Mental category of Chi *et al.* (1993, 1994) and Vosniadou (1994, 1998). This ontological category shift can be utilised by researchers studying conceptual change and growth. A change in the concept of energy from being material to abstract in nature would indicate a major shift in thinking and a change in the mental framework of the learner. Much research has found that students place energy in the Matter category with the frameworks of Duit and Haeussler (1994), Gayford (1986b) and Watts (1983) include frameworks that belong in the Matter category.

The debate of the 1980s on what and when to teach energy is reflected in this positioning of energy within the different ontological categories and also in the modes of thinking of Collis *et al.* (1998). Students are not capable of thinking in the abstract until their cognitive structures are sufficiently developed and even then they need direction to help them fit the more scientifically acceptable abstract notions into their cognitive framework (Brook *et al.* 1988). Without this help, few students are able to make the adjustment and hence research has shown learners in university courses still hold concrete views of energy (Baird, *et al.* 1987; Kirkwood, *et al.* 1986; Kruger, *et al.* 1992)

Chi *et al.* (1994) placed energy into the tree of Processes and into the sub-category of Constraint-Based Interactions since it has the attributes of not being a constraint based event, no causal agent (acausal), no progression, on-going, uniform in magnitude, simultaneous, no beginning or end, no change in location and it is not confined within disciplinary boundaries.

Pre-instructional students and the many other students view energy as being concrete and so place energy into the category of Matter. This placement is evidenced by such conceptions as its particulate nature, that energy flows, can be stored, can be burnt, can be lost and wasted and is an ingredient. Duit (1987) even proposes energy be taught as quasi-material which can later be developed into the abstract phenomena it is.

Features which could be used to categorise energy into the Mental State of Chi *et al.* would include the ability to have intentional or causal effects. For example, to deliberately cause an effect or something to happen such as making us hear or see or making something change all of which implies energy has thought capabilities and hence fit the Mental State.

So Chi *et al.* would see many students and adults as having energy in two categories, neither of which is correct. They would see conceptual change as being very difficult since there is the need to firstly develop the category of Process and the subcategory of Constraint-Based Interactions then to place the concept of energy into these trees. This they would see as being extremely difficult for teachers and their students to carry out.

Most researchers do not place energy into a category but rather deal with ontological changes without categorisation. They follow the conceptual change model of Posner *et al.* and observe the changes which occur rather than try to explain why there is a change and the process(es) which have lead to the change in mental structures which facilitate the observed change.

2.5.2 Epistemological Changes And Energy

Vosniadou and her co-workers have as part of their conceptual change theory, the need to study epistemological change as well. To look at epistemological change, the researcher must examine the thinking processes involved with a concept and how these change(d) as the concept changed. Researchers such as Posner *et al.* (1982), Strike and Posner (1992), diSessa (1993), Tytler (2000) and Kaper (2000), to name a few, have also discussed epistemological change and processes to facilitate the change.

Hewson and Thorley (1989) have claimed that most researchers who have said they have carried out studies of epistemological change have not examined this, rather they have looked at ontological change or knowledge growth. This claim arose due to the study of pre and post instructional tests which did not examine the underlying thinking processes and reasoning behind each concept.

Vosniadou and Ioannides (1998) point out that children are not aware of their beliefs and what they are based upon. Both Driver *et al.* (1994a, 1996) and Matthews (1998) have indicated the need to give teaching-time for students to develop an appreciation of the nature of science (an awareness of the processes of science and the way scientists think). From this appreciation of science, students may be able to develop a set of epistemological constructs that will help them understand their beliefs and why they think as they do. This metacognition (Beeth, 1998) will enable students to be aware of their ‘explanatory frameworks’ and from this metaconceptual awareness they will be able to question their notions when dissatisfaction arises and to help identify why this dissatisfaction exists. In this way, students may be able to explain why their past explanations have proved implausible, unfruitful or unintelligible. These researchers all claim this epistemological change will be better able to facilitate ontological change when there is dissatisfaction with current concepts.

To examine epistemological changes in a student it is necessary to examine the changes in status of a concept from the point of view of the concept’s plausibility, intelligibility and fruitfulness when the student is confronted with conflicting information. This cannot be carried out using pre and post-test data, as this form of data does not reveal the processes which went on in the learners mind as the new data was being processed. One source of data for this type of analysis is from interviews and classroom conversations. Here students discuss and explain their thoughts as they process the new information and attempt to reconcile the new data with their current position as illustrated by Hewson and Hewson (1984) and Treagust (1996) who have used this process.

2.6 POSITION OF THIS RESEARCH PROJECT

Part of the research reported in this thesis involves the identification of learners’ ontological categories and to observe if and how these categories change over time. The changes over time will be based on data from age cohorts rather than individual students over a number of years. Each year cohort should have a number of similar categories into which the cohort members’ concepts can be placed. There is evidence to indicate a progression in the development of concepts and that the concepts change with age and formal education (Driver *et al.* 1994b; Galili & Bar, 1997; Shymansky *et al.* 1997). The diversity within a cohort is due to the members of that cohort being at different stages in their learning of the energy concept in general and then its application to the human body. This variation is due to varying degrees of exposure to energy notions both in and out of school. It is anticipated that each year cohort would have a number of categories and parallel categories in to which concepts of energy have been placed and these will have commonalities and also differences with other age groupings.

The collection of data for this study has not facilitated a study on epistemological changes rather it facilitates (to a degree) ontological change by concentrating on the underpinning reasons for students holding their concepts and not how these concepts have developed over time.

2.7 SUMMARY

This chapter has discussed the origins and development of the fields of study involving alternative conceptions and conceptual change, beginning with the early work on conceptions held by students and the related field of constructivism in its many guises and how these have shaped the many aspects of research into student learning. A vast quantity of information on student conceptions has been gathered in the domain of physics and in the area of energy with only a small amount in the domain of biology and energy.

Alternative conception studies and the processes of conceptual change are both aimed at informing teachers and researchers about aspects of education which impede or assist students in their learning of scientifically acceptable notions. Alternative conceptions studies show where students have notions in respect to the current topic being studied in the classroom and that universally students frequently hold these notions at various stages of their education at both informal and formal levels.

The research into conceptual development is showing educators how students formulate their own conceptions of the world around them and how the further development of student preconceptions towards more scientifically acceptable notions can be better facilitated. Approaches to enhancing conceptual change may be through guiding students to becoming aware of their current beliefs and attempting to change these beliefs with the presentation of data that conflict with current notions and followed up by data which reinforces the newly forming conception.

One aspect, which impinges greatly on concept formation, is that of language, since it is through social interactions that many concepts are negotiated and formed. The importance of language usage needs to be taken into consideration when teaching and interpreting student responses as the students may use either everyday, scientific language or a combination of these in their responses and discussions

From this review it has been concluded that there is a paucity of data informing research about student held notions on energy and the human body despite the large quantity of research into energy particularly in the domain of Physics. This study is aimed at reducing this paucity of knowledge on student conceptions in energy and human body and to investigate student transfer of knowledge across domains, namely from physics to biology by investigating student held conceptions in this aspect of physics and biology. From the identified conceptions, a diagnostic instrument has been developed that can be used by both teachers and students to identify the current conceptions with respect to energy and the human body. Also an interventionist strategy has been developed and employed in an endeavour to facilitate the change of student conceptions in an aspect of energy intake into the human body.

CHAPTER 3

CURRICLUM FRAMEWORKS ANALYSIS

3.1 INTRODUCTION

This chapter has the purpose of laying the scene of education in the state of Western Australia in the last decade of the nineteenth and first of the twenty-first centuries. In this State, there has been a major overhaul of the curriculum for all levels of schooling from K through to 12. While this chapter deals with the *Curriculum Framework for Kindergarten to Year 12 Education in Western Australia* (Curriculum Council,1998) it should be noted that in April 2001, the Labor Government released the new Post Compulsory Education documents and the changes that will occur in the Years 11 and 12. This document is an extension of the Frameworks Document and is still in the developmental stages of implementation.

After a brief look at the history and role of the Federal and State Governments leading up to the development of the *Curriculum Framework* (Section 3.2), the development of this new curriculum is explored (Section 3.3 and 3.4). From here the Format and layout for curriculum and assessment are explained with the strands and levels of achievement (Section 3.3 and 3.7). In Sections 3.5 and 3.6 the position of energy in the *Curriculum Framework* is discussed. In the final sections of this chapter the manner in which this document links to this piece of research is outlined (Section 3.8 and 3.9) and the possible applications of this research's findings discussed (Section 3.9).

3.2 HISTORY OF THE CURRICLUM FRAMEWORK IN WESTERN AUSTRALIA

In this and future Chapters, I shall be using an abbreviation for the full name of the curriculum package legislated for in 1997. The document produced as a result of this legislation is titled *Curriculum Framework for Kindergarten to Year 12 Education in Western Australia*. I shall refer to this as the *Curriculum Framework* because in Western Australia this term has become a very commonly used abbreviation for the whole package of educational change that are associated with the legislation of 1997. This term is clearly understood and used in everyday conversation in education circles and is now being shortened to ‘Frameworks’. This document is associated with the large changes to education in Western Australia which are a result of the legislation of 1997.

3.2.1 Role of the Federal Government

To follow the development of the *Curriculum Framework* in Western Australia one needs to look not only to Western Australia history of education but also at the role of the Federal Government and its quest for greater control over the education of children in Australia. This push for a greater influence in State education has resulted from a tension between the States' and Territories’ constitutional rights in education and the wishes of the Federal Government. Over the past 40 years, there have been efforts by both the Federal Labor and Liberal political parties to gain more control over State education. The push in the last three decades has been for a national curriculum. But, any such push by the Federal Government has been thwarted by the constitutional powers of the States and their strong desire to retain sovereignty over their education policies and directions. Despite the power to determine the curriculum residing in the State or Territory, the Federal Government can exert an influence via Federal Grants to the States and through the specific allocation of monies to target money to the States.

During the late 1980s and the rise of economic rationalism both overseas and in Australia, education became to be seen as a competitor in the market place and so as an economic commodity. This economic rationalist approach saw an emphasis on economic priorities and the outcomes of education in comparison with to other OECD countries. This period saw a renewed desire for Federal control over a national curriculum.

In 1991, the Australian Education Council (AEC), which is made up of both Federal, State and Territory Ministers of Education, developed a national framework of eight learning areas on which the *National Curriculum Frameworks and Profile* were to be based. One of these learning areas was Science. From this meeting of the AEC, it became apparent a push had recommenced by the Federal Government to gain control of the education curriculum in the States and Territories (Lingard, Knight, Barlett & Porter, submitted)

In 1993, a change in Federal Government saw an attempt by the new Labor Government to coerce the States into accepting the National Statements and Profiles. This coercion was strongly resisted. In 1996, there was a change of Government to Liberal control. This Government had Federalist tendencies that resulted in the States regaining their control over education. Despite this regaining of control of education, the National Curriculum Framework was used by the States and Territories to develop their own State Outcomes Statements for education. Each State/Territory used its own interpretation of the National Statements and Profiles to suit their own desired needs and outcomes from their students.

3.2.2 Role of the State Government

In parallel with the Federal Government push for a national curriculum were a number of influences and initiatives in Western Australia, some of which have been already alluded to. The "Better Schools" Report of 1987 (Beazley, 1987) which followed an earlier report by Beazley (1984), saw a number of changes such as increased devolution of responsibility to districts and schools. This devolution paved the way for a number of changes needed to implement *Curriculum Framework* in Western Australia. In 1990 the Ministry of Education (Western Australia) held the view that

> *Schools have the capacity to be more effective when teachers have the optimal amount of professional discretion to create an environment that produces the best outcomes for students. Through devolution, the system as a whole can become more responsive, flexible and accountable. (Education Department Education Circular, 1990, p. 122)*

This view was vital to the success of educational reform and led ultimately to the ability to implement the *Curriculum Framework* and empower each school to develop its own curriculum based upon the *Curriculum Framework*.

Both the Vickery Report (1993) and Hoffman Report (1994) reinforced the devolution of curriculum responsibility and its implementation in the school. The Hoffman report, whose full title is *Devolution of decision- making authority in the government school system of Western Australia: prepared for the Hon. Norman Moore MLC, Minister for Education*, recommended that teachers be more accountable for their students' performance on outcomes which were to be based on a curriculum framework. This accountability was further applied and reinforced by the gazetting of the Local Management of Schools (March, 1999). In this situation, there was the ability of schools to take on even more responsibility for self-management and accountability to the school community.

In 1994, the States and Territories took back control of education in Australia from the Federal Government, although they followed a model of outcomes-based education modelled upon the "National Curriculum Frameworks and Profiles" with its eight learning areas. Western Australia ultimately developed what is now called the *Curriculum Framework* with its eight learning areas, and for government schools there were eight levels of attainment of the outcomes. While this document derived from the "National Curriculum Frameworks and Profiles" it has a distinct Western Australian orientation which makes it different to the curricula of the other States and Territories.

3.2.3 Curriculum Framework's Development

The 1995 *Review of School, Curriculum Development Procedures and Process in Western Australia* (also known as the Temby Report) identified a number of priorities in a curriculum which included a "common curriculum direction", a "seamless curriculum" and "a greater involvement for non government and community in the curriculum development process" (pp. 6 – 7). As a result of this review, the Curriculum Council evolved and ultimately the *Curriculum Framework* document was written to cover education from Preschool to Year 12.

Fifteen years after the *Better Schools* (Beasley, 1987) report which was a follow on document from the Beasley Report of 1984 (Beasley, 1984), the Western Australian education system was still moving towards greater devolution, especially with regard to curriculum development and implementation – provided it was based on the *Curriculum Framework*. Consequently, in Western Australia the *Curriculum Framework* was developed and the draft trailed in schools in 1994. Over the following three years of trialing, feedback was sought from all stakeholders. This feedback was acted upon and resulted in modifications to the original draft version and a final *Curriculum Framework* was developed. Through legislation in 1997, via the Curriculum Council Act of 1997, the *Curriculum Framework* became mandatory on all education systems and schools in Western Australia and is to be fully implemented in all Western Australia schools by 2004. This model of education based on a set of Student Outcome Statements, included not only the *Curriculum Framework* but also methods of implementation, both of which were to have the same gradual lead-in period.

This framework set out a series of learning outcomes in the Overarching Statements and eight Learning Area Statements. It is these Overarching Statements which are mandatory in all schools in Western Australia. In the section on the background to the *Curriculum Framework* which is found within the *Curriculum Framework* document, it states, "the *Curriculum Framework* makes explicit the learning outcomes which all Western Australian students should achieve" (p. 6). It continues by stating, "Schools and teachers will use the *Curriculum Framework* to develop their own learning and teaching programs according to their circumstances, ethos and the needs of their students" (p. 6). It is only this document which is law, all other material and information is supplemental.

3.2.4 Legislation and the Curriculum Framework

During the period from 1997 to the end of 2003, schools and systems could experiment with and develop their own curriculum to suit their desired outcomes and clientele with 1999 being the first year of official implementation. This development could take any form and be as required but was to be fully in place by 2004. After this date, all students in compulsory education must be educated and assessed using the *Curriculum Framework*. The changes to the curriculum delivered by a school may only be in refining the procedures used to deliver the curriculum as outlined in the *Curriculum Framework*.

In conjunction with the legislation for the *Curriculum Framework* was the gazetting of changes to the Secondary Education Authority (SEA) which was to be responsible for overseeing the implementation and running of the *Curriculum Framework*. The old Secondary Education Authority (SEA) became the Curriculum Council with a different structure and a modified set of roles within Western Australia education.

In 2000, most schools in Western Australia had at least commenced implementing the *Curriculum Framework* to some extent, with new Government Schools being fully committed to Student Outcome Statement based education centred on the *Curriculum Framework*. However, older government schools and the private education systems had the choice of when and how to implement their curriculum.

The push for an outcomes-based education by the Federal Government (of either political persuasion) and the increased devolution of power to schools (in Western Australia) to develop and implement their own curriculum and be accountable to their community for that curriculum, led to the implementation of this type of education.

3.3 THE STRUCTURE OF THE *CURRICULUM FRAMEWORK*

The overall aim of the *Curriculum Framework* is to lead to the creation of a broad, interlinked and comprehensive educational curriculum which is outcomes-based for all students within Western Australia from K to 12. Each school's curriculum should reflect the requirements of the local community while fitting within the broad-brush strokes of the *Curriculum Framework* that comprises a number of sub-divisions or hierarchical levels.

3.3.1 The Curriculum Framework

At the top of *Curriculum Framework* is the Overarching Statement, which comprises seven key principles that underpin both the *Curriculum Framework* and the 13 Overarching Learning Area Outcomes to which all Learning Areas contribute. Number seven of these Learning Outcomes directly relates to Science when it says, "Students understand and appreciate the physical, biological and technological world and have the knowledge and skills and values to make decisions in relation to it" (*Curriculum Framework*, 1998, p. 23). From this statement, called the "Science Learning Area Statement", nine Learning Outcomes are derived. These outcomes are placed into two subdivisions of Working Scientifically and Understanding Concepts with each of these subdivisions being further subdivided. This hierarchy is illustrated in Figure 3.1.

3.3.2 School Curriculum Development

The development of a curriculum for implementation within the school or class is left up to the individual teacher, school or system as explained in the following statement

In some situations, teachers may choose to develop a science program based on the traditional disciplines of science. In others, an integrated approach, perhaps developed in the context of other learning areas may be appropriate. (Curriculum Framework, 1998, p. 221)

This sentence is followed by a listing of the types of things that would be expected of a student when studying aspects of that outcome.

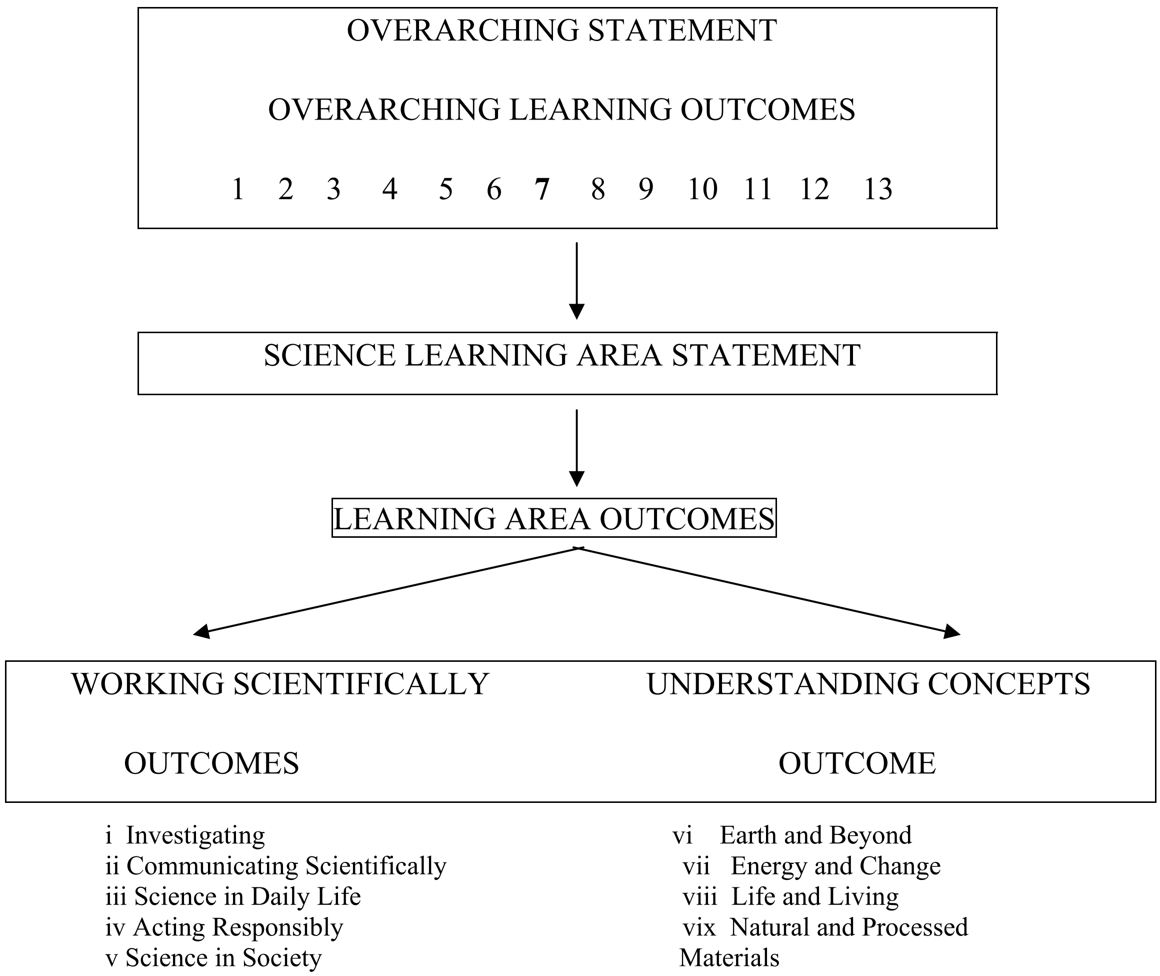

Figure 3.1: The hierarchy of the outcomes of Curriculum Framework as Related to Science

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There is no method of assessment described or implied other than a policy that assessment be based upon outcomes rather than objectives as it has been in the past (and may still be until 2004) under such curricula as the Achievement Certificate of the1970s to 1987 and the Unit Curriculum from 1987 – 1997. At the end of the Science Learning

Area Statement (*Curriculum Framework*, pp. 242 - 243) there is a section titled "Assessment". This section is divided into five sub-sections based upon an educationally sound assessment policy that would be expected in any effective teaching and learning situation. These sections state that assessment should be valid, educative, explicit, fair and comprehensive and then describe each such feature.

While the *Curriculum Framework* was and still is intended to cover a child's education from K – 12, in reality it covers K – 10 since the post-compulsory years (Years 11 and 12) are governed by a different educational style and format. This format is based on formal tests and examinations and the Curriculum Council prescribes the content separately from schools. The prescribing takes the form of a series of objectives which specify what may be examined in the Tertiary Entrance Examination (TEE). As acknowledged by most if not all Year 12 teachers, it is this examination which is driving the curriculum and not the other way around (personal experience and word of mouth). This situation has undergone a review through a Post Compulsory Review and resulted in the release of a report titled *Our youth, Our Future: Post Compulsory Education Review* (Curriculum Council, 2002) with recommendations which contain the future directions in the post-compulsory years of education will be outcomes based and result in a seamless education from K to 12.

3.3.3 Supporting Documentation

It should be remembered that the *Curriculum Framework* document is the only part of all the material so far produced with regard to the Curriculum Framework that has been legislated for (in 1997). All other material is supplemental only. Most of this available material has been produced by the Education Department of Western Australia (EDWA) for their employees' use. For example, for science there are a number of documents which include:

Outcomes and Standards Framework, Student Outcome Statements, Overview (1998),

Outcomes and Standards Framework, Student Outcome Statements, Science (1998),

Outcomes and Standards Framework. Student Work Samples (1998), *Working Scientifically: Implementing and Assessing Open Investigation Work in Science* (1998)

A List of Resources (1998).

*Getting Started, Scienc*e (1999).

The use of these documents is regulated for use in Government Schools while many non-government schools also are using this material to help in developing an appropriate curriculum.

In this Chapter and from now on I shall be referring only to the *Curriculum Framework* document and the supplemental EDWA material mentioned above and not any commercially produced or other material. This is done for the following reasons: firstly it is applicable (by Government Education Regulations) to over 50% of students in the State of Western Australia. Secondly, much of the other material available is commercial in nature or specific to individual schools. Thirdly, many schools outside the Government System are using the EDWA material either fully or partially as a guide to their curriculum development. Finally, there is a great variation and degree of use of this non-EDWA material. The study and integration of this non-EDWA material into this Chapter is too great for the space and scope of this study.

3.3.4 Achievement Levels and Curriculum Framework

In their documents which supplement the *Curriculum Framework*, EDWA has changed the name of the Investigating Outcome into Investigating Scientifically. To help assess student attainment of the Outcomes, a series of eight levels were created. These eight levels only apply to the four 'Understanding Concepts' and the Investigating Scientifically Concept of the Science Learning Area. Each of the levels requires more complexity in cognitive development and the level of knowledge required by a student learning at the higher level. Higher levels subsume lower ones. These EDWA subdivisions can be seen in Figure 3.2.

3.4 UNDERPINNING THEORIES FOR THE SCIENCE LEARNING AREA

The *Curriculum Framework* has as its main aim "to improve the learning outcomes of all students and to enable schools to develop learning and teaching programs which meet the needs of their students…" (p. 13). To achieve this aim, a number of underpinning notions have been the driving forces in its formulation and construction. Overall, the shift has been from an objectives-based education of what is taught and how it is taught to what is actually learnt by each student towards achieving the outcomes in a number of

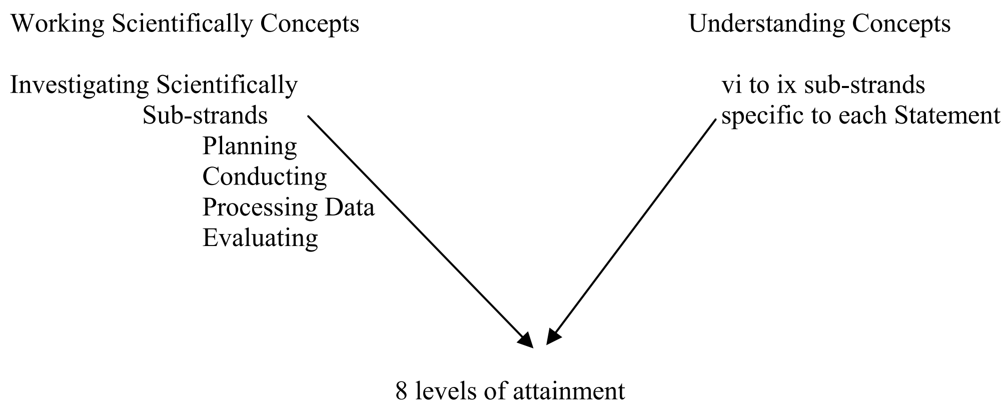

Figure 3.2: Shows the further sub-divisions of the StudentOutcomes Statements by EDWA

Learning Areas. To this end, the outcomes are progressive in their nature and match the child's increase in cognitive development and processing ability. The outcomes progress from the concrete to abstract, from personal to objective experiences, with an increase in problem solving ability and an increasing ability to think scientifically. This is illustrated in Table 3.1.

3.4.1 *Curriculum Framework* Outcomes Assessment

The first aim of the *Curriculum Framework* is the focus on outcomes-based education with the outcomes being achievable by all students as they develop both physically and mentally. From these outcomes, which are worded so as to be very broad in nature, a student-centred curriculum can be developed which supplies the students with structured learning experiences that are achievable and for which each child's progress can be readily assessed. This alone sets the *Curriculum Framework* apart from prior education curricula used in Western Australia, where in the past the emphasis has been on the student achieving certain objectives, often comprising primarily content based knowledge.

Table 3.1: Showing various trends across levels to reflect thinking and cognitive development of a student as they progress through the levels.

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Self							Social and social issues
Concrete (hands-on and real information)							Abstract
Personal (own personal view only)							Objective
Concept					Models		Theory
Concrete	Problems			Solve	Problems	Abstract	Problems
Think singularly of a concept				Think Scientifically			
Identify	Describe	Describe patterns	Compare, processes Relate changes	Explain and use Concepts and Models	Explain systems by using concepts and models	Analyse systems Evaluate Apply theories	Meta-analyse Recommend, categorise Compare approaches Make theories

Note: The progression from left to right is a continuum as the student progresses from simple cognitive and physical attributes to more demanding and abstract operations.

With the *Curriculum Framework* being student-centred and outcomes-based, the levels of attainment of the Science Learning Area Statement have been broken into eight levels by EDWA as discussed earlier in the section on the Structure of the Curriculum Framework. These eight levels for each 'Concept Strand' and for 'Investigating Scientifically' can be found in the two publications *Outcomes and Standards Framework, Student Outcome Statements, Science* (1998), and *Outcomes and Standards Framework. Student Work Samples* (1998).

Level 1 is concerned with the student and his/her view of the world (usually egocentric) and the levels progress from there through to viewing the world from societal aspects as well as from the learner's own point of view. The eight levels are arranged in such a way to fit the average student's physical and mental development as they progress through their compulsory formal education. This is illustrated in Figure 3.3.

Levels 1 and 2
Students are developing language and thinking logic in one direction.
Students only see the world from one point of view.
General description of observations.

Levels 3, 4 and 5
Students can solve concrete problems.
They understand conservation, are able to classify.
They can describe structure and function and examine their own thoughts.
They can use concepts to explain and assess data.

Levels 6, 7 and 8
Students can solve abstract problems
Show concern for social issues
Systematically solve problems
Use theories to aid in their explanations.
They can use evidence to help their explanations.

Levels 7 and 8
Students are able to appreciate the social aspects of science.
They see science as a way of knowing.

Figure 3.3: General description of the Levels as they reflect various stages of development of a learner.

From this pattern of development, concepts within a Strand should be able to be developed such that, as a child progresses, more combining and linking of concepts to form models and theories should develop along with the ability to employ these concepts, models and theories.

3.4.2 Assessing Student Achievement

As described in *Outcomes and Standards Framework, Student Outcome Statements: Science* (1998), the Science Learning Area Outcomes and Strands reflect this philosophy. In this Student Outcomes document, there is a set of benchmarks designed to help a teacher decide the level a student is achieving at in a particular Strand. This guide to levelling a student's progress is in two forms. Firstly, there is a series of descriptions about what to expect for a particular level and for a particular strand of work. This is followed by a shorter set of examples called 'Pointers' which describe possible examples of what would indicate achievement at a level and also at each sub-level for a particular Level. A break down of the Conceptual Strand called "Energy and Change" is given in Figure 3.4.

Science Learning Area Statement
Students understand and appreciate the physical, biological and technological world and have the knowledge and skills and values to make decisions in relation to it. (Student Outcomes Statements, 1998, p. 23).

"Energy and Change" Strand Outcome Statement
Students understand the scientific concept of energy and explain that energy is vital to our existence and to our quality of life." (Student Outcomes Statements, 1998, p. 52).

Outcome Statements
There are 9 levels within this Strand Statement, with the 'first' Level which is called the "Foundation Outcome Statement" being for those students with intellectual disabilities. The other 8 levels are for the rest of the student population and are as follows:

Level 1 Demonstrates an awareness that energy is present in daily life.
Level 2 Understands that energy is required for different purposes in life.
Level 3 Understands ways that energy is transferred and that people use different types of energy for different purposes.
Level 4 Understands that energy interacts differently with different substances and that this can affect the use and transfer of energy.
Level 5 Understands models and concepts used to explain the transfer of energy in an energy interaction.
Level 6 Understands the principles and concepts used to explain the transfer of energy that occurs in energy systems.
Level 7 Understands the role of science in developing systems of energy transfer.
Level 8 Understands how to assess the role of science in helping us to explain energy systems, production and use.

(Student Outcome Statements; Science, 1998, p. 52)

Figure 3.4: The Breakdown of the Science Learning Area
to show the "Energy and Change" Strand

Each of these levels for "Energy and Change" is sub-divided into three sub-levels which are:

A. Energy is vital to our existence and to the quality of life for individuals and society.
B. Energy can be transferred between objects and systems.
C. Processes of energy transfer can be controlled, enabling particular changes to be achieved more efficiently.

These levels and sublevels create a rubric of 9 x 3 which can be used to place a student within a level in respect to how the are progressing towards the achievement of the

Energy and Change

Level 1

- A Need for energy to do things eg play, go to school
- B Get energy from food, other objects we see, hear

Level 2

- A Other children use energy to do things
- B Types of energy the child uses (heat, light, sound, chemical energy in food)

Level 3

- A The more one exercises the more energy we need; get tired or decrease in energy when we exercise; need more energy in winter than summer
- B Light, sound and heat have sources of energy which are away from body (i.e., external source)
- C Get energy from Sun, light, sound and which part of the body receives it

Level 4

- A Different values for different food types (fats, sugars, protein)
- B Insulation from cloths and fat layer
- C How eye and ear work on gross level only i.e. black of choroid coat and its function, clear lens of eye for transmission

Level 5

- A Role of respiration in energy flow in body and cell
- B Production of heat as a bi-product of metabolism (efficiency of energy conversions)
- C Body as energy transfer system i.e. food to respiration to ATP to muscle to movement

Level 6

- A Body as simple machine for doing useful work/things
- B Calculate useful energy from food as it is utilised/ diets
- C Use of diets in different people

Level 7

- A Improvement of crops to feed population or meet human population demands
- B Ear and eye at sub-microscopic level of functioning
- C Energy and chemical interaction in retina to electrical impulse energy/ sound energy conversions in ear

Level 8

- A Improvements in crops to meet energy demands of population
- B Options for feeding population of world in future

Figure 3.5: The levels and sub-levels for the Strand of 'Energy'

Strand Outcome Statement for "Energy and Change". The sublevels for the "Energy and

Change" strand and each level within it can be found in Figure 3.5. Students who are said to be achieving at a level must consistently demonstrate that they can operate within that level (including all three sub-levels).

A rubric showing a set of examples or pointers for the levels and sublevels for the Strand of Energy and Change for energy and its involvement with the human body can be found in Appendix 8.

It must be stated that while there are a number of outcomes in the Science Learning Area of which four are conceptual strands, at no stage or place is any content knowledge specified as is evident in Figure 3.4 and Tables 3.1 and 3.2. The students, it is expected, will learn the content knowledge as they progress and develop their abilities in and knowledge of science. Content knowledge is implied within the outcome statements and what is learnt will be a result of the attaining of the outcomes. In reality, knowledge will be included in the curriculum as and when the teacher/curriculum developer deems necessary. This knowledge forms part of the outcome rather than being the outcome as is the case in many objective-orientated curricula. This is one of the major paradigm shifts in this new curriculum.

3.5 ENERGY ACROSS THE LEARNING AREAS

It should be appreciated that in many areas of science energy is ubiquitous. For this reason, the links between "Energy and Change" and the other learning areas are numerous. Across the four conceptual learning strands of "Earth and Beyond", "Energy and Change", "Life and Living" and "Natural and Processed Materials", energy can be linked to various concepts within each of these strands. These links may be incidental to the major thrust of the concept or conversely may be an important aspect of that concept but be better suited to another learning area rather than "Energy and Change". These links may be direct in that they could be placed in the "Energy and Change" Strand itself or less direct in that the link to energy is incidental or an adjunct to that of the overall concept.

While there are a number of situations where energy is involved in the Science Learning Area, there are some topics in which energy is directly involved but often the energy aspect is either left out or glossed over and so forms an adjunct. This creates a situation, which is similar to the incidental situations mentioned below. One such example is when explaining or discussing the damage due to seismic activity. Often the damage is discussed in terms of the Earth's surface moving and hence being unstable for man-made constructions such as buildings and bridges. Little discussion on the release of energy during the earthquake or even energy involvement is usually made, merely the fact the Earth’s movement shakes the object and it is consequently damaged. Typically energy is not discussed for its role in the damage caused.

Some examples of where energy is incidental to a strand are to be found in “Earth and Beyond” (Level one) where the outcome is "the Sun and its influence on life" and the Level 2 outcome of "the effects of temperature on behaviour". In both of these cases, the concept better fits the “Earth and Beyond” Strand rather than be isolated if placed in “Energy and Change”. For similar reasons in Life and Living (Level 1), there is a need for “food for energy” while in Natural and Processed Materials (Level 2) includes “the effects of heat on chemical reactions”. In each of these examples, particularly at these early levels, the involvement of energy may be left out as the notion is considered self-explanatory. There is no underlying explanation of the involvement of energy in the notion required.

Further examples occur in the strand of "Earth and Beyond", where two major areas of energy involvement may be found. Firstly winds, their formation and their effects in such areas as wave formation and environmental changes through wind erosion (Levels 3 and 4) and secondly in Plate Tectonics (Levels 4 to 6). Plate Tectonics deals with the theories of plate tectonics as well as using this theory to explain such phenomena as earthquakes, tsunamis, the formation of mountain ranges and faults and folding as well as the effects these can have on the Earth and its surface. As previously discussed, in the classroom energy is frequently not implicated as being involved in these processes, rather their occurrence is explained as a result of plate movements. Typically it is left up to the students to make the energy connection.

In “Natural and Processed Materials” (Levels 2 and 3), there is the discussion of heat transfer. These involve the methods of heat transfer through substances, the different rates of energy transfer and the way insulating materials reduce heat transfer. This is also discussed in Energy and Change (Level 4) where the enabling or impeding of energy transfer is studied.

In the learning of the “Natural and Processed Materials” outcome (Levels 3 - 6), the interactions of temperature and reaction rates on chemical reactions are introduced. In this case, the enthalpy and entropy aspects of the reaction are not discussed in lower school (up to Year 10). How energy actually effects the rate of reaction is often left out of the discussion: rather examples are given (by experiment or graphically) to illustrate this concept.

Also in this same learning area (Level 4), the concept of evaporation and its effects are introduced where evaporation is used as a method for separating the components of a solution. In Level 5, there is mention of evaporation in affecting temperature change. However, this concept of evaporation also fits and is used in “Energy and Change” (Level 4) where it is introduced as a method for cooling the body as an aid in the regulation of body temperature. In “Natural and Processed Materials” it is Level 5 where the process of evaporation is discussed and in “Earth and Beyond” (Level 6) the role of evaporation in the water cycle is introduced. Consequently, it is evident that there is some confusion about the level in which the concept of evaporation should be placed because the same concept and its application to cooling appears in two different Strands at two different levels.

In “Life and Living” (Levels 4 - 6) food chains, food webs, food pyramids and their role in energy movement through an ecosystem are covered. These same concepts are found in “Energy and Change” (Levels 4 and 5). In Level 4 of “Energy and Change”, these concepts come under sources of energy and in Level 5 the concepts are related to energy in an ecosystem and the effects of the removal of all or part(s) of a trophic level from a food chain or web. The application of these concepts to explain the energy transfers, which occur within an ecosystem, is an emphasis. This also fits into Level 6 where the need to quantify the energy changes and effects are introduced.

3.6 LINKS BETWEEN ENERGY AND THE HUMAN BODY

As a teaching aid, to enhance the objectives of the *Curriculum Framework* in such areas as cross-strand and the inter-relatedness of strands, the use of the human body is a good starting point. Using the learner's own body makes the material being covered personal and of intrinsic interest. This topic can be used to access many of the concepts involved in "Energy and Change" and as a point for integration of the learning areas where applicable (See Appendix 8). A number of links between energy and the human body are found in the learning areas other than Energy and Change.

The interaction between temperature and chemical reactions ("Natural and Processed Materials") directly relate to respiration, metabolism and body temperature all of which involve some aspect of energy and the human body. That is, the rate of metabolism is dependent upon the body temperature and conversely body temperature is dependent upon metabolism and a number of other factors, particularly for lowering the body temperature. For example, evaporation and its cooling effects which appear in "Energy and Change" (Level 5) have been previously discussed.

The human being's place in food chains and the transfer or flow of energy through a food chain or web is found in "Life and Living" (Levels 4 – 6) and ties in with "Energy and Change" at Levels 3 – 5. Through these levels, there is a progression from sources of energy to transfer of energy and then the conversion of this energy (via respiration) to achieve a desired outcome such as muscle movement to carry out useful work.

This last example is a good example of a situation where two strands can be linked. The food chains and webs of "Life and Living" can be combined directly to "Energy and Change" with the learner being used as a member of the food chain or web.

3.7 SOME OTHER CHARACTERISTICS OF THE CURRICULUM FRAMEWORK

3.7.1 Constructivism

The *Curriculum Framework* has the underlying premise of a constructivist classroom and constructivist teaching and there is the need to illustrate to teachers both old and new, what this term "constructivist" means. In Western Australia, this definition of meaning has not really occurred and one consequence of this lack of clarity is the continuation of old instructional methods by many teachers, in particular those who have been teaching for many years (personal observation). It is highly likely these old instructional methods will continue in the future, with much of the purpose of the *Curriculum Framework* of student-centred learning that caters for all abilities, not being met. Teachers will continue their old pedagogy and only change or rather adapt their assessment methods to arrive at levels rather than the current grades.

3.7.2 Student Role

In conjunction with the changed role of the teacher is the changed role of the student to develop a set of skills to facilitate learning and be motivated to become an active learner. At an early age of formal education this may be very difficult and require much teacher help and guidance. But with continual direction and guidance from all teachers, students should be able to become a self-directed learners who will take responsibility for their own learning and be self-monitoring of their progress. This development requires much help from all the learners' teachers over a number of years and as such requires the teachers to have these skills and the ability to facilitate this general progression or improvement in self-learning ability. Many teachers are not trained in this area but rather are trained as imparters of knowledge.

3.7.3 Teacher Role

Many of the benefits of the *Curriculum Framework* and its outcomes-based pedagogy rely on the student becoming motivated to learn and be willing to accept the role of an active discoverer. Under the *Curriculum Framework*, the emphasis is now on the student as a learner. This emphasis leads to the changed role of the teacher. In the past the teacher has been seen as a source of knowledge to be passed on to the student. Now the teacher has the role of facilitator with the student being taught to learn and then carrying out learning within the teacher supplied context(s) through their interaction with the designed learning material. There is a paradigm shift in pedagogy from the familiar role of imparter of knowledge to the unfamiliar role of teacher as facilitator. This change of role can be daunting for many teachers who have been trained as imparters of knowledge and have been successful in this role. For this change to occur, teachers need time and guidance to accept the need for and the change in roles and to enable this change (Hand & Treagust, 1994). (The time line for the implementation of the *Curriculum Framework* could help in the transition.)

All the teachers of each student need to help and guide the individual as he/she develops both physically, mentally and as a self-directed learner. This guidance needs to be in such a manner as to reinforce previous development and to guide the learner towards the next stage of development. All teachers need to work in conjunction with each other so no conflict of messages to a student arises. In a large education system such as that of the Education Department of Western Australia, with its diversity of teachers and mobility of both staff and students, this becomes an almost unrealistic expectation. Unless the student has been shown how to learn and to monitor his or her own learning from a very early age, it is unreasonable to expect a student to achieve fully if they are just given a set of outcomes and a programme to follow.

With the students taking responsibility for their own learning, the onus is on the teacher to supply material that will enable each student to learn the concepts being covered. This learning material should guide the student such that he/she may discover the concept(s) being covered and to develop the concept(s) into their own conceptual framework. When the student has attained the concept(s) it should be tested against other situations and examples to which the student may not be familiar. These phenomena should be both within the context in which learning occurred and then be outside the initial context(s) such that the newly incorporated material becomes more widely tested and less specifically contextualised. To achieve this broad learning, the students will need to be actively engaged in the learning process through their interaction with the learning material. At the same time, the teacher should be able to monitor each student’s progress and hence the level the student is working at any time of the learning programme.

The series of structured learning experiences should be based upon a constructivist classroom as is implied in the sections of the *Curriculum Framework* titled ‘Implementation of the Curriculum Framework’ (p.9), ‘Introduction’ (p.13) and the section headed ‘Learning, Teaching and Assessment’ (p. 33). While no description of what a constructivist classroom should be is given, there is a description of a number of “principles about learning and teaching” in the *Curriculum Framework* document (p.

33). The overall emphasis is on the learner being actively engaged in his or her own learning through the use of guided learning experiences and interaction with each other and the experiences. This is a paradigm shift from what is taught and how it is taught to what is learnt by each student (*Curriculum Framework,* 1998). As described previously, the prescribed outcomes are general in nature and it is up to the teacher (or school) to interpret these in such a fashion to meet the needs of the school's community (*Curriculum Framework* 1998). As an aid to helping teachers in their planning and assessing, EDWA has produced a series of books for each Learning Area. The books related to science have been listed earlier in this Chapter (Section 3.3.3).

3.7.4 Cross-Strand Teaching

In conjunction with learning experiences which guide the learner is the potential to show how a concept can be demonstrated in a variety of contexts and hence how that concept may be integrated within a number of learning areas by the use of a curriculum based upon themes. As discussed by Wallace, Rennie, Malone and Venville (2001), there are problems with the integration of concepts across strands especially when teachers leave a school. These authors state that with schools organised around subjects, teachers focus on the subject content with which they are familiar, but in many cases teachers still "manage to make the links to students' experience, to the wider world and to other subjects, almost regardless of the subject taught" (Wallace *et al.* 2001, p.14). These writers go on to say while integration is attractive, the core to effective learning is good teaching. To enable this good teaching the teachers need to be in-serviced on what a good teacher requires in their repertoire to become 'good' within a *Curriculum Framework's* curriculum and its new demands.

With the possibility of linking strands (and Learning Areas) comes the need to ensure that the timing of the links across Strands, the Levels and even Learning Areas actually match. As previously discussed (Section 3.5), the example of the evaporation of sweat as a method for cooling the body and helping in body temperature regulation is Levels 4 or 5 in "Life and Living" where it describes systems of the body and their interactions. In the pointers for Level 5 of "Natural and Processed Materials", there is an example of why wet clothes cool a person down. If care is not taken, a student could understand what sweating relates to as per “Natural and Processed Materials” (Level 5) but the student could also be at a lower level using the same information in “Life and Living” or “Energy and Change” (Level 4).

The creation of cross-linked programmes and the construction of material which will actively engage the student and aid in monitoring learning requires a thorough working knowledge of all the levels and all the strands within a learning area (and possibly other areas). In many cases at this early stage of implementation, this thematic approach is not familiar to average high school teachers in that they do not understand sufficiently nor do they have the necessary knowledge of *Curriculum Framework*. While the cross-linking of the Learning Areas and Strands is excellent for student learning, it can place tremendous strain on the teacher creating the programme. This is particularly the case during the developmental stages of a curriculum. Also the teachers’ understanding of this new curriculum has not been fully established and the purposes and aims have not been fully articulated so teachers can accurately implement the intended curriculum. Rather, their interpretation of the curriculum as they understand it will be utilised. The intended and implemented curriculum may be different as indicated by van den Akker (1998) and Bekalo and Welford (1999). One consequence of this is that teachers will continue to use their tried and proven old methods of instruction, as they do not have the time to develop good effective new learning material which is more suitable for the purposes of the *Curriculum Framework*.

3.7.5 Comparison of Outcomes and Objective Based Education

Griffin (1997) created a table comparing the differences between content-based and outcomes-based programmes, listing 14 components where differences occur. The examples or dichotomy he used are the extremes along a continuum from a purely content to a purely outcomes-based education programme. In many classrooms these extremes are not visible. For each of the 14 components, a learning programme in a typical classroom would incorporate varying positions along each of these 14 continua. For example, with instructional content, Griffin has content-based programs being subject matter based and the outcomes-based program being outcome based. But within the outcomes-based instructional content there needs to be some knowledge which may or may not be specifically subject based. For a student to achieve the desired outcomes some subject specific knowledge is necessary. But this knowledge may be gained in a variety of contexts.

A normal Year 8 to 10 science classroom programme in Western Australia will most likely involve a series of outcomes which will include contextualised subject matter and knowledge to be covered through a variety of instructional techniques with both immediate and delayed feedback. The learner will be encouraged to acquire a certain amount of knowledge as well as develop inquiry, reasoning ability and problem-solving skills. The methods employed to 'teach' the students will vary depending upon the teacher, facilities available and what is being covered.

Under "mode of instruction" for outcomes-based education, Griffin has the teacher as a facilitator of learning using a variety of instructional techniques. In general a Year 8 – 10 science class in Western Australia will be exposed to all of Griffin's components at different times. But over a period of time, it is more than likely the components used will be along the continuum. The teaching techniques employed in each lesson will vary depending upon the desired outcomes of that lesson or lessons and the epistemology of the teacher. These techniques also will vary with the material being covered by the learners in their progression to gaining the understanding of a concept.

While Griffin has the extremes for content (objectives) and outcomes-based programmes, through my observations and discussions with a range of teachers, from beginning through to highly experienced, it would be rare to find a class which fitted one of these extremes, especially over a period of time. Where teachers are attempting outcomes-based education they are employing a variety of techniques to facilitate learning.

3.7.6 Scientific Knowledge and Curriculum Framework

While the depth of coverage of a concept or group of concepts is left up to the curriculum developer (as is the breadth), one perceived problem for many science teachers is the lack of any prescribed knowledge (outcomes). The depth of knowledge required of a student is left entirely up to the teacher. So students at different schools may acquire different depths of knowledge but still be given the same level of attainment for a Strand. However, this situation creates comparability problems and is an expressed concern of many teachers. While this is of concern to teachers, according to the Curriculum Framework the degree or depth of knowledge should be sufficient to communicate effectively using scientific language to show a student's understanding of what has been learnt.

Another potential danger of this knowledge problem is that science could become too process-orientated where knowledge becomes of secondary importance. Certain facts or definitions and the language of science are required knowledge for any learner to become an effective member of the science community. A lack of prescribed knowledge can create difficulties in assessing the depth of knowledge required for a level especially for a teacher when teaching out-of-subject or for a newly graduated teacher who is the only teacher of that Learning Area in a school or district. The knowledge and its appropriate depth both require training and a good understanding of the area of science to be able to accurately judge the knowledge required for a particular level. Despite the examples in the documents supplied by the Education Department of Western Australia to aid a teacher in providing a level for a student, their implementation can be a difficult exercise for a teacher who may not be confident that their processes are comparable to other teachers.

With the role of teacher as facilitator and learners taking responsibility for their own learning comes the change in assessing a student's progress. The students demonstrate the level of attainment of the concepts as they progress through the their task(s). The teacher can then continuously assesses progress towards the desired outcome(s) and should supply feedback to the learner on their progress. With this continual feedback, more effective learning should be forthcoming.

3.7.7 Progression of Achievement

To enable progress towards attaining an outcome (for a strand of a Learning Area), the levels within a strand need to be progressive in their cognitive demands and show increasing progression in the cognitive processes involved, the conceptual developments demanded and the problem solving abilities demanded for each level. This has been achieved by having levels progress from concrete to abstract phenomena, being related to personal experience through to objective analysis, requiring an increasing ability to solve problems starting at the concrete and progressing to the abstract and also requiring more complex logical development. There is a progression in the difficulty of the cognitive processes utilised by a student as they move up the Levels with each strand since they need to combine concepts and use these concepts to solve problems.

While breadth and depth and integration are major good points of a framework, one potential weakness is that of the delineation of levels. Many teachers and students find that the blurring of the boundaries between levels creates problems. To reduce this concern, each level needs to be as clearly defined as possible so knowledge of what is required in the learning context as a minimum standard is readily available. There is also the need to indicate not just a level's requirement but also the strands which are involved, as there may be more than one strand involved in the development of a concept or section of the curriculum.

3.7.8 Curriculum Framework Inclusivity

A major thrust of the *Curriculum Framework* is the inclusiveness of the curriculum in that it can cater for a range of student abilities and so to meet the needs of all students either in the same class or different classes. With the inclusiveness of the curriculum comes the ability to link Learning Areas. For example, the idea of energy can be used to link "Life and Living", "Natural and Processed Materials" and "Energy and Change" from the Science Strand and Society and the Environment (Strands 3 and 6). This linking of energy across Learning Areas could be done by a careful and complete study of the process of photosynthesis. Where the need for photosynthesis by plants and how chlorophyll traps energy and the subsequent food chains and food webs would be in "Life and Living", the chemical reactions from a simple word equation to a complex level would place it in "Natural and Processed Materials".

Another benefit of the *Curriculum Framework* is that of breadth versus depth of study for a concept. With the links between Strands and even between Learning Areas, a curriculum can be developed which can have what breadth and depth is deemed necessary for the students. At the same time as breadth is incorporated, care needs to be taken to ensure depth of study is appropriate. The depth and breadth of coverage is left up to the individual school as is cross-linking of Strands and Learning Areas and the knowledge required.

Associated with the breadth and depth problem is the ability to integrate Learning Areas as well as different Strands. With the integration of the Learning Areas and the connected contexts, teachers who are able to employ this could potentially facilitate the transfer of knowledge through students being exposed to a concept in a range of differing contexts.

3.7.9 In-service Requirements

From the above discussion it can be seen that the implementation of the *Curriculum Framework* needs to be fully supported with a comprehensive in-servicing programme for all teachers. In-servicing education needs to deal with 'constructivist teaching', a good understanding of the strands and levels and finally assessment of student progress for awarding a level. Despite verbal promises by the Government to this effect, this pre-requisite in-service education has not occurred, especially in the four 'concept strands'. This lack of in-servicing is a continual complaint by teachers of all subject areas or Learning Areas as witnessed by the author at many subject teacher meetings (personal observation).

While there are a number of apparent problems, the overall benefits of the *Curriculum Framework* out-weigh these problems in the long term as teachers become more familiar with the new pedagogy and its demands. This change period will have associated with it a number of mistakes and errors that can be used to refine the education processes and procedures to arrive at the desired goals of the *Curriculum Framework*.

3.8 RELATIONSHIP OF THIS RESEARCH TO *CURRICUUM FRAMEWORK*

3.8.1 Curriculum Framework Requirements

A number of major new initiatives, which arise from the *Curriculum Framework*, should result in a number of new processes being implemented by many teachers in their classrooms. Many of these new processes may require from minor to major paradigm shifts by the teachers and/or students. The degree of shift will depend upon the individual and their own current education situation and involves a shift from the objective based curriculum of the past to the outcomes-based curriculum of the *Curriculum Framework*.

The *Curriculum Framework* and all its processes are based upon an outcomes curriculum which necessitates the learners interacting with the learning material and being able to monitor their own progress. This paradigm is from a teacher-centred supplier of learning experiences to a more student-centred one with the teacher continually monitoring each student's progression through the lessons as well as towards the attainment of the desired outcome(s). It is incumbent upon the teacher to supply material that will enable these experiences to occur.

3.8.2 Constructivist Classroom and Processes

One of the requirements of the *Curriculum Framework* is that science be taught in a learning environment "supported by contemporary research and professional knowledge about learning" (p 33). To most science teachers in Western Australia this is viewed as a constructivist classroom and this constructivist approach is alluded to in a number of sections within the *Curriculum Framework*.

This notion of a modern classroom that will facilitate learning and teaching as expected in the *Curriculum Framework* is illustrated when the authors outline their vision of the learning environment. These authors state learners should have the opportunity to "observe and practise the actual processes, products, skills and values which are expected of them" (p. 33). The learners should connect this learning to what they already know. Teachers should challenge current thinking by ensuring that the learning experiences are meaningful, motivational and with a clear purpose while encouraging reflection. This teaching must be inclusive of students' ability. The learning environment should be supportive of safe learning and allow for a variety of learning situations such as independent or collaborative learning.

Current constructivist practices require that students commence formal learning processes from their current knowledge position and be aware of their current knowledge status or the metacognition of their current knowledge. From this self-awareness, students can develop or build upon their knowledge framework. The development of knowledge should be via the active interaction of the learner with the learning material. Through this interaction, the learner should develop new models as they incorporate the new knowledge into their cognitive framework (Baird, 1996; Beeth, 1998; Glynn & Duit, 1995; Novak, 1998).

During the 1970s and 1980s, much of constructivist research was directed into identifying misconceptions and methods to facilitate the processes of adjusting these misconceptions to the currently scientifically acceptable notions. This led to the general conclusion that it was very difficult if not impossible for students to change their held notions (Chi *et al.* 1993; Duit & Treagust, 1995; Glynn & Duit, 1995; Solomon, 1983a; Vosniadou & Ioannides, 1998). Glynn and Duit, for example, go on to state that most people will retain their old conceptions and when in formal education situations will develop new conceptions in parallel to these. The suggestion by these authors is for the teacher to develop these acceptable conceptions and to help the learners to know when to employ them appropriately.

From this aim, the situation of prior knowledge becomes important so the learner can find out what they already know and its current acceptability and then what they need to adjust or develop in the form of new concepts. Learners need to have their current knowledge status indicated to them so they can then proceed to further develop their cognitive framework. In association with this aim is the need for the teacher to know where to start the teaching sequence (Ausubel, 1968), what conceptions the learners bring with them and what problems could develop with the learning process. The teacher needs to know or be forewarned about the knowledge students currently hold so the preparation of learning materials which will reduce these problems can be undertaken.

3.9 THIS STUDY AND THE *CURRICULUM FRAMEWORK*

A number of the objectives of this study are of such a nature as to aid in helping teachers and students in their meeting of the requirements of the *Curriculum Framework* and its implementation during a student's formal education.

The use of levels for the outcome of "Energy and Change" has been catered for in the worked example of energy and the human body which is in Appendix 8 where a set of examples of energy and the human body and how they relate to the Outcome Statement of "Energy and Change" are briefly discussed (Section 3.4.2). This worked example, which is by no means complete, can be used by a classroom teacher to help in the design of a curriculum that centres upon this learning area. These examples can be used as an aid to help in the assessment of each student's progress towards the attainment of an outcome.

Baird (1996), Beeth (1998), Glynn and Duit (1995) and Novak (1998) have discussed the need for student metacognition with regard to learning a concept and to know how students' own ideas fit with respect to the currently held views of science. This self-awareness will help in directing student's learning and in adjusting their existing conceptions to become more scientifically acceptable, to create new scientifically acceptable conceptions or to know when it is appropriate to use the models and conceptions that they have developed. As well as helping students think about their cognitive positions, the use of the human body as an example to think about has intrinsic motivation since it involves the learner personally. This position becomes a viable starting point from which to develop the concept further and in different contexts.

The identification of misconceptions or alternative conceptions from this study can be an aid for both the teacher and student. While the student could possibly identify his or her current conceptualisation of energy with regard to himself or herself, the identified misconceptions can also indicate to the teacher potential areas for emphases and where work needs to be carried out to facilitate changes in models. This knowledge should help in the formulation of a more effective curriculum and learning materials. In conjunction with the identification of misconceptions is the way student-held conceptions change with the students' age.

In association with this cross section study, the identification of possible ontological positions of the students' conceptions and how these change with student age are identified (Section 6.6) and should further help guide the design of curricula and material for the student to work with during their learning experiences in science. This ontological study should act as an aid to help the teacher assess the development of the students and where they are placed upon their development of the outcome. This could be used to help guide student learning and conceptual development through the use of more appropriate learning experiences.

Through the use of the examples or pointers illustrated in Appendix 8, a teacher can get assistance to aid in placing a student within a level (of attainment) for the Strand of "Energy and Change". While this set of examples is restricted to energy and its relationship to the human body, as discussed previously, the use of the student as an example of the application of a concept is motivational, relevant and makes the topic being taught more real to the learner.

From the information on alternative conceptions held by students, a diagnostic instrument was created. It is envisaged teachers and students could use this instrument to identify conceptions held and in the case of students this would aid them to become aware of their knowledge base (metacognition). From the teacher's point of view, this instrument could be used to develop a sequence of lessons with the aim of adjusting student conceptions towards more acceptable scientific notions.

3.10 SUMMARY

This chapter has discussed the origins and development of the new curriculum recently introduced into the State of Western Australia titled *Curriculum Framework for Kindergarten to Year 12 Education in Western Australia*. From this historical perspective the structure of this document was investigated and the underpinning theories which have driven the philosophy and hence structure and desired outcomes of this curriculum

From this description of the curriculum, the position of energy is located and then links to the other seven Learning Areas and within the Science Learning Area itself is outlined. The paucity of relationships to energy and the human body as pointers for describing the different levels within the Science Learning Area was noted and a worked set of pointers briefly described. This is followed by a brief outline of some characteristics of this new curriculum document which further describes it and leads into the links between the new curriculum and this research. From this position, the relationship between the *Curriculum Framework* and this piece of research is briefly described.

Chapter 3 discussed the introduction of a new curriculum framework that has recently been introduced into the State of Western Australia. With the introduction of this new framework has come the ability of schools and teachers to develop new curricula for all subjects which is claimed should be based on 'constructivist principles'. It is into this new curriculum development process that the results of this research can be utilised by the curriculum developers and teachers. Chapter 4 shows the position and relevance of the findings of this piece of research to the development of the new curriculum and its implementation by classroom teachers.

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

The present chapter has as its aim the development of instruments to facilitate the identification of students' conceptions in relation to energy and their body. To this end, a procedure proposed by Treagust (1991,1995) and Treagust and Mann (2000) was followed to create two questionnaires which would elicit student notions with respect to energy and the student's body. From the data collected from these questionnaires, students' conceptions were identified and from this information a series of modified two-tier multiple choice items was developed to identify student held conceptions and their underpinning reasons. This section of the methodology deals with the development of the questionnaire and is followed in Chapter 7 with the development, administration and trialing of a two-tier diagnostic instrument.

This chapter describes the research methodology used in this study to identify problem areas in student knowledge as it is related to energy and the human body (Sections 4. 2) from which two questionnaires were created (Sections 4.2.3). The process of data collection using these two questionnaires (Sections 4.4) and the sample used are briefly described (Section 4. 4.1 and 4.4.2) as is the ethical issue with the need for the identification of students (Section 4.3.3).

4.2 QUESTIONNAIRE DEVELOPMENT PROCESS

4.2.1 Delineation of Study Area

A number of propositions relating to the area of study, energy in the human body, were created. Three experienced teachers of Human Biology reviewed and validated these propositions to ensure that they fully covered the proposed study area. Each of the three teachers had a minimum of ten years classroom experience involving the teaching of Human Biology and/or Biology. Any changes suggested in the wording of the statements, deletions and additions suggested were considered and made if applicable. The final list of propositions (see Appendix 1) can be grouped or placed into a number

Table 4.1: Grouping of propositions related to energy and the human body.

Proposition Topic	Proposition Sub-Topic	Content Of Proposition Topic
SOURCES OF ENERGY		General sources of the energy required by the body
ENERGY INTAKE AND RECEPTION		Areas of the body by which energy can enter the human body
PROCESSING AND MOVEMENT OF ENERGY SOURCES		Covers the intake of food, its digestion, absorption and movement around the body
	Food Digestion	Digestion of food
	Absorption	Absorption of digested food
	Transportation Of Energy	Movement of absorbed food around body via blood and lymph
ENERGY REACTIONS		Range of energy conversions carried out by the body, grouped into major processes
	Respiration	Process of cellular respiration to form ATP
	Role Of ATP	Function of ATP in the body
	Sleep	Role of sleep in energy level replenishment for the body cells
	Sight	Energy conversions in the eye
	Hearing	Energy conversions in the ear
	Skin	Intake and loss of energy via skin
"USES"		
	Terminology	Definitions of various terms such as metabolism, anabolic, catabolic and respiration
	General Uses	Encompassing statement of energy use
BODY TEMPERATURE REGULATION		Production, utilisation of heat and the need to regulate body temperature. Role of sweat in temperature regulation
STORAGE		chemical storage of energy in the body
ENERGY "LOSSES"		Second Law of Thermodynamics. How heat is moved into and out of the body and the processes involved in this movement. Role of latent heat of evaporation.

of sub-groups as shown in Table 4.1. Some of the propositions could be placed into a number of sub-groups but were placed into the sub-group related to the major purpose of that Proposition. For example, Proposition 79: “Sweat, when it evaporates, removes heat from the skin” was placed in the sub-group of body temperature regulation.

A concept map of energy and the human body was drawn up (see Appendix 2). The same three teachers who earlier validated the proposition list also validated this map for accuracy out at a later date from validating the propositions. Any suggestions were acted upon and any necessary changes were made to the concept map.

As suggested by Treagust (1991, 1995), the development of diagnostic assessment instruments required the contents of the proposition list be inclusive. To this end, the number of each proposition linked the proposition list to the concept map. These numbers are shown in the circles on the concept map (see Appendix 2) where they relate to the concept links. This process showed the propositions did reliably cover the content and clearly delineated the boundaries of the study area.

While carrying out this procedure, it was revealed that a learner needed certain knowledge before some propositions could be covered in class. For example, knowledge about the process of evaporation (and the role of latent heat of evaporation), the effects on the heat content of a body is needed to understand the way in which heat is lost (from the skin) when a body sweats and bond energy for the production of ATP and the release of heat from chemical reactions.

4.2.2 Identification of Problem Areas

A series of studies involving a literature search, interviews and two essays was carried out to help identify problem areas within the area of energy and the human body. The procedures used to identify the major problem areas of this study are outlined in detail here.

4.2.2.1 Literature Search

A study of the literature was carried out to help identify any misconceptions or problem areas already discovered by previous researchers. A number of studies in the area of energy and how it relates to the human body were identified through a search of such facilities as ERIC (Education Research Information Centre) and AEI (Australian Education Index) and the bibliographies of Pfundt and Duit (1998) and Duit (2002). This perusal of a range of written media was carried out and a large number of journal and book articles identified each containing information fitting the criteria of energy related to students' views of energy and more specifically energy and the human body. From this extensive literature search (as discussed in Chapter 2), a range of problem areas that involved energy and the human body were identified and a list created.

4.2.2.2 Interview Sample

A series of interviews was held with nine students, all of whom were enrolled in the school at which this researcher was employed. (A description of this school's demographic profile is in Section 4.3). All interviewees volunteered to participate. These students comprised two males from Year 8, one male and two females from Year 10 and one male and three females from Year 12. The degree of formal education related to energy and also to energy and the human body varied with the student's age, but in Year 11 and 12 it also varied with the subjects studied in each of these Upper School Years. For example, all Year 9 students had just completed a semester studying energy, part of which involved energy processes in the human body. In Years 11 and 12, some students were only studying Physics and Chemistry and so had not formally studied energy and their body since Year 9.

4.2.2.3 Description of Interview Sample

The Year 8 students were not yet exposed to energy work in their science course except in the area of chemistry where they had studied evaporation as a separation technique and had observed temperature changes as an indication that a chemical reaction had occurred. No knowledge of their primary science education was known except that primary teachers are generalists and not specifically trained in science. Any science studied during primary school was through their teachers' use of a Curriculum titled *Primary Investigations* (Australian Academy of Science, 1994) which is based on scientific processes rather than knowledge accumulation.

The Year 8 students were enrolled in science classes that were of average academic ability and they were not above the general ability of this class. Consequently, these students were of average academic ability and were representative of the Year 8 cohort in this study school.

Year 10 students had studied a semester of science in Year 9 which dealt with many aspects of energy including all those found in the list of propositions in Appendix 1. This course of study was completed 11 months prior to the commencement of the interviews, so energy was not fresh in the students' minds. The students' current science courses were chemistry and genetics but neither of these courses included energy objectives.

Two Year 12 students were studying Chemistry and Physics and were considered to be academically above average. The other two students were studying Human Biology and were considered average students by their teachers. The current Human Biology course being studied by these two students does not include work on energy except the regulation of body temperature, which had been covered two months prior to the interviews taking place. No other energy related areas were in the course studied to date. It was expected the two students studying Human Biology might have been more knowledgable about energy and their body because of the nature of the curriculum.

4.2.2.4 Interview Description, Collage Description and Interview Procedures

Each interview was based on the model of 'interviews about events' as described by Osborne and Gilbert (1980) and later used by such researchers as Carr (1996), Kruger (1990) and Leach (1995). Rather than just one picture of an event, a number of pictures which all related to a common theme or situation were used to create a collage. A series of four collages were presented to the interviewee with each collage relating to some different aspect of energy and the human body (Appendix 3). These aspects were the intake of food, exercise, cooling down processes and weight gain and loss, with a series of questions based on each collage.

Each collage was accompanied by an opening question that was to ensure both parties were discussing the same feature in the collage. This question took the form of "What is common to all the people you can see in this set of pictures?" Once the commonality was established, questions were posed to elicit the notions and their underpinning reasons as held by the interviewee.   For the eating collage such questions as “Why are they eating?” “What is the purpose of eating food?” while questions for the exercise collage included “What is needed by all the people in these pictures to do what they are doing – exercising?” and “Where do they get these things they need to exercise from?”

More specific questions were then asked to have students clarify information supplied or to probe for the underlying reasons for the answers given. This process was repeated until the interviewer was satisfied he had obtained as much detail as was possible. At this point a new collage was presented and the procedure repeated.

The final collage involved pictures of people with before and after pictures that showed the person had undergone a loss of weight. The same procedure was followed for this collage as the previous three events or situations. One of the pair of pictures was of two different people who were of different weight regimes and this picture was used as the subject of a separate series of backup questions on weight loss and weight gain. The questions revolved around how one person could gain or loose weight and the reasons why this might work.

The interviews took place during the month of July and August at the beginning of second semester of the school year in the State of Western Australia, in a classroom within the Science Block of the school in which all the students were enrolled. Each interview took place during the student's lunch break so no time limit was placed on the interview as there was in excess of 40 minutes available. Each interview took between 20 and 25 minutes, the time varying depending upon the interviewee’s knowledge and hence responses to the initial questions asked for each collage and any back-up questions that were needed. Areas of interest to the interviewer arising from the initial set of questions on each collage were pursued by further questioning until that area had been clarified or no further information was obtainable.

During the introduction to each interview the purpose of the interview, how the results would be used and that each interview would be treated anonymously was explained. This introduction was designed to help clarify the purpose of the interview and help the interviewees relax. Many students thought they were being tested for the correctness of their answers so it was pointed out that the underlying reason(s) for answers were more important than the answer being right or wrong and that this would in no way go towards any grade these students may be awarded. At this time it was asked if the student minded the interview being tape-recorded and the reasons for this recording were explained. No interviewee objected to the use of the tape-recorder.

Each interview was tape-recorded so the interview could be carefully analysed at a later date. No interviewee appeared to be at all concerned by the presence of the tape recorder. Paper and pencil were provided in case a student needed to illustrate a reply to a question. Some students availed themselves of this facility.

After transcription of the interviews, an analysis of each interview was carried out to identify the errors and misconceptions presented and their underlying reasons. These problem areas were collated and further analysed to identify any emerging patterns, in particular for any age, or in the case of Years 11 and 12 students, subject-related problems.

4.2.2.5 Essay Procedures

As an aid to further identification of student-held conceptions, a set of two essay style questions was composed and administered to the following classes, four Year 8, two Year 9 and three Year 10 classes. These essays and accompanying instructions are to be found in Figure 4.1. The first question requests students to list 10 examples of energy use and was designed to firstly help the students orientate their thoughts and secondly to ensure that a simple identification of energy use by the body could be made. Only one of the two essays was to be answered by a student - one question was allocated randomly by the class teacher at the time of administration. The only stipulation was that no student was to sit next to another student who was answering the same question so as to reduce the chances of collusion.

From the responses to the essay questions, a number of scientifically unacceptable conceptions that were held by these students were identified together with areas of conceptual weaknesses. From the lists of errors and misconceptions created for each of

READ EACH QUESTION CAREFULLY PLEASE.
Make a list of 10 things you can do which involve your body using energy.

INSTRUCTIONS
Please answer the following questions. In your answers please be as detailed as you possibly can in explaining what you are saying. If you use terms or words of importance (eg, digestion, photosynthesis, work or joule etc) briefly explain them as you go.
If you need more paper please ask for it.

1 What things do you need to take into your body to get the energy you need to do such things as live and exercise?

2 How does your body get the energy it needs from the things it takes in for living and exercise?

Figure 4.1: Essay questions to aid in the discovery of students' concepts held on energy and human body

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the previously described search areas - essays, interviews and the extant literature - a single composite list of common errors and conceptions was compiled. These non-scientific conceptions were used to help create items for the diagnostic questionnaires, which were to be constructed to help identify notions held by the subjects of this study.

4.2.3 QUESTIONNAIRE DEVELOPMENT

4.2.3.1 Questionnaire Design

The questionnaires titled *What do you know about Energy and Your Body? Questionnaires 1 and 2* each consisted of two parts. Part one was composed of two questions and was identical in each instrument. These items had a two fold function: first to encourage students to think about their body and its energy uses, and second to discover how much students did know about their body and energy use in general. Item 1 asked for examples where energy is used during gross bodily activity and Item 2 asked for examples where energy is used by the body excluding gross bodily movement. This second item was to investigate what students did know about body energy that did not involve gross activity or body movement.

Part 2 of each instrument consisted of a series of items designed to diagnose student conceptions by the use of a modified multiple choice type questions. The first part or stem of each item was a simple statement to which the respondents indicated whether or not they agreed or disagreed with that particular statement. The stem was followed by space being provided via the provision of seven ruled lines on which the respondents wrote their reason(s) for agreement or disagreement. An example of an item from Questionnaire 1 item 7 is shown in Figure 4.2. The final Questionnaires are presented in Appendices 4 and 5.

7 In the process of respiration, energy in sugars is converted into energy that the cell can use to do things.

AGREE / DISAGREE

REASON

Figure 4.2: Example of questionnaire item used to diagnose student conceptions and their underpinning reasons.

4.2.3.2 Questionnaire Development Procedure

The list of propositions (see Appendix 1) were rearranged as necessary such that each proposition occurred in the sequence in which energy moves into, through or is utilised and eventually lost by the human body. The propositions were combined and in some cases reworded to produce statements which reflected scientifically acceptable notions. Each of these composite statements covered a segment of the body processes that involved energy. Some statements were discarded because they were seen as being of low importance, not involving a significant problem area, not being involved directly with energy use by the body, or beyond what was a reasonable expectation for a school student to know. Those statements remaining and still deemed useful for inclusion in the questionnaire were then modified so they had scientifically unacceptable features in them. These features would appear logical or reasonable to students who held conceptions in that area such as, for example, the location of energy within ingested food being particles of energy between food particles or particles within the food molecules (Item 1 on both questionnaires). Other statements arose from the way that teachers teach aspects of energy such as respiration and from the conceptions identified in the literature with respect to energy in general or specifically the human body. For example, energy can be obtained from sleep (Boyes *et al.* 1991a) or air (Boyes *et al.* 1991a) or through digestion (Lavoie, 1997), particulate nature of energy (Arzi, 1988), that it is a substance (Carr *et al.* 1987) or energy associated with a human activity (Kruger, 1990).

After the creation of an initial list of statements, a number was eliminated or recombined to arrive at the final 28 statements, some of which were true and others false. Each of these 28 statements related to a process or part of a process involving energy in a body as identified by the propositions. For example, item 1 on both questionnaires is related to the location of energy in food, item 7 on both questionnaires and item 6 (questionnaire 2) are related to respiration, while item 11 (questionnaire 1) and item 10 (questionnaire 2) are identical and are an example of energy utilisation by the body to make an object move.

To ensure the major areas of energy and the human body were covered by the 28 items, a specification grid was constructed to ensure the items did deal with the area to be covered and that no unnecessary sections of this topic were excluded (see Table 3.3) unless regarded as beyond the scope of this piece of research or the students' potential formal education as, for example, the detail surrounding the formation of ATP by the process of respiration. Any adjustments were made to the instrument by deleting or adding or altering items where this was deemed necessary.

The subsequent list of 28 items was then divided into two questionnaires such that each questionnaire had alternative statements from the completed list of statements. It was necessary to make two complementary questionnaires, as a single questionnaire of 28 items was considered by the author as being too long for any student to respond to with any degree of reliability and within a realistic time frame provided within a lesson's length. With these two lists of items, a check was carried out by the researcher to ensure that each questionnaire had a balance of items which covered each area to be studied and also that they had roughly the same number of questions. The final order of the statements for each instrument was then checked to ensure they followed a reasonable

Table 4.2: Specification Grids of proposition knowledge areas and questionnaire item numbers.

Proposition Topic	Proposition Sub-Topic	Questionnaire Item Numbers
SOURCES OF ENERGY		Questionnaire 1, numbers 1, 2, 5, 6, 8, 10 Questionnaire 2, numbers 1, 2, 3, 4, 5, 11, 12, 13
ENERGY INTAKE AND RECEPTION		Questionnaire 1, numbers 8, 9, Questionnaire 2, numbers 3, 4, 5, 11, 12, 13
PROCESSING AND MOVEMENT OF ENERGY SOURCES		
	Food Digestion	Questionnaire 1, numbers 9 Questionnaire 2, numbers 1, 4
	Absorption	Questionnaire 1, numbers 9 Questionnaire 2, numbers 1, 4
	Transportation Of Energy	
ENERGY REACTIONS		Questionnaire 2, numbers 12
	Respiration	Questionnaire 1, numbers 7 Questionnaire 2, numbers 6, 7, 8, 11, 12,
	Role Of ATP	
	Sleep	Questionnaire 2, numbers 3,
	Sight	
	Hearing	Questionnaire 1, numbers 10 Questionnaire 2, numbers 12,
	Skin	Questionnaire 1, numbers 13 Questionnaire 2, numbers 12, 15
"USES"		
	Terminology	
	General Uses	Questionnaire 1, numbers 11 Questionnaire 2, numbers 10
BODY TEMPERATURE REGULATION		Questionnaire 1, numbers 11, 12, 13 Questionnaire 2, numbers 14, 15
STORAGE		Questionnaire 2, numbers 9
ENERGY 'LOSSES'		Questionnaire 1, numbers 11, 13 Questionnaire 2 numbers 10, 15

sequencing of energy movement and use by a human body from intake to utilisation and removal from the body.

The two questionnaires covered the various aspects of energy and the human body and had the following item in common, "When we ride a bicycle, some of the energy is transferred to the bike" with Questionnaire 1 consisting of 13 items while questionnaire 2 had 15 items. In an instrument given to another two schools at a later date, another question was added to questionnaire 1 to make 14 items. This extra question identified a potential problem in item 8 of questionnaire 1 where students thought these organs all received energy since they were made up of cells and so needed energy to survive. This new item removed this possible answer and tested the original intention of the item. The relationship between the two questionnaire items is shown in Table 4.4.

S signifies that the two items are similar in that they probe for conceptions within the same area of energy while X shows the two items are from the same area of energy but probe for different aspects within that area. A blank indicates there is no relationship between the two items. Items testing similar concepts could be used to assess the comparability of the responses between the two instruments during the analysis of the students' responses.

When the instruments appeared to satisfy the desired outcomes, the drafts were submitted to a group of 12 doctoral colleagues of the author and to the same group of three Human Biology teachers who had earlier assessed the propositions and concept map for their comment. These two groups were asked to check the questions for any problems in readability, comprehension and any other problems they detected in the items' construction. Any comments or suggestions were acted upon and incorporated into the final version.

Subsequently, the instruments were administered to a middle ability class of Year 9 and a middle ability class of Year 10 students to assess (i) the readability and comprehensibility of each item, and (ii) that each item elicited responses related to the propositions that the stems were supposed to be testing. Students also had the chance to comment on and re-write statements if they found them unclear, unable to be understood or for any other reason were felt to be difficult to answer. Any re-written statement was to be replied to in the same fashion as the other statements on the questionnaire.

Table 4.3: Grid to show cross check of items between Questionnaires 1 and 2

Questionnaire 1

		1	2	3	4	5	6	7	8	9	10	11	12	13
Q	1	X												
u	2		X	X	S	X	X		X	X				
e	3						X		X					
s	4		X	S	X	S	X			S				
t	5		X	X	S	S		X		X				
i	6			X	X	X	X	S		X				
o	7						X	S		S				
n	8				X	X		X					S	
n	9			S		X		X		X				
a	10											I		
i	11						I		X		X			
r	12								S					
e	13								X		S	X		
	14										X	X	I	X
2	15											X		S

Note: In Table 3.4, the code used is: I identical items S similar items X items from the same area.

This set of student responses revealed a number of problems that were subsequently addressed by modifying the statements. At this stage it was revealed that 15 items were sufficient for students to effectively answer in a time of approximately 40 minutes. The modified instruments were then administered to a different class of Year 10 students for their suggestions and any suggestions from this group were acted upon.

The final set of two instruments were colour coded by being printed on different coloured paper, so they appeared to be different and that they were different was pointed out during the instruction session prior to the students responding to the questionnaires. It was felt that using the Year 9 and 10 students would ensure that the questionnaire's readability was appropriate for the target age group of the questionnaire, viz. Year 8 through 12 students with the items being neither too difficult nor too easy to all students.

4.3 SCHOOL PROFILES AND STUDENT PERMISSION

4.3.1 School Profiles

Students who participated in this study came from schools in two different suburbs found in the northern corridor of the metropolitan area of Perth in Western Australia. The schools' populations were predominantly from Caucasian middle-income families who are either self-employed trades people or office workers with a few families having parent(s) who hold managerial positions. (From personal communication with the

Principals of the two schools it was found approximately 98% of the students have English spoken at home as their first language and were predominantly from families which were of English or Australian parentage and so English is the first or major language. The ethnicity of the students is not a relevant issue in this study and so will be ignored in the analysis of the data.)

The initial administering of the two questionnaires was to the students of Years 8, 9, 10, 11 and 12 currently enrolled in the school in which the author was teaching in and one other geographically close school where the teachers had volunteered to participate in the administration of the questionnaires. Both schools were from the Department of Education (Western Australia) system and were very similar in their population profiles but each had education programs created independently of each other.

The author's school was the major study school in that it provided 456 of the subjects and is referred to as the School A of this study while the other school, School B, was selected as being representative of Government Schools in general. In all cases the teachers volunteering their classes to participate in this survey were science teachers who taught the classes who responded to the questionnaires.

4.3.2 Subject Numbers

The number of respondents in both of the study schools is shown in Table 4.5. A total of 616 respondents which comprised of 456 students from School A of the study and a further 160 students from School B.

4.3.3 Permission for Participation and Ethical Issues

The selection of students was dependent upon the science teachers allowing classes to attempt the instruments and this will be further discussed later in this section on administration of the instruments.

4.3.3.1 Permission

The Principal of School A suggested the method to be used for the parents/guardians granting permission for students to participate in this study. He suggested this method as it was quite acceptable to both himself and the Education Department of Western Australia and would ensure a reasonable number of participants volunteering. In both schools, parent/guardian permission was obtained for all students who were to participate in the data collection process. The Permission and Information letters (Appendices 6 and 7, respectively) were sent home with each student in the school's monthly newsletters.

Table 4.4. Average age and number of students responding in Years 8 to 12 in the two schools of this study.

Grade	8	9	10	11	12
Age Range (yrs)	12 – 13	13 – 14	14 – 15	15 – 16	16 - 17
Student Numbers School A	127	78	139	68	44
Student Numbers School B	47	93		20	

This permission was by default, that is the permission letter was worded in such a way that parents could withdraw their child(ren) by returning a slip attached to the permission letter. If the slip was returned this indicated at least one member of the family did not wish the student to participate. Of a potential 745 students in the initial study population only 14 families returned the non-permission slip.

The Principal of School B did not agree to this method of obtaining permission for the students' of his school to participate in this survey so another letter which had to be returned for permission to participate was used.

An information sheet which discussed what was to occur, how all information would be confidential and how all responses would be stored and then be destroyed as required by the University accompanied the permission letter. Further, that participation was voluntary was also discussed with the participants at the commencement of each data collection session and that the students could leave the material blank or in the case of interviews not to volunteer to be interviewed. No child withdrew from the questionnaires or declined interviews (if specifically asked) during the entire process even though this choice was offered to all potential subjects at all stages of administration of the data collecting tools.

4.3.3.2 Security Code and Names

Since follow-up re-administration of the questionnaires was planned for the next year, all participants had to have their name recorded so their two sets of answers could be compared. To do this a code was devised which could be used to identify each student and their respective data. The code number was given to the student by the researcher and so it could be written at the top right hand corner of each questionnaire. The only person who has access to this code was the author and this code was kept secure and isolated from the questionnaires to further reduce the risk of someone being able to link the student with their responses. At no stage was the code divulged to any other person and will be retained only as long as university guidelines require, after which it will be destroyed.

4.4 QUESTIONNAIRE ADMINISTRATION PROCEDURES

4.4.1 Student Sample Selection

The questionnaires were made available for all science teachers to administer to all ability levels and Years within the school. During an informal discussion about the questionnaires and their administration with the science staff at the author's school, it was decided by the teachers of the classes composed entirely of lower academic achieving students not to administer the test to their students. The reasoning for this decision was that these students due to their poor reading and comprehension ability, might not be able to answer the questions fully, and to give reasons which were valid or useful and in some cases even sensible. However, it happened that one teacher did administer the test to his students and the responses were as the teachers had predicted. For example, the class of low ability Year 10 students were administered the test and upon a quick reading of the responses it was found many students had written reasons which made little or no sense when related to the item's stem. Some responses written for reasons were nonsensical for example, *"I dunno"; "This is stupid"* or *"Fred is gay".* Once this information was passed around the staff, no further administration of the questionnaire to the less academically achieving student classes occurred. But, it should be noted that the other science classes, did include a number of less able students and so a small sample of these students were included in the overall student sample. So, while there is a bias in student ability levels there is still a small sample of less able students included in each age cohort.

The ability level of the students included in this student sample was both for general ability in school and more specifically in science ability. This was evidenced when class lists were compared for subjects such as Science, English, Mathematics and Society and the Environment as these class lists were similar for all four areas of study.

4.4.2 Student Sample Description

The respondents had a wide range of experience in formal science education and an even wider range with respect to energy and the human body. The formal classroom learning experiences with respect to energy ranged from little formal teaching (Year 8) through to sufficient coverage to enable a respondent to answer all items with competence in the area being examined (Year 12 Human Biology students). The administration of the questionnaire took place during the last few weeks of term 3 and early in term 4 of 1999.

4.4.3 Instructions and Administration

A set of instructions was verbally given to the students to supplement those already on the questionnaire. These instructions were given by the author except at School B and during the second administration of the questionnaires. In this case, the normal class teachers gave similar instructions. During these verbal instructions, the importance of a reason being given for all items was emphasised. An emphasis was made that it was the reasons which were of the most importance to this study not the agree/disagree response. In addition to this instruction, students were asked to agree or disagree to the statement even if they could think of no reason for their response but to note they had no reason to supply. This approach would at least have students responding to all items and could reveal an area that was not a misconception area but still a problem area due to a lack of knowledge by the respondent.

As the two questionnaires were colour coded, students were informed that the questionnaires were different not just in colour but in content also. The questionnaires were handed out alternatively, Questionnaire1 followed by Questionnaire 2 and so on in an attempt to remove the chances of students easily copying responses from each other.

Following the administration of the questionnaires at School A, the questionnaires were also administered at School B in the same education district. In this school, the staff of the science department chose two classes from each year cohort; the teachers of these classes had volunteered to be part of the study. Once again no classes of low academically achieving students were utilised for the same reasons as in School A. The responses from this school are to form a check that the data obtained from the main administration of the instruments did in fact appear representative of all students in the Education Department of Western Australia.

A re-administration of the questionnaire was carried out on the School A the following year in August 2001. In this follow-up study, each student re-sat the same questionnaire as he/she had completed previously. Which form of the questionnaire to be re-administered was obtained from records kept of which student answered which questionnaire the first time.

4.4.4 Time for Responding by Students

The time allowed for the students to respond to the instruments was almost unlimited, with teachers providing either as long as was required in one session (approximately 35 minutes) or over two sessions on separate days (approximately 20 minutes each session). Consequently, it was intended that all students would have had ample time to fully respond to the best of their knowledge and ability to the questionnaire. This unlimited amount of time was verbally indicated to the students prior to them starting to respond to the instrument.

4.5 INTERVIEWS FOR MEANING OF TERMINOLOGY

After the questionnaires had been administered and while the results were being analysed, a series of terms were collected which could have a number of meanings, in particular colloquial meanings. It was necessary to know the precise meaning, as used by the respondents, of some of the less obvious, colloquial or everyday terms as suggested in Section 2.3.5. Terms such as ‘burn energy’, ‘junk food’, ‘burn’ and ‘recharge’ were incorporated in a series of short interviews held with some of the respondents who had used at least one of these terms.

The interviews were carried out during normal science class time. Each interview only took as long as was necessary to elicit an agreed meaning of the terms. To this end the interviewee was given his/her questionnaire to read before the questions were asked. In some cases the meaning of terms not used by the interviewee were also asked for. This was to determine the meaning of a term from the listener's perspective and so ensure there was a common agreed meaning for these terms.

The interviewees were asked if they would mind the interview being tape-recorded to which each student said that he/she had no objection. It was then explained what was to take place and the reasons for this information being sought. The interview then proceeded. Each interview took approximately five minutes and occurred during that student's normal science class time.

The analysis of the data collected from the transcriptions of these interviews was carried out and the common meaning(s) determined. All of these meanings of colloquial terms had similar meaning across all age groups and it was these meanings which were used during the analysis of the data from the questionnaires and for the other data collected and discussed elsewhere (Chapter 7 and 8).

4.6 QUESTIONNAIRE ANALYSIS

In Part 1 of each instrument all responses, whether left blank or completed to varying degrees, were tallied as it was thought that a blank item indicated a lack of knowledge and this was considered important in the analysis of this section of the instruments.

The responses to Part 2 of the instruments were collated for each statement to show the number of students who agreed or disagreed with a statement and two lists were compiled from the given reasons; one list with the agreement reasons and one list with the disagreement reasons. Each of these lists of reasons was then analysed to identify student conceptions. While doing this analysis, care was taken to ensure the students' own language was accurately interpreted, to ensure an accurate interpretation of the errors and misconceptions was made as was discussed in Section 2.3.5. The analysis of the data collected from the administration of the two questionnaires is presented in the Chapters 5 and 6.

A cross section study of the conceptual changes was made using the pooled data for each year cohort. Such researchers as Trumper, (1993a, 1998), Westbrook and Marek (1992) have carried out this form of cross sectional analysis. This form of pooled data analysis is acceptable in light of the comments made by Watts (1983), Gayford (1986b) and Trumper (1990a) when they claim there is a consistency in alternative conceptions which appears to be consistent across year groups.

4.7 SUMMARY

Chapter 4 initially described an explanation of how the boundaries for the science content of this study were described and delineated by the use of proposition statements and a concept map, a literature search and the use of two essays and a series of interviews are described. These were used to collect data which exposed student conceptions and where possible their underlying reasons. These data were used in the construction of a series of items for inclusion in two questionnaires. These diagnostic instruments were administered to 605 respondents to collect data for analysis. Some (75%) of these respondents completed the same instrument twice in consecutive years.

Chapter 4 goes partially towards answering Objective 1 in that it describes the development of a series of two tier true/false items which combined to form two instruments designed to identify student held notions on energy and the human body.

Chapter 5 analyses the combined data collected from the administration of the questionnaires to Schools A and B, and identifies commonly held student conceptions. Chapter 6 uses the data collected to identify changes that occur over different ages of students while Chapter 7 utilised this information to help in the construction of a diagnostic instrument identifying student alternative notions with respect to energy and their body. In Chapter 8 an interventionist strategy was developed to overcome the non-scientific notions students hold with regard to digestion and energy.

CHAPTER 5

ANALYSIS OF QUESTIONNAIRE DATA

5.1 INTRODUCTION

This chapter discusses the data collected using two questionnaires *What do You Know About Energy and Your Body? Questionnaire 1 and 2* that the author created and administered to 610 students in Years 8 – 12 to obtain data on their notions with respect to energy and the human body. The data from these two sources were collated to arrive at a set of commonly held student conceptions and their underpinning reasons.

Data from Part 1 of the two questionnaires was combined to form one data set since this part was common to both questionnaires. From this combined data it was found a number of students had problems identifying when energy was expended by the body in situations which did not involve activity and gross muscle movement. A number of students had difficulty in identifying the required number of examples for each item.

The data from Part 2 of the two questionnaires was combined for analysis because many of the items covered similar areas within the overarching domain of energy and the human body. This analysis was carried out in two parts, firstly on the agree/disagree section of each item and secondly on the underpinning reasons given in support of the agree/disagree response.

Analysis of the agree/disagree responses showed that to rely upon these parts of the responses alone gives a wrong impression of the students' understanding, as students may agree or disagree but have entirely unacceptable reasons for their agreement or disagreement or have no reason at all. Hence when using this item format, it is imperative to utilise all the information given by the student and to treat agree/disagree items with a high degree of scepticism.

A number of trends were identified in the agree/disagree data and these trends are discussed in detail bearing in mind the caution that it is necessary to look at the reasons given in support as these reasons may not match up with the agreement or not. The trends in many cases showed poor valid reasoning offered as warrants for the agreement or otherwise, resulting in a generalised conclusion that many students had little acceptable knowledge they could call upon to support their agreement or not.

The major problem found in analysing the pooled reason's data was the general lack of knowledge which could be called upon by the students to support their agreement or not, with many students simply not giving a supporting reason. This reduced the number of useful reasons given but did offer information about student knowledge in general. It should be noted that very few students offered no reasons in support of their agreement or not to the statement, rather most students gave a reason for the majority of items.

From the analysis of the reasons given for each item, the pooled data were placed into a number of categories that shared common conceptions. From these categories, three assertions were created which encapsulated the general conception areas in which students had notions about energy use in their body. Further to the three assertions, the transfer of knowledge from science areas of study in general to the situations involving the human body is discussed with the conclusion that with their generally poor knowledge base, students also had difficulty in the transference of knowledge to novel testing situations. Students appeared not to relate class-work to themselves unless specifically instructed to do so or if they do transfer at the time of instruction it is not remembered at later times.

Throughout this thesis, quotes of student responses to items that are used as supporting evidence are followed by a code to identify which student is responsible for the particular quote. These appear as a set of three numbers in brackets, viz (8-123-1999). The first number (8) indicating which Year cohort the student belongs to, the second number (123) is the student's identification number for that year cohort and the final number (1999) is the calendar year that response was made.

5.2 ANALYSIS OF PART 1 OF THE QUESTIONNAIRES

Part 1 was common to both questionnaires and so the results were pooled where a total of 610 students responded to items 1 and 2. These items had a dual purpose for their inclusion in the questionnaires. The first was to help direct the students into thinking about energy and their body and the second was to discover if examples could be called forth on energy and its resultant use by the body. While this researcher thought that energy and body movement would create few problems for the students, he also thought if movement was to be excluded some students may have difficulty in arriving at examples of energy expenditure by the body. This situation proved to be the case as most students, in both a pilot study and the final questionnaires, did include examples that actually involve a small degree of movement while the body utilised energy.

Nevertheless it was decided that only examples involving gross movement of the body or its parts would be scored as correct for Item 1. Valid examples such as run, jump, skip, swim, walk and many named sports were considered to fit the gross movement category and so would be acceptable examples for Item 1 but not for Item 2. Acceptable examples of small degrees of muscle movement such as eating, talking, sitting, standing, breathing, digestion, heartbeat and writing would be considered valid examples for Item 2 but not Item 1. A number of students did choose to include these small muscle movement examples for Item 2.

5.2.1 Student Responses to Item 1 of Part I

Students were asked to respond to the following question “List 5 things which involve energy, movement and your body” and were given five spaces in which to respond. (See Appendix 4 and 5 for both questionnaires.)

Responses to the first item on both questionnaires showed a surprising trend since it was considered to be relatively easy to list five examples of gross muscle activities; 44% of Year 8 students listed five valid examples but only 25% of Year 12 students were able to do this. From Year 8 through to Year 10 there was approximately the same percentage of students who gave five correct examples, while Years 11 and 12 had less correct examples than these lower Years. These results are shown in Table 5.1 where the percentage for each valid response is shown for both items 1 and 2. Little explanation can be offered for the decline in valid examples for Item 1 with age.

While for Item 1 a wide variety of examples were given over all year levels and both sexes, most centred on the activities of running, jogging, walking and swimming. A number of students gave examples that centred on less common activities in which they were somehow involved, such as, dancing, aerobics, in-line skating and 'football'. A number of students gave answers that, while they do involve energy expenditure, do not involve gross movement of the body. Examples such as eating, drinking, talking, breathing, and sleep were common across all the student ages in the two schools studied (Table 5.2).

While these examples do involve activity, in a number of cases the same students also gave these as examples for the second item where the requirement was for no movement of the body. From these repeated examples, it would appear some students had difficulty in deciding into which category the examples should be placed.

Table 5.1: Percentage of students by year cohort who gave valid examples to Items 1 and 2

	Year 8		Year 9		Year 10		Year 11		Year 12	
Number Valid Examples	Item 1	Item2	Item 1	Item 2	Item 1	Item 2	Item 1	Item 2	Item 1	Item 2
5	44.3	41.4	36	46.2	44.6	47.9	28.4	64.2	25	40.9
4	16.7	9.77	19.4	14.6	20.2	13.6	27.6	14.2	20.5	22.7
0 –3	36.2	43.7	43.9	36.4	34.3	34.3	44	19.4	54.5	36.4
No Idea	2.87	5.17	0.79	2.77	0.83	4.13	0	2.24	0	0
n	174	174	253	253	242	242	134	134	44	44

No Idea in Table 5.1 refers to either blank or incorrect answers, both of which indicate the student did not have an idea to write down. Since the rest of the questionnaire was answered this would appear to be a reasonable assumption.

5.2.2 Student Responses to Item 2 of Part I

Item 2 asked students to respond to the following, "List 4 things which involve your body and energy, but do not involve exercise or any movement of your body by muscles." and there were four spaces in which to respond (See Appendix 4 and 5 for Questionnaires).

This item was designed to show student knowledge of energy-related uses that did not involve activity, hence the wording to exclude exercise and movement. As previously discussed, many students ignored the movement section of the question and interpreted this question to exclude the gross muscle activity of the body but to include any other muscle activity which did not lead to large movements of the body. A look at Table 5.2 shows that, if the strict wording of Item 2 were adhered to and only thinking, respiration, cell divisions, vision, hearing, smell, sweating, growing and metabolism were included, very few students supplied examples of energy use that did not include movement. Three students made comments to the effect that no responses were possible here that did not involve muscle activity. In reality, there are many such examples but in most cases, energy use is not obvious as the use is not linked to visible activity. Table 5.2 shows varying numbers of students in each Year who included some of these examples where activity is not obvious, with the most common examples being eating, drinking, breathing, standing, digestion, talking, and heart beating. Each of these activities have a small amount of body movement, for example, the movement of the jaw whilst eating or the diaphragm whilst breathing.

As the students' average age increased, more examples of non-muscle use were given and included respiration, sleeping, thinking, meiosis and mitosis. The latter two examples from Years 11 and 12 students plus one Year 10 student, are a result of their continued study in a field of Biology. In parallel to the use of more sophisticated examples in Years 11 and 12, some respondents had a comment that clarified why the example was included in Item 2 and not Item 1. This is illustrated by — *"digesting (chemical)"* (11-46-1999), — *"reading (without turning pages)* (11-54-1999), — *"standing still"* (11-32-1999) and — *"standing in front of a heater"* (11-12-1999).

A number of students in each Year gave food or food groups as an example of energy use for both items 1 and 2 (see Table 5.3). As an example for Item 1, this is not appropriate as it does not involve muscle use at any point but it is another way of interpreting Item 2.

In other words, food is the major method through which the body gains utilisable energy and for this reason food was regarded as a valid response for Item 2. Some Year 8, 9 and 10 responses showed that students were unable to provide any examples (refer to Table 5.1) and this number generally decreased with age. The tallied responses showed many

Table 5.2: Percentage of students in Years 8 – 12 providing examples for Items 1 and 2 that did not involve gross activity

	Year 8		Year 9		Year 10		Year 11		Year 12	
	Item 1	Item 2	Item 1	Item 2	Item 1	Item 2	Item 1	Item 2	Item 1	Item 2
Stand				7.51		9.92		5.22		
Sit		12.64		13.44		13.22				
Eat/Drink	12.07	12.07	20.16	14.23	25.21	9.92	21.64		56.82	6.82
Talk		20.11	15.42	8.70	19.83	9.50	8.21		34.09	
Breath		29.89	7.91	24.11	9.09	33.88	13.43	17.16	29.55	34.09
Sleep		54.00		44.27	6.20	47.11	5.97	21.64	22.73	61.36
Digestion	54.00	15.52	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
Thinking		25.29		27.27		35.95		30.60	20.45	68.18
Circulation				12.65		6.61		5.97	9.09	13.64
Respiration				5.93			6.72	17.16	15.91	47.73
Meiosis								8.21		27.27
Mitosis								9.70		27.27
See/Look		17.24	9.88	12.65	9.09	17.77	5.22	8.96		
Hear/Listen		13.79	1.58	14.62		20.25		17.16		11.36
Smell		10.34		9.88		5.37		11.19		
Read		6.32		6.72						13.64
Excrete										6.82
Relax/Rest		6.32		7.91		7.44				
Food			8.30		7.02				9.09	
Sweat						5.79				
Grow						7.44		17.91	9.09	25.00
Blink		5.75								
Write					5.37				13.64	
Cough/Sneeze		5.17								
Reproduction									11.36	
Metabolism										9.09
Total (n) Respondents	174	174	171	171	139	139	88	88	44	44

Note: Table 5.2 only includes those examples of energy use where at least one cell in the row had a value exceeding five percent (5%) of the students giving the example; for example, cough/sneeze or reproduction was chosen by 5.1% and 11.4% of students respectively. Shading of a cell indicates less than 5% of student(s) did use this example while a blank cell indicates no student used that example for that particular year.

Table 5.3: Percentage of examples of food as an example to Items 1 and 2

	Year 8	Year 9	Year 10	Year 11	Year 12
Item 1	8	25	9	5	5
Item 2	5	8	6	2	6

students did not supply sufficient examples as requested. Generally, these items, while intended to encourage students to think about energy and their body, showed that many students of all age groups did not have readily available examples which they could recall when asked.

5.3 ANALYSIS OF PART 2 OF THE QUESTIONAIRES

5.3.1 Discussion of Agree/Disagree Section of Items

While the students had to agree or disagree with each item's statement, the main purpose of each item was to collect as much information on the underpinning reasons for the student's agreement or not. The reason for including this agreement or disagreement was to make the students think about the item statement and in doing so direct their thinking processes rather than ask the students to write just a response in a general manner about the item. The numbers of students agreeing or disagreeing was secondary to the underpinning reasons for the agreement and as such the agree or disagree responses in isolation should be treated with a lot of suspicion. Students may agree or not and have entirely wrong notions which underpin the agreement claim. Care is needed when interpreting the value of students agreeing or disagreeing with the statements in isolation and this will be illustrated in the following examination of the trends which emerged from the percentages shown in Table 5.4. Items with no obvious trends will not be discussed in the following section (5.3.1.1). Item 10 in Questionnaire 1 is an example of this:

> *"When you hear a friend talking, the sound energy comes from that friend's mouth into your ear and then into your brain where it is used to hear."*

In the responses to this item the students were fairly evenly divided as to the veracity of this statement which would indicate it does reveal some knowledge is present. But upon studying the reasons we find there is little scientific knowledge backing up the agreement or not. The majority of reasons given for agreeing or disagreeing indicated a lack of understanding of what hearing entails with many students simply reiterating the statement. Table 5.4 shows the percentage of students who agreed or disagreed to each item on Questionnaires 1 and 2, respectively.

5.3.1.1 Questionnaire 1 Trends And The Reasons Given

Item 2, which examined the notion that all food contains the same amount of energy, had very few students claiming this to be correct. The reasons given for this disagreement were that all foods are different and therefore have different amounts of energy. A number of students even gave examples to illustrate further their reasoning. For example, —*"…eat chocolate it gives you more energy because it contains sugar"* (8-23-1999) or — *"foods high in fat have more energy…"* (11-60-1999) while other reasons

Table 5.4: Percentage of students responding to agree/disagree in the two questionnaires

Questionnaire 1

	Item number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Agree													
Year 8	32	7	84	78	91	39	77	59	49	79	49	62	38
9	35	0	79	86	82	44	85	59	54	73	43	66	49
10	23	3	78	86	90	48	73	61	42	69	47	61	61
11	19	3	91	82	91	39	72	84	18	55	45	77	36
12	32	8	62	83	88	54	87	92	100	54	49	70	63
Disagree													
Year 8	66	93	16	20	9	61	24	41	51	21	35	32	60
9	56	100	21	14	18	53	6	32	46	21	28	13	39
10	58	95	21	13	10	39	13	25	49	22	21	16	39
11	81	97	9	18	9	58	28	16	81	41	19	17	65
12	64	92	39	17	13	46	13	8	0	46	4	30	38

Questionnaire 2

	Item number														
Agree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year 8	82	100	52	51	76	46	46	64	36	51	39	74	56	70	69
9	63	98	44	58	68	79	53	49	62	66	51	58	84	60	43
10	57	95	56	54	67	57	49	60	42	67	37	50	60	46	62
11	40	100	47	53	82	59	48	30	79	66	27	52	70	77	78
12	53	95	55	52	60	68	61	29	63	94	41	33	59	88	69
Disagree															
Year 8	18	0	47	49	24	55	54	32	65	49	55	23	44	30	28
9	34	3	54	33	27	21	42	41	29	34	39	28	14	22	51
10	33	5	44	40	26	32	35	35	58	33	52	27	27	35	31
11	60	0	53	49	18	38	52	79	21	34	73	48	26	15	19
12	47	5	45	43	32	26	33	71	21	6	59	61	41	13	33

Note: In Table 5.4 the percentages have been rounded to the nearest whole number. Where the total percentage does not total 100% this is due to either the students not responding to this item or to the effects of the rounding process.

given followed this line of reasoning but had other preconceptions which were inaccurate, for example, —*"…ice-cream isn't that healthy so wouldn't give you the same amount of energy…"* (8-88-1999).

Of those students who agreed with this statement, many reiterated the statement as a reason while others gave reasons which claimed the quantity of food eaten would regulate the amount of energy or that food contained the same type of energy. These latter reasons indicated there was more a misunderstanding of the statement rather than an inaccurate conception.

Item 3 examined the usefulness of energy and the availability of this useful energy in food. Of those who agreed with this statement, many claimed there was useful energy and this was because we could use it or we needed it. Reasons such as —*" ... we would need the energy in the food but if we feel very strong and healthy we may not need energy"* (8-65-1999) and — *"we might be running or watching TV"* (8-130-1999) for the body needing energy. If we did not need energy then it was not good for us since we could convert it into fats —*" it could be stored as fat"* (11-47-1999) or — *"if not used, stored as fat"* (11-37-1999). It would appear from the reasons given that students think that if we do not use energy almost immediately then that energy is of no use to our body. This shows a conception of energy availability as being short-term rather than the usefulness of the stored energy in lipids.

Item 4 examined the notion there were different types of energy needed by the body for it to function. All year cohorts showed a high percentage (in excess of 75%) of students who agreed that there were different types of energy in different foods. The reason frequently given for agreement was that there are different types of food groups and so different types of energy —*"different foods and ingredients have different types of energy"* (8-32-1999) while a common reason given for disagreement was —*"there is only one kind of energy"* (8-57-1999) or — *"you can't get different types of energy"* (8-99-1999). Some of the students interpreted this statement to involve the quantity of energy in foods and so agreed with the statement —*"because all foods have different amounts of energy"* (11-55-1999).

Item 5 looks at the notion of energy quantity and types in foods, with the majority of students agreeing with this statement (in excess of 80% in each year). Many Year 8 students looked at this question from the point of having an illness; if we do not have a variety of foods in our diet we will become ill and so they agreed with the statement.

Those who did not make this interpretation agreed because of the different types of energy in different foods, which supports the reasons given for Item 4 on this questionnaire. Both of these reasons were commonly given for the other four Year cohorts. The largest reason for disagreeing was that there is only one type of energy and you could eat one food and still get all the energy needed —*"there is one type of energy but some foods have more energy than others"* (9-39-1999).

Item 7 covered the role of respiration; from the statement students should have been able to distinguish between the two common meanings of this term (cellular respiration and breathing). Despite this, many students who disagreed did so because to them respiration was breathing and nothing else —*"the respiration process includes breathing in and out and sugar is not converted into energy because of breathing"* (8-27-1999) and —*"respiration is breathing"* (many students in each year). This breathing reason was most frequently given for disagreeing with the statement. Year 8 students had been introduced to the process of respiration in class but had had no depth of coverage other than respiration was a chemical process which gave the body useable energy. All other year cohorts had received detailed instruction about the process of respiration. Despite this class instruction, some students in Year 9 – 12 still persisted with the breathing only claim.

Of the students who agreed, there were few that indicated they knew much about the process of respiration. Some claimed —*"it just gives us energy"* (10-51-1999) while others said —*" the cells in your body take out the energy from sugars and store it somewhere and when the body needs energy it will take it from there"* (10-105-1999). As the age of the student cohorts increased there appeared to be a small improvement in their knowledge of cellular respiration but this is small and not obvious unless careful scrutiny of the reason is undertaken. (A more detailed discussion of respiration occurs in Section 5.3.2.2.)

With Item 8 there is a difference between the percentages of the Years 8, 9 and 10 and the Year 11 and 12 students. The lower school students had approximately 60% agreeing while Year 11 and 12 students had between 84 or 90% agreeing. Despite this obvious difference between upper and lower school years the reasons given were similar.

Item 8 had two different interpretations made of it by the students. One was that the organs mentioned in the statement were seen as receivers of energy from the external environment while the other interpretation was the cells of these organs needed energy to function. The majority of the students (at least 85% in each year cohort) who agreed did so because energy was seen as being received by the cells of the organ so that organ could function. This interpretation of the item had not been anticipated nor was shown during the piloting of the questionnaires. Nevertheless these responses showed students did think carefully about the question and had a fair grasp of energy movement within the body since energy was seen as being needed. Some examples illustrating this point are, —*" because they need energy to work"* (8-25-1999), —*"all these parts have muscles which need energy to move and do things"* (12-32-1999), —*"otherwise it would be a dead mass"* (10-6-1999) and —*"because they are made out of cells and cells need energy"* (8-67-1999). Of all the reasons given, only three referred to the reception of energy aspect of these organs while the majority proffered reasons which referred to muscles requiring energy to perform movement or that some organs have not got muscles and so did not need energy.

The students who disagreed with the statement did so for two main reasons. These were that there was no movement or activity or the muscles were not involved and so the organ did not need energy. Typical of responses were — *" only places the energy can be stored and used is our muscles"* (10-89-1999) and —*"we only need energy for our muscles. Our eyes don't use energy…"* (8-88-1999).

Item 9 shows a decline in the percentage of students, from lower school to upper school, who agreed with the statement. Many of the lower school students appear to respond to the first and last part of the question placing emphasis on the excess food being excreted —*"because it is waste and the body only needs energy"* (8-118-1999). This response has a feature the students are familiar with, excretion, and not the connection between food and energy absorption. So it would appear logical that excess food and energy is excreted. Those who disagreed did so because they believed that energy is stored in the body in some form.

The upper school students appeared to hold the notion of excess energy being stored until needed — *"it is stored as fat and is used as a reserve supply of energy."* (11-14-1999). This reason shows that energy is stored as or in fat since — *"we absorb all energy and save it for times of famine"* (10-41-1999) as stated by a number of students. More will be said about this aspect in Section 5.3.2.1.

The decline in the percentage of students who agreed with the statement for Item 10 was due to some students understanding the energy conversions involved, but these students were few in number. Most of the reasons given (agreement or not) indicated little knowledge of any energy conversions within the ear. The reasons given in agreement or not are either repeats of the statement or have little scientific basis. Typical responses were — *"sound is not an energy"* (8-133-1999) and — *"our ear converts sound into vibrations which your brain can understand and identify"* (11-38-1999). This item showed that students had little understanding of the hearing process and is a good example of not using just the agree/disagree part of the items because so many students agreed with the statement but showed little accurate reasoning for their commitment (see Table 5.4).

Item 12 reasons showed a small increasing trend (with increase in student age) in the percentage of students who agreed with the statement. No obvious or apparent reason was found to explain this trend. Many students who agreed did so because of the constant temperature aspect of the statement or there was reiteration of the statement as the reason. There was a lack of knowledge on the causes of body temperature although many students indicated the temperature is constant. A variety of reasons were given with no pattern shown to explain this increasing trend of agreement to the statement. Many students did not give reasons for their agreement or disagreement with only one Year 9 student disagreeing and giving a reason.

5.3.1.2 Questionnaire 2 Trends

Item 1 investigated the nature of the energy in food and whether this energy is particulate or not. There was a declining trend, as the respondents' ages increased, in those who agreed with this statement with a slight rise from Year 11 to Year 12. It would appear from examining the reasons given that students slowly discarded their particulate notion of energy as they had more exposure in a formal education setting to the notion of energy. Students also discarded the notion that energy is found between the food particles and developed the concept the energy as in the food particles - or do they mean molecules? Both of these reasons contributed to the decline in the acceptance of this statement as the students' age increased. In conjunction with the increased acceptance of these two notions, there was a decrease in reasons of a general and less relevant nature.

Item 2 looked at the energy value of food. Nearly all students agreed (4 did not agree) that food does give us energy and many reasons elaborated on how the quantity of energy in foods varied —*"all foods have some sort of energy, some more than others…"* (8-95-1999). Of the four students who disagreed none gave a valid reason to support their disagreement. Two of the reasons given supported agreement with the statement and of the other two students one did not give a reason and one reason was unrelated to the statement.

The rest of the items from Questionnaire 2 do not show any obvious trends or patterns for changing student age. Each of these remaining items had approximately equal percentages of students agreeing or disagreeing with statements or the percentage difference between the agree and disagreement across the five year cohorts was not large (varying by less than 10%) and showed no distinct pattern. For example, Item 15 from Questionnaire 2 had a spread of 35% from highest to lowest in agreement across all years but had no distinct pattern or spread of percentages with increasing age of respondents.

5.3.2 Analysis of Supporting Reasons Given

The data collected from the administration of Part 2 of the Questionnaires were carefully scrutinised and subsequently categorised into three assertions based upon the reasons given by the students as support for their agreement or disagreement with the statements. Data from both questionnaires were combined for this analysis as originally the 28 items were separated into two questionnaires to reduce the time needed for the students to respond to all the items and to reduce the chances of getting invalid answers (see Section 3.2.3.2). Supporting data, based only on the responses given, were collected to provide a foundation for each assertion to be discussed here.

In the following discussion, it is not possible to accurately give the numbers of students as a percentage of any year cohort since the reasons used as evidence for an assertion come from a number of items and as such the number of potential students was indeterminate. In these cases, I have used the total number of responses that supply that form of evidence.

5.3.2.1 Assertion I

Students' perceptions of energy availability in food varied according to their perception of the type of food eaten.

Almost all students (≈ 90%) in this study agreed that food supplied energy — *"We get energy from the food we eat"* (10-90-1999). However, a number (6% in Years 8 and 9, 11% in Years10 and 11 and 12% in year 12) of students failed to agree with the item. This latter group gave a food group or food type such as sugars, carbohydrate, protein, vitamins and minerals was the source of energy rather than food in general. No student who disagreed with the statement wrote that food was not a source of energy. For the students who disagreed with the statement, sugars and carbohydrates were stated to be the most frequently chosen sources of energy, with vitamins and minerals given only by a minority of students. Generally, a small number of students identified sugars and carbohydrates as entirely separate chemical families with both supplying energy. Some students (n = 60 from all Year levels) also claimed fats as a source of energy while a small number indicated that fats were a poor source of energy.

Food as the only source of energy for the body was specified by some students (n = 20, with 7 from Year 8), while 74 students with no specific year group having a significantly higher percentage than other year groups, stated that energy was one of a number of sources, with oxygen and sleep being nominated as two of the other energy sources — *"…and oxygen gives us some energy"* (8-5-1999), — *"we absorb some energy through food and other through sleep and drink"* (8-103-1999) and — *" it also comes from food"* (9-35-1999). Students who stated that food was the only source of energy for the body also indicated oxygen had no role in energy at all. These students said air is breathing and this keeps us alive —*"yes, you live on air if you don't have air you can't breathe"* (8-55-1999).

Many students (58.8%) indicated correctly that different foods had different amounts of energy. There was approximately the same percentage of students in each year level who made this claim (refer to Table 5.5). That the quantity of energy in the food depends upon the type and quantity of each food group present in the food eaten was seen in the following responses —*"chocolate gives you lots of energy while other foods like vegetables don't"* (8-25-1999) and — *"it depends upon how much sugar, Carbohydrates etc are in the food as some ingredients have higher energy contents than others*" (8-32-1999). These quantities of energy were perceived to determine the amount of food needed to meet the energy requirements of the individual.

Table 5.5. Year cohort related views of the energy quantities in foods.

Type Of Energy In Foods	Year 8	Year 9	Year 10	Year 11	Year 12
Different Amount	19.5%	16.1%	15.1%	9.4%	14.5%
Same Amount	3.2%	2.9%	2.5%	0.6%	2.2%

However, a small number (n = 22) of students claimed that all food has the same amount of energy but few of these students gave reasons which could be related back to the question and four of the reasons supported agreement with the relevant statement. Some of these agreeing students elaborated on their claim by stating that some energy is available for absorption and so is used by the body while the rest of the energy in food is excess or unavailable and excreted — "*...the body (its cells) takes energy it needs both immediately and what it stores and additional energy is excreted"* (11-51-1999). A total of 72 students claimed that excess energy is excreted, with no pattern in the year groups for claiming this more frequently.

Respondents in all year levels, but more commonly in later year levels, expressed the notion that all energy in food was absorbed and if not used quickly it was converted into fats for use later —*"it takes in all energy and stores it if its not used it turns into fat*" (8-29-1999) and —*"if we take in too much energy then the body stores it away and some is converted to fat"* (12-1-1999). But, a number of students in Years 8 and 9 thought that they excreted the excess energy in food, while the older students (Year 10 and up) stated that the excess energy was stored as fats. A number of students in the study (n = 95), particularly in Years 8, 9, 10, thought that once energy was stored as fats it was unavailable for future use while the older students indicated this fat could be used later should the need arise. For example, lower school examples included such comments as — "*most of the weight people put on is the bad, unuseful fat that can't be used* " (8-97-1999), — *"no because excess fat is useless"* (9-2-1999) and — *"because when you put on weight you can't use the energy later on"* (9-53-1999). On the other hand, many upper school students thought the fat could be used later, for example, — *"because that's why you lose weight when you don't eat or don't eat as much. Your body uses up fat to support itself"* (10-44-1999, — *"fat people can loose weight and convert the energy into muscle*" (11-20-1999) and — *"when you go to lose weight the fat stored is burned and you're using the energy stored to burn the fat"* (10-63-2000).

The value and role of fats changed with the respondents' age. Younger students (Year 8) stated that once energy was stored as fat it was locked away and no longer available for use —*" fat (excess) is stored around the body, it isn't saving it for use later"* (10-96-1999), — *"respiration doesn't convert foods or fat into energy"* (8-101-1999) and — *"fat does not give energy"* (8-19-1999) or fats are not a source of energy and so are not good for us. This latter type of reason appeared throughout the reasons given for a number of items; for example, in Item 9 Questionnaire 1, and Items 7, 9 of Questionnaire 2. Many students in Years 11 and 12 showed a changed view from those of the younger age cohorts on the role of fats when they stated that excess energy was stored in fats for later use (after other energy sources were depleted) and so fats were seen as being useful if needed later. There were some younger students who indicated fats are stored and used later as an energy source but far more indicated that fats locked away the available energy.

A relatively small number of students (n = 24) coming mainly from Years 10 –12, indicated that there was only one form of energy in food as indicated by this Year 8 student's reason —*"there is no different types of energy just less or more energy. The energy in a 'Snikers' is less or more that the energy in a red jelly but it is not a different type"* (8-27-1999) compared to a large number (n =198) who said there is a variety of energy types in food. For example, —*"all parts of the body need different kinds of* *energy to make them work"* (8-8-1999)*, — "different foods and ingredients have different types of energy"* (8-87-1999) and — *"certain foods carry different kinds of energy"* (8-9-1999). Some of these students went on to state that to get all these types of energy, the body needed to ingest a variety of foods.

The meaning of the term 'energy value' in food had a number of connotations with two, that is quantity and quality being predominant. The value of the energy in food was not specified in any of the students' responses to the items referring to energy and food (Item3 in Questionnaire 1 and Items 4 and 5 in Questionnaire 2) but in the responses to other items. Students defined useful or good energy as energy we used or energy which allowed us to carry out an activity — *"it will be useful if you are active, not useful if you're not"* (8-87-1999), while other students said too much energy is bad for you as you become hyperactive — *"because if you have too much energy you might go hypo"* (8-110-1999). A group of students (n = 22) said some energy, for example from sugars, was easily or readily available and so quick to be used and therefore valuable, while the energy in some food was hard or impossible to use and so was useless, for example fats. Typical responses from the latter group were — *"you only utilise the useful energy. The rest is converted into and stored as fat"* (11-44-1999) and — *"if we want lots of energy… you eat lots of carbohydrates. But if you want a quick burst… you eat sugary foods"* (10-58-1999).

The only appearance of the terms 'good' and 'bad' when referring to energy occurred in Year 8 and was defined in a similar fashion to the way that useful and useless energy was used by other students. Many Years 8 and 9 students see useful energy as being energy we used or which we could use in some activity. Typical responses were — *"Healthy foods are easy to use, some foods are difficult to use and foods like chips or biscuits cannot be used at all"* (9-43-1999). One other interpretation of useful energy occurred, in Item 2 Questionnaire 1 and Item 5 Questionnaire 2, where useful energy was taken to mean the speed at which the energy was available for use. Many older students (Year 10 and up) indicated that all energy was useful even if not used immediately, as it was stored as fat for later use if and when required. The way students perceived the usefulness of energy changed along an age-based continuum from being useful only if the energy is used immediately (Years 8 and 9) through to all energy being useful either when it is used immediately or stored for later use (Figure 5.1).

In lower school, particularly Year 8, students stated that they only absorbed the useful energy or what they would need in the immediate future with the rest excreted —*"body*

Year 8 --	Year 12
Useful only if used immediately	All useful as can store in fats
(little stored and lots excreted)	(lots stored and little excreted)

Figure 5.1: Diagram showing the continuum of energy usefulness with student age

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expels anything it doesn't need" (10-144-1999), — *"the body exhausts unwanted energies"* (11-21-1999), — *"the rest passes our of our body because we don't need it"* (9-22-1999) and —*" if we don't use the energy and our body doesn't store it then it passes out"* (10-77-1999). A small group of older students (n=4) in Years 11 and 12 stated that individuals absorb all the energy in food but what is not needed is excreted — *" not all energy is taken out of the food some of it stores as fat and some passes out of the body"* (11-13-1999). This response contrasted with the majority of these older students who indicated that we absorb all of the energy in our food and store the excess as fats for later use —*"the energy is deposited in our bodies"* (8-67-1999) and — *"it is stored as fat and used as a reserve supply of energy"* (11-14-1999). Students in lower school saw fats as being of no use except to store and lock away excess energy.

5.3.2.2 Assertion 2

There is a low understanding of energy use, energy conversions and energy transfers in the body.

Assertion 1 showed there was a general lack of knowledge about energy in food other than that food is required as an energy source and that different foods possess different quantities of energy. Within the cohort studied, there was confusion over the role of the different food groups with respect to energy and what happens to the food once it has been ingested. Some students thought energy was only absorbed if it is needed, others that if energy is absorbed the excess is stored as fat and is never used while still other students thought that the fat may be used when other energy in the body has become depleted. A number of students on the other hand have the notion that there are a number of types of energy found in food and that different food groups or ingredients have these energy types. This later notion changed with the age of the students as more students in Year 10 and upwards hold the conception that there is a single energy type in food; only a few students in Year 12 hold the notion of bond energy or that the energy in food is in the chemical bonds.

The lack of knowledge on the usefulness of energy would appear to have its roots in the students' knowledge about the process of respiration and its functions. The role of respiration in converting food energy into useful energy for the cell was poorly known with few students' responses indicating they knew anything about the role of respiration in energy conversions and transfers (see Table 5.6). If this knowledge of respiration was present and understood, students' understanding of the fate of food would be better known since they are linked. As the students' age increased, so did their knowledge of respiration and its position in the formation of useable energy - but this knowledge still remained rudimentary in detail.

No Year 8 student discussed energy and respiration while many more of the older students did. Year 8 students recognized the need for sugars and fats as energy sources and agreed with the statement but there were no reasons supplied which revealed any knowledge of respiration, while disagreement was because — "*sugar is energy and is not converted into anything"* (8-127-1999) or — *"not all fats break down and your body can't use it"* (8-43-1999). It must be pointed out that at this stage of the Year 8's formal education in both the surveyed schools, the students had not been formally taught respiration in class so student notions were through preconceptions. One Year 9 student indicated some knowledge of respiration with the statement — *" because sugar and oxygen combines it is converted into energy"* (9-3-1999), while Year 10 reasons gave no hint of any knowledge of energy transfer or conversions. In general, the students in Year 11 followed the types of responses given by the three younger cohorts but with slightly more students (n=6) indicating some knowledge of the respiration processes. However, this knowledge was still vague and very general in its nature —*"cellular respiration gives energy"* (11-12-1999), — *" ... the mitochondria converts sugars to energy"* (11-

50-1999) and — *"if the sugar and protein is used up fat is converted"* (11-59-1999). A number of Year 12 students (n= 10) gave the simple summary equation of respiration and nine supplied more detailed responses such as — *"respiration is the process by which organic molecules, taken in as food are broken down in the cells to release energy"* (12-36-1999).

As well as more detail in the responses with increasing student age, there was an increase in the frequency of reasons which showed that student knowledge of respiration was rudimentary, even though students indicated they knew respiration is involved in energy conversions in some way. A small number of students claimed respiration uses energy and is not involved in the production of useable energy when they gave reasons such as — *"respiration uses energy, not creates it"* (11-44-1999) and — *"respiration is not the process of making energy"* (11-5-1999). Both of these reasons might be a result of respiration being seen as the process of breathing, in which case these would be valid reasons for the items.

Without this knowledge of respiration (indicated in Table 5.6) and its function to produce ATP or the 'universal energy molecule', it is understandable that students would not know about many of the possible energy conversions which occur in the body and so they come to the conclusion that there was good and bad energy or energy that was useable or not useable (see Table 5.6).

A problem with the use of only the word respiration and not cellular respiration in the statements examining knowledge on cellular respiration was that approximately 10% of all students saw respiration as being synonymous with breathing and therefore respiration was not seen to be involved in energy production. Typical responses indicating this are — *"in respiration you breath in oxygen and breath out carbon dioxide"* (8-97-1999) or — *"respiration is breathing"* (10-127-1999). This reasoning was despite the rest of the question indicating the alternative meaning of the term respiration. From the large population of 610, only five Year 11 students and one Year 12 student used the term cellular respiration to make their response specific. No Year 8, 9 or 10 students used this term in their response to mean cellular respiration despite this term being frequently used in class for the chemical processes which result in ATP formation and breathing as the exchange of gasses between the body and atmosphere.

Of those who agreed with the role of respiration as involving converting the energy in food into useable energy, a few students stated that food was burnt with oxygen and this released the useful energy, but, these students showed no understanding of the actual

Table 5.6. Year-related views on aspects of respiration as percentage of total respondents

	Year 8	Year 9	Year 10	Year 11	Year 12
Role Of Respiration Involves Energy Conversions	0% 27/0	31.5% 19/6	17.5% 25/7	36.3% 22/8	66.7% 9/6
Respiration Involves Conversion Of Sugars Into Useful Energy	3.6% 25/9	53.8% 13/7	15.3% 26/4	61.1% 18/11	83.3% 12/10
Respiration Involves Conversion Of Fats Into Useful Energy	19% 21/4	11.7% 17/2	4.3% 23/1	31.5% 19/6	61.5% 13/8
Respiration Converts Energy In Food Into Useable Energy	3.7% 27/1	47.3% 19/9	20% 25/5	54.5% 22/12	19.2% 26/5
Respiration Involves Oxygen	0% 76/0	15.6% 51/8	9.2% 76/7	48.9% 49/24	3% 33/10

Note: The fractional number at the bottom of each box (for example 27/0) is the number of respondents (27) who gave a response fitting this category and the second smaller number (0) is the number of students who gave a valid reason.

process of respiration. During the interviews of students in Years 8 – 10 which were carried out to reveal the meaning of a number of terms including the word burnt (see Section 3. 5), students were found to hold a dual meaning for the word burn. The first meaning was a situation similar to that of the burning of paper or wood in the presence of air and the second was a misuse of the term burning by students who used it as a substitute for oxidation as burning occurred during respiration. Initially, students referred to burnt as something that had been burning but after further questioning the oxidation meaning was brought out, in that they recognised that sugar or fat when combining with oxygen produced or released energy.

While the role of respiration was poorly understood by all Year groups, the role of oxygen in energy conversions during respiration not surprisingly was also poorly understood since the two concepts are inextricably linked. A small number of Year 8, 9 and10 students (n=35) wrote that oxygen was an energy source or was actually energy —*"we get energy from oxygen"* (8-61-1999 and 8-48-1999) while many Year 8, 9 and 10 students wrote that respiration did not involve oxygen. In Years 9 to12, this problem declined with increasingly more students seeing oxygen as being involved in respiration. A number of respondents stated that food was burnt with air/oxygen to release useable energy. This burning is referred to by a number of researchers such as Barak *et al.* (1997) and Arzi (1988). Despite these responses, even in Years 11 and 12 few students appeared to know any detail about the processes involving respiration and energy transfer.

With a poor understanding of the process of respiration, it is understandable that students' comprehension of the role of sugars, carbohydrates and lipids in energy production was unclear. Few students made a connection between these food groups and respiration and energy. Students in Years 8 and 9 thought that people only got energy from food and that energy was released from food by the process of digestion with only the energy which was needed by the body being absorbed into the body or blood. But, students in Years 10, 11 and 12 indicated that the body absorbs all food energy and stores the excess energy as fat. Year 9 students appeared to be in a transition state as there were few students older than this Year cohort who made the claim of energy being released by digestion and the body only absorbing the energy which was needed, rather the food is absorbed and if energy is found between the food particles it is all absorbed. The role of fats as an energy source was mixed with younger respondents indicating fats were not an energy source or that excess energy was stored in fats and became locked away. This notion decreased with age and it became more common to find reasons given claiming that excess energy was stored in fats or as fats and was available for later use when required.

With this poor understanding of energy conversions and respiration, it is not surprising that a number of students in Years 8 (n = 10), 9 (n = 5) and 10 (n = 10) thought sleep was an energy source —*" our body rests and when we wake up we have produced energy to use"* (11-66-1999) or that sleep restored or replenished the energy supply of the body —*"because sleep rests our body and recharges our body"* (8-98-1999) or — *"…our body relaxes and recharges"* (8-97-1999). Many Year 8 students used the terms 'recharge', 'restores' and 'rest' when referring to the role sleep has in energy restoration, claiming that these terms somehow involve replenishing the body's energy supply. A number (n=5) of those who disagreed stated that we still used energy when we were asleep while other students claimed we did not increase stored energy as we were not active — *"because our blood supply shuts of because we are not active"* (8-114-1999) or — *"we aren't being active"* (10-4-1999) or we did not eat and so did not get any energy — *"… we are loosing energy because all food is being used up and properly digested"* (10-133-1999). One Year 8 and one Year 9 student plus a number of Years 10 to 12 students stated that we used energy when asleep but used less than when awake. Further, these students stated that the body produced more energy when asleep than was used when asleep — *"our body processes food when we sleep but we don't consume energy"* (10-72-1999) and — *"when we sleep our body is using energy but not as much as we do when we're awake therefore we are conserving energy"* (10-121-1999). This excess energy restores our body's energy levels and this notion is in contrast to the many students who claimed that we still use energy when asleep but do not replace that energy. This contrasted with another small group of students in Years 8 – 10 (n = 10) who stated that they do not use energy when asleep.

The clarification interviews revealed the terms recharge, rest and restore when asleep were all ways to gain energy. However the interviewees could not explain how we recharged our energy supply when asleep it just happened for some inexplicable reason because you go to sleep feeling as if you are low in energy and wake up feeling as if the energy has been returned back to full capacity.

All students agreed that at least one energy source was food and a minority of students claimed other energy sources were sleep and oxygen/air. These last two responses provided further evidence of the poor understanding of respiration, and so it should come as no surprise that there was a poor understanding of the energy conversions and transfers which occur in the body. However, an understanding of these energy conversions and transfers did improve with age since these facets of energy are covered in all science classes during the Year 9 science course.

The items that related to the ear, the eye and the bicycle (Figure 5.2) all cover energy conversions and showed that few students knew about energy conversions and transfers which are carried out within and by these body organs. Despite energy conversions and transfers being taught in Year 9 along with the functions of the eye and ear, students

> When we see something like a tree, some of the light energy from the tree is transferred via the eye to our brain and so we see that tree.
>
> When you hear a friend talking, the sound energy comes from that friend's mouth into your ear and then into your brain where it is used to hear.
>
> When we ride a bicycle, some of our energy is transferred to the bike.

Figure 5.2: Statements from questionnaires used to examine knowledge on energy conversions.

appear not to know that energy is converted or that it exists in a variety of forms and that these forms can be converted into other forms. They also appear not to know how the ear or eye works to enable the brain to receive nerve impulses, that is, how there are energy conversions that occur and how the nerve impulses are transferred to the brain. The other reason for the poor knowledge of energy conversions is that the students are not told (in formal classes) that these organs convert energy from light or sound energy into nerve (electrical) impulses. A very small number of students (n = 8) reasoned that sound and light were not energy. A suggestion for teaching this in class is that coverage could be via the position of 'this is what happens to the sound or light as it passes into and through the organ and these are the energy conversions involved in the process' so the energy can stimulate the brain. That is, energy is received by the organ, passes through to the cochlea or the retina where the sound or light energy is converted into nervous impulses (form of electrical energy) and these impulses enter the brain where they are interpreted and acted upon as necessary.

This low knowledge of energy conversions and transfers ties in with the poor understanding of energy conversions in respiration which was found in all respondent groups. There is little general understanding that energy can be converted, more specifically that external energy is used by the body and that the conversions of this energy is the function of many organs and processes (respiration is one) in the body, for example, the eye and ear.

The poor knowledge of energy conversions as illustrated in the respiration discussion was further illustrated when responses to the items on the role of the ear and eye were investigated. Generally, the reasons given to the items involving energy conversions carried out by the ear and eye indicated a lack of knowledge about what happens during the hearing or vision processes, especially with respect to energy conversions (see Item 1 in both Questionnaires). Many students (n=30) indicated some knowledge of the vision process which was rudimentary and inaccurate when they stated that the light from the tree went from the object through the eye to the brain without any processing by the eye and that the brain directly translated the light energy.

A similar finding applied to the role of the ear and hearing where students claimed that the brain translated the sound to enable people to hear the object (n=58). This lack of knowledge is despite all students in Year 9 as part of their normal science curriculum, being taught about the structure and operation of both these sense organs. Only some Year 11 and Year 12 (n=5) students and one Year 10 indicated that the eye or ear converted light or sound energy into nervous impulses, which the brain could then translate. A small number of students (n=8) claimed light and sound were not forms of energy.

Further evidence of energy conversions and transfers not being known, understood and/or applied was shown in the written responses to the items on the bicycle (Questionnaire 1 Item 11 and Questionnaire 2 Item 10). A minority of students indicated energy was transferred to the bicycle from the rider while 80 students stated that energy was not transferred. Further, a number of Year 8 and Year 10 students claimed energy transfer could not happen as the bicycle was inanimate and therefore could not possess energy, making claims such as — *"the bike is not living so it can't get the energy"* (8-106-1999) and — *"the bike doesn't have energy – isn't living"* (9-34-1999). Authors such as Trumper (1991) and Duit *et al*. (1994) have reported this anthropocentric view of energy held by many students.

A minority of Year 8 students stated that when energy is used it is lost or destroyed and so is unavailable for further use —*"we use all the energy ourselves"* (8-117-1999) or — *"we can't give energy to a bike, we use up all of the energy"* (8-131-1999). Another reason for humans not transferring energy to the bicycle was that the bicycle has its own energy and that it is this energy which makes the bicycle move.

With many students, there was a general agreement that the bicycle needed a person to expend energy to make it move. But, 58 students who made this claim also made no mention of energy transfer to the bicycle while 78 students did think energy was transferred to the bicycle in the process of making the bicycle move. Many Year 11 and 12 students expressed the idea that using the legs to move the pedals resulted in the transfer of energy to the bicycle via the pedals and this resulted in the bicycle moving — *"because our energy is moving the pedals-> chain -> gears -> wheels -> bike"* (8-108-1999) and — *"we use energy in our legs to move the pedals…"* (9-43-1999). Four of the Year 12 students also discussed the role of kinetic energy in the energy conversions required for the bicycle to move —*"we transfer kinetic energy from our legs to the pedals which turns the crank which in turn starts the wheel spinning"* (12-38-1999).

With no evidenced knowledge of the processes or chemistry of respiration and that energy is in the bonds of compounds (i.e., location of energy in foods as found in Item 1 which related to bundles of energy in food), it is not surprising that most students had no idea of how body heat and hence body temperature was derived. Many students in all year levels simply restated or reworded the statement and showed no understanding of the concept that chemical reactions often give rise to a temperature change which, in the case of biological reactions, frequently evolve heat. Only two upper school students mentioned that chemical reactions do evolve heat and that this heat leads to the body having a temperature above that of the environment — *" chemical reactions in our body all give out heat. This maintains our body temperature"* (12-11-1999). This lack of knowledge is despite Year 8 students from School A having been taught the concept of exothermic reactions as part of their Chemistry course. This lack of valid responses would indicate that the Year 8 students either forgot this concept or did not transfer the knowledge across to a novel situation.

One problem with the coverage of exothermic reactions in class may be that this form of reaction is taught as a fact and in isolation without the use of real-life examples such as the effects of exercise to illustrate this point. Also, it is often taught in a didactic fashion where students are told that some chemical reactions can be identified as a result of an increase in temperature and students do not experience the effects of exothermic reactions by carrying out reactions of their own or by being given relevant examples. (This lack of transferability of knowledge further illustrates the notion that teaching something does not guarantee students will incorporate the new material into their knowledge base.)

The role of sweat leaving the skin or body surface via evaporation and hence cooling the body was poorly understood, a minority of students indicated that the process of evaporation led to a cooling effect (two Year 11students both from School B with both studying Physics) and that there was no hint of the latent heat of evaporation in any of the reasons given. The lack of knowledge about the cooling effect of the evaporation of sweat is most likely due to a lack of knowledge about the process of evaporation and/or the application of evaporation to this or any cooling situation. There may also be a lack of transference of knowledge about evaporation and cooling as a number of researchers such as Dreyfus and Jungwirth (1980) have shown there is a poor transfer of knowledge. In School A, the lack of knowledge is more likely the case as students were not overtly taught the cooling effects of evaporation unless incidentally in some other situation.

While no student stated that heat is converted into sweat as was found by Westbrook and Marek (1992), many students stated that heat energy (or particles if the particulate notion held used by the respondent) went into the sweat and as the sweat left the body the heat accompanied it — *"when sweat is evaporated, heat is taken out with the sweat"* (11-37-1999).

Two other reasons given were that air coming in contact with the sweat somehow cooled the sweat down — *"the wind cools us down"* (9-25-1999) and — *"when air blows over us it makes us feel cooler"* (10-87-1999) and sweat has no effect or influence in cooling the body — *"...sweating doesn't make us cool"* (10-68-1999). One reason for the latter idea, made by a few students in each group, particularly in Years 8 – 10, was that when they sweated they did not cool down but still felt hot and so sweating did not have a cooling effect —*"when I sweat I still feel just as hot"* (8-32-199).

5.3.2.3 Assertion 3

Many students see energy when involved with the body as existing in a variety of types and existing in packets.

Many students across all Year levels (n=198), ranging from 20% (Year 12) to 60% (Year 8) of each year cohort, indicated energy in food comes in a range of types or varieties but what these types of energy were was never revealed in the written responses. A typical response was — *"because there is loads of types of sources with different uses"* (8-75-1999). These students expressed the idea that the energy in food is found in a variety of forms, which the body uses to carry out its various functions, thus necessitating a variety of foods to supply the variety of energy types required —*"food gives all types of energy"* (10-21-1999) or — *"Different food has different energy types"* (11-47-1999; 12-49-1999; 9-115-2000) and — *"a good balanced diet contains all the types of energy we need"* 12-40-2000. Only 13 Year 8 to 10 students indicated that there was only one type of energy in food while of the older students six stated that there was only one type of energy in food and some claimed that all of this energy was absorbed to be either used or stored as fat. (Not all of the 19 students indicated that the excess energy-bearing food is absorbed and converted into fats for potential use latter.)

This notion of energy types can be tied in with the need for a balanced diet and with different foods having different energy values. In everyday life, students come across the need for different food groups to meet the requirements of the body. Also, the body is involved with different types of energy such as movement, muscle, heat and thinking. A natural extension of combining these two notions is the need for an ‘energy type’ to match each of these energies required by the body as illustrated by statements such as, — *“the body required a variety of different energy types to perform different functions”* (12-68-2000), — *“different foods are made up of different types and amounts of ingredients so therefore energy levels differ and so do the types of energy in different food”* (12-21-2000), — *“different foods contain different types of energy. (different foods contain different amounts and types of energy - eg- high carbohydrate food and high sugar food)*” (12-11-2000) and — *“we need all different types of energy so all foods need to be eaten, some more than others”* (12-1-2000).

The fact that students thought energy in food comes as a number of different types is a further indication that many students in this study do not have a scientifically acceptable notion of what energy is and the role of respiration in the body. That is, they do not consider that glucose, carbohydrates, proteins and lipids are energy sources with energy being transferred during respiration to ATP or the ‘universal energy molecule’ as it is described in the earlier years of high school. This finding supports work in this area carried out by researchers such as Arzi (1988), Barak (1997) and Duit (1984, 1994).

Many students expressed the idea that energy exists in packets found between the food particles. There was a decreasing number of members of each year cohort (Year 8 (33.6%), Year 9 (32%), Year 10 (23.7%), Year 11 (17.6%) and Year 12 (22.7%)) who thought that food energy is found in packets or bundles or as particles between food particles or molecules rather than in the food itself. The reasons given did not specify why the packets were not inside the food particles/molecules but revolved around arguments that food has energy and so why shouldn’t it be in packets — *“because our body releases tiny bundles of energy found between the food particles into our blood”* (8-8-1999) or that energy is released from the food when it is digested — *“ because the energy in the food is changed into workable energy through the process of digestion* (10-136-1999). The latter reasons were given as support for those students who agreed with the idea for energy as bundles. Only two Year 12 students indicated the energy in foods was found in the chemical bonds; the other students who stated energy was in the food particles or molecules gave no specific location for the energy.

The idea of packets of energy fits in with the notions that there are different types of energy, different types of energy are found in different foods, digestion releases energy, energy can be useful and only useful energy is absorbed. If energy is in particles then the particles can be different and unique to each food type, energy type and energy use. The concept of the particulate nature of energy can fruitfully explain many of the concepts held by students with regard to energy and the body, for example, sweat carrying heat energy out with it, or the absorption of useful energy only or the types of energy in food. The notion of a particle of oxygen being a type of energy and since light and sound are non-particulate they are not energy also supports in the student's mind that energy is a concrete material and so is particulate. This finding is further evidence that supports work reported by Duit (1984), *Chi et al.* (1994) and Trumper (1997a) who both found that students thought energy was substance-like. Duit (1987) advocated that energy should be taught as a concrete substance-like material and that this conception be modified later in a student's life when the learner can think in an abstract fashion.

The notions of energy in packets, oxygen as a type of energy and light and sound not being energy declined with age but at varying rates for each of these separate notions as shown in Table 5.8.

Table 5.7: Notions held by students as percentage of year cohort and how they change with increasing age.

	Year 8	Year 9	Year 10	Year 11	Year 12
Packets Of Energy	29.8	14.6	13.6	9.1	18.2
Oxygen As Type Of Energy	17.8	10.5	13.6	9.1	18.2
Light Or Sound Is Not Energy	0		1.4	2.2	6.8
One Type Of Energy In Food	4	3.5	3.5	2.2	9.1

Another form of energy was the useful/ not useful nature of energy as discussed in Section 5.3.2.1. Many Years 8 and 9 students believed that energy could be useful or not, that the useful energy was used after it was absorbed and that the not so useful energy or excess useful energy was excreted, viz, that energy is only useful to the body when it is used immediately. This notion can be linked to the notion that energy which is stored as fats is not useful as it is not useable in the near future. As with the packets of energy concept, this usefulness concept also declined with age to be replaced with the notion of excess energy being stored as fat for latter use.

5.3.2.4 Findings reported in the literature

Energy and the human body is such a broad area of study with many different aspects of energy encompassed within its perimeter and so it is not surprising that so many of the energy conceptions held by students have already been reported by other researchers. Much of this past work has been as a result of investigations into energy in settings other than the human body but it would appear that these findings are transferable to the human body situation. The following findings from this piece of research have already been reported by other researchers and will be displayed in tabular form as many have already been referred to in previous sections of this or previous chapters. Table 5.11 shows a number of research reports on energy conceptions. This table is in no way a complete list of published reports but it does give an indication of the conceptions found over the past 30 or so years of research into student conceptions of energy and the human body.

5.3.2.5 'New' Findings From this Study

A search of the English language literature was carried out to discover the conceptions that have been identified and reported in this literature. A comparison of the previously reported findings to the conceptions unveiled during this study has revealed a number of possibly unreported conceptions held by students.

Sugars and carbohydrates are seen as being different.

Sugars and carbohydrates are seen as being different and the carbohydrate food group does not include sugar and visa versa — *"food contains carbohydrates, sugars, fats etc…"* (11-39-1999). This difference was found in some of the reasons given across all the year levels with an increase in the use of the word carbohydrate as the students got older. Both of these chemicals were claimed to be sources of energy for the human body but with different speeds of availability for use as shown in the following reasons — *"…contains carbohydrates – energy that lasts longer or contains glucose – fast acting…"* (9-34-1999) and — *"carbohydrates are long term energy source whereas a food high in sugar provides energy straight away"* (11-48-1999).

Table 5. 8: Table showing findings from this study and some other studies reported in the literature.

Finding	Previous Research Report
Good And Bad Energy	Albert (1978)
	Arzi (1988)
	Francis *et al.* (1992)
Energy Is Substance Like	Duit (1987)
	Carr *et al.* (1988)
	Erickson (1989)
	Collis *et al.* (1998)
	Kaper *et al.* (2000)
Energy Is Not Conserved	Albert (1978)
	Solomon (1983a and b)
	Gayford (1986a)
	Brook *et al.* (1988)
	Duit *et al.* (1994)
	Goldring *et al.* (1994)
	Barak *et al.* (1997)
Glucose (Carbohydrates) Is Energy	Ault *et al.* (1988)
Energy Stored As Fat	Baird *et al.* (1987)
Activity Releases Energy	Bliss (1985)
Or	Jennison *et al.* (1991)
Energy Only When Active	Nicholls *et al.* (1993)
Energy From Variety Of Sources Such As Sleep, Air	Gilbert *et al.* (1983)
	Solomon (1985)
	Boyes *et al.* (1991a)
Variety Of Energy Types In Food	de Bueger-van der Brorght *et al.* (1989)
Poor Knowledge On Energy Transfer	Finegold *et al.* (1989)
Location Of Energy In Food (Chemical Energy)	Gayford (1986a)
Energy Rechargeable	Gilbert *et al.* (1983)
Poor Energy Transformations	Kesidou *et al.* (1993)
Anthropocentric	Trumper (1990b)
Vitalism	Kruger (1990)
	Lijnse (1990)
	Kruger *et al.* (1992)
Respiration	Lavoie (1997)
Energy Released During Digestion	Simpson *et al.* (1982b)
	Ross (1991)
	Lavoie (1997)
Active Person Has More Energy That 'Fat' Person	Francis *et al.* (1992)
Food Turns Into Energy	Ross (1991)
Energy Released Through Burning	Solomon (1985)
	Ross (1991)

All energy-receiving organs need energy to function.

All energy receiving organs and tissues of the body such as the skin, ears and eyes while receiving energy from the environment also need energy so they can function. This was a major reason given for agreeing to the statement 'Some parts of our body which receive energy are our eyes, our ears, our nose, our skin and our lungs' and was given by a number of students from all year groups. While the item had been an attempt to identify which parts of the body received energy from the environment and at the same time to indicate the types of energy or sources of energy such as air and light, the question did bring out this different interpretation. But this interpretation led to the discovery that the majority of students correctly thought the cells of the organs mentioned required energy to function. An example which illustrates this conception clearly is — *"you need energy in our eyes, ... and our lungs or else they wouldn't work"* (8-115-1999) and— *" they all need energy to function properly"* (9-62-1999).

Availability of energy in fats.

A range of notions about the availability of energy in fats has been found varying from energy being readily available through to this energy is locked away permanently once incorporated into fat. This range of notions does acknowledge that fats contain energy but that this energy has varying availability for later use rather than the previously reported notion that fat is a useable energy store site for excess absorbed energy (Baird *et al.* 1987). However, the data in this study have found that a number of students reported excess energy is unavailable for use later as it is locked away in the fat or that it has varying degrees of availability — *"fat is not a useful source of energy for people"* (12-30-1999, — *"...because not all fats break down and your body can't use it"* (8-43-1999), — *"fat is fat, it has energy but cells can't use it easily"* (9-34-1999), — *"fat does not give energy"* (8-19-1999) — *"energy not used is fat"* (8-80-1999) and — *"fat is not useful"* (10-127-1999). Other students stated that energy stored in fat was not useful — *"Fat is not a useful source of energy"* (12-30-1999) or that we do not convert fats into energy during respiration — *"energy in fats can't be converted during respiration"* (9-56-1999). Each of these reasons illustrates the notion of fats being an energy store and that this stored energy has varying degrees of availability for later use.

The role of the eye and ear in converting energy.

Work has been reported by a number of researchers in both vision and hearing but in all cases this has involved a study of the passage of the energy from the object to the ear or eye and not what goes on inside the body. For example, Guesne (1985), Osborne *et al.*

(1993) and Collis *et al*. (1998) all looked at the passage of light to the object and from there to the eye, while Boyes (1991b) studied the passage of both light and sound but only to the ear or eye. However, there has been no work carried out (to my knowledge) on what happens once the eye receives the light. This current study started where the other work left off and investigated the transformations that occur within the ear and eye. A number of findings were made which indicated a lack of understanding of the processes involved in both hearing and seeing and have been discussed in Section 5.3.2.2 under Assertion 2. Of these findings, new discoveries included the belief that both hearing and seeing do not involve any energy conversions or transformations, rather the sound or light energy was perceived to go straight to the brain where translation of the information is carried out. That is, there is no energy conversion from sound to electrical impulses taking place in the ear, as for example in the response — *"Sound is only a vibration which is decoded in the brain"* (8-67-1999). Similarly, light from the object being observed enters the eye and goes via the retina to the brain where it is interpreted — *" …The eye is simply a tool in transferring that vision to our brain, where the image is interpreted"* (12-48-1999).

As well as the light going directly to the brain for translation a small number of students made claims such as — *"not contacting anything with the tree"* (8-39-1999) and light not coming from the tree and vision involving — *"no energy being transferred"* (11-6-1999) (some of these results have been previously reported on in the literature).

Body temperature regulation and the role of sweat.

Westbrook (1992) studied student conceptions on homeostasis but did not investigate conceptions on body cooling or heat removal via the evaporation of sweat. He did find students had problems with the role of perspiration, in particular that heat was removed with the sweat. This study found this as well as a very poor understanding of the roles of evaporation and sweat in cooling the body. While students had a range of alternative conceptions about the role of sweat, including it having no effect on cooling the body, one conception common across all years was that sweat cools the body down because air or wind came in contact with the sweat. A reason like — *"because sweat comes out hot but when reached air it cools"* (8-43-1999) could be interpreted to involve evaporation or just be an observation of sweating while — *"...it's the sweat cooling with something* *like the wind"* (10-64-1999) and — *"...the air blows on the sweaty skin to cool it"* (11-40-1999) showed it was the contact of the wind or air which has the cooling effect and is also reflected in the following reason — *"while this is happening the air or wind blows on our skin and cools us down"* (11-10-1999).

Absorption of excess energy.

While the role of food as an energy source was beyond dispute and the amount of energy present varied with the content and quantity of food eaten, a number of students held the concept of excess energy not being absorbed into the body, if it was absorbed, it was only the useful energy which was absorbed that all the excess or not useful energy was excreted — *"we use up all the good stuff and poo out all the bad stuff"* (8-77-1999) or — *"the non-useful energy is discarded from our body"* (8-72-1999) and — *"useful energy is absorbed, useless energy is excreted /eliminated"* (9-58-1999). Somehow to these students, the gut can filter or separate the food or energy before absorption but no indication of how this occurs was offered. One student claimed that people absorb all the energy then excrete the excess — *"we absorb everything then excrete the things we do not need."* (10-132-1999).

Animacy and the role of energy transfer.

A number of researchers have reported the notion that energy can only be found in living things (Barak *et al.* 1997; Bliss, 1985; Gilbert & Watts, 1983; Kruger, 1990) and this study has found evidence of this concept. As well as this animacy aspect, a number of other reasons including — *"the bike does not need energy to move"* (8-9-1999) and — *"The bike does not need energy because we're the one who is making the bike move"* (10-35-1999) supports the notion that the bicycle does not need energy to enable it to move and that the bike makes its own energy once we have expended energy to get it moving — *"the bike creates it's own energy"* (8-123-1999) and — *"the bike creates its own energy we just get it started"* (9-45-1999).

In addition to this lack of energy being required by the bicycle to move, a series of reasons students gave have claimed the rider uses up energy and so it cannot be transferred to the bicycle with typical responses of —*"energy is used on the bike but not transferred to it"* (8-67-1999), — *" the turning of the pedals causes the bike to move, we just use energy from our muscles in our legs"* (9-14-1999) and — *"all energy is used by* *the body. No energy is transferred"* (11-37-1999). This 'using the energy up' has been reported by Kesidou *et al*. (1993) and further reflects a lack of the notion of energy conservation discussed earlier in Section 2.6.1 and 2.6.2 when the literature on conservation of energy was discussed, and in Section 5.3.2.2 where energy conservation in relation to the bicycle and energy was discussed.

5.3.2.6 Notions of energy taught in the classroom and the transfer of this knowledge

An investigation of the items relating to sweating, energy location, respiration, type of energy and the transfer of energy to the bicycle should reveal how much knowledge is transferred by the subjects of this investigation to novel situations. These items are not directly taught (or if taught at all, there is little time spent for depth of coverage to occur) during formal lessons in Years 8 to 10 classes and are only taught in Human Biology during Year 12. During this analysis, it should be borne in mind that there is a paucity of knowledge regarding energy and the human body held by many of the students and so any conclusions drawn here are made with this in mind.

Sweating as a mechanism for cooling the body assumes a student understands the process of evaporation and its cooling effects via the latent heat of evaporation. In School A, no student even hinted at the latent heat of evaporation while in School B, three students used latent heat and three others mentioned heat removal with evaporation. The students of School A had all studied evaporation but not directly as a cooling process with the associated heat loss. Despite this lack of formal teaching, a majority of students did not think evaporation cools the body down with some students even saying they stay hot when sweating. It would appear that this group of students could not recall observations that they could have made about sweat leading to their cooling down or that this is why we sweat. They also have not connected any observations of the cooling effect of evaporation they may have made at some stage during their life. Not being able to draw upon past experiences indicates a lack of ability to transfer knowledge to this apparently novel situation.

During formal lessons at both of the schools investigated, the major forms of energy are well discussed and examined, especially in Year 9 when the area of energy is covered in detail. But, the reasons given to a number of items (Items 3 and 4 in Questionnaire 1and

Items 5 and 8 in Questionnaire 2) revealed students think there are a number of energy types with each type having a specific function in the body. This would also indicate poor transference of knowledge.

Further to the major forms of energy being taught in both schools, the role of photosynthesis is also taught when it is discussed that energy from the Sun is converted into chemical energy in the sugars (or starch in the lower years) produced by the plant. It is further looked at during the coverage of energy movement through an environment via food chains and webs; that is, chemical energy in food is being taken into an animal and that energy is passed on through the food chains and food webs and that the energy is used by the various organisms of these food chains. Despite this coverage in formal lessons, many students gave reasons that indicated there was little knowledge application or transfer of there being chemical energy within the food being eaten. The notion of there being different energy types found in food was given by a majority of the students which showed many students thought there are specific types of energy within different food groups. Responses indicated that a number of students thought there are a variety of different types of energy found in food — *"... they have different amounts of energy and different types"* (8-115-1999) and —*"different ingredients which have different energies"* (8-87-1999). Students who disagreed with the statements about energy and food made claims such as — *"there is only one type of energy"* (8-40-1999) but did not mention it was chemical energy just that the energy is identical in all foods eaten and of these students very few indicated why they thought this. Only two Year 11 and 12 students discussed chemical bond energy as the energy in food while there was one student who indicated food was used in respiration to produce useable energy.

Respiration was taught in classes in Years 8 and 9 at both schools with ample detail as to the processes involved with its function as a process whereby energy is transformed to a form that can be used by the organism and the cells of these organisms to carry out various functions. From the generalised manner in which this process was taught in class, the general assumption of teachers who have no understanding of the research into conceptual change and which is not supported by the literature is that, it should be possible for students to relate this knowledge to other situations such as their body. But not only was this process very poorly understood, the application of this process was not carried out by all but a few students.

Bearing in mind the low knowledge levels about energy and their body held by the students in this study, it is not hard to appreciate the difficulty that students had in transferring what knowledge they did recall to novel situations such as their body and how it uses energy.

5.4 SUMMARY OF CHAPTER

In this chapter, the data collected from the administration of two questionnaires *What do You Know About Energy and Your Body? Questionnaire 1 and 2*, containing a total of 28 items designed to reveal student conceptions on energy and the human body was analysed. This collated data revealed a number of problems in the conceptions held by the students in Years 8 through to Year 12. These problem areas were identified from the students' agreement or disagreement to the series of 28 statements and from the combined underpinning reasons given for agreement or disagreement to these statements.

The major identified problem-areas related to energy and the human body were the energy types in food, sources of energy for the human body, the processes of vision, hearing and respiration, energy conversions and transfers within the body and temperature regulation which were all very poorly understood. From these problem areas, three assertions were derived: 1) Students' perceptions of energy availability in food varied according to their perception of the type of food eaten; 2) There is a low understanding of energy use, conversions and transfers in the body; and 3) Many students see energy when involved with the body as being in a variety of types and existing in packets.

While these problem-areas were identified from the data collected, a caution was issued about interpreting the agreement or disagreement section of the items in isolation or without reference to the underpinning reason. While these agreements may appear to indicate conceptions held on a topic, it is essential that the underpinning reasons be examined as these revealed many preconceptions or misconceptions held by the respondents which were scientifically unacceptable.

The author's work further revealed a number of conceptions held by the respondents that were common to those previously identified by other researchers. For example, the particulate nature of energy, useful or not useful energy in food, energy obtained from air or oxygen, energy not being conserved when used and fat not used as a source of energy by the body. While many conceptions have already been reported in previous reports, a number of new findings were presented including carbohydrates are different to sugars, energy is needed for organs to function, fats lock away energy and the degree of locking away is variable from forever to being difficult to use through to easy to use, excess energy is not absorbed but excreted, the eye and ear do not convert energy but merely relay it directly to the brain where it is interpreted, sweat cools the body because air or wind comes in contact with it (not through evaporation) and objects do not need energy to move only to get the movement started.

In Chapter 6, the data are further analysed to determine any changes in the conceptions held by students which may occur over the students' age range from Years 8 through to 12 and then to investigate any ontological changes observed and what these changes involve.

These findings have partially satisfied the research questions for Objective 1. From these identified conceptions and problems a series of two-tier multiple choice diagnostic items were created covering the areas of weakness identified. The development and trialing of these diagnostic items are reported in Chapter 7.

CHAPTER 6

CROSS SECTIONAL CHANGES IN STUDENTS' NOTIONS OF ENERGY AND THEIR BODY

6.1 INTRODUCTION

This chapter involves a cross section study of the conceptions revealed from an analysis of the combined data from Part 2 of the two questionnaires, *What do You Know About Energy and Your Body? Questionnaires 1 and 2*, whose development was discussed in Chapter 4. From this set of conceptions, a number of possible cognitive frameworks were developed. Each year-cohort's set of identified conceptions was then combined and examined to reveal patterns of conceptual change which may occur as students modify their cognitive framework and develop towards the more scientifically acceptable framework. Because a range of frameworks were found in each year-cohort, a number of pathways of conceptual development are discussed, any of which may be followed by a student.

Chapter 5 discussed the analysis of the data from the two questionnaires administered by the author to 610 students from Years 8 to 12 which revealed a number of student-held conceptions and their underpinning reasons with respect to energy and the human body. These problems included the notion that energy that the body could use was only available from food and this food energy was converted into useable energy when the food was digested or the energy was released from the food either during digestion or at a later time. This food energy was considered as having a variety of different energy types that are used by the body to carry out a range of different tasks with each task matching a specific energy type. There was also a poor understanding of respiration, energy conversions and transfers by the body and a poor comprehension of body temperature regulation. Over the range of ages studied in this investigation, a number of these conceptions were consistent across all years and, when there was change, these changes were progressive and partially age-related and involved a series of possible steps in the cognitive change processes of students. The data from these two questionnaires was further analysed in this Chapter to arrive at some changes which could occur as students' cognitive frameworks develop as they progress through their secondary education.

From the conceptual problems identified in Chapter 5, a number of areas where student-held conceptions have changed with increasing student age were identified such as how the energy in food is converted into utilisable energy, the roles of digestion, sleep and respiration in this energy-conversion process and the particulate nature of energy (Sections 5. 3.2.2 and 5. 3.2.5). Other sources of energy that the body uses to adequately function such as light, sound, air and sleep and the uses and conversions of the utilisable energy were all concept areas which showed changes as student cohorts' ages increased (Sections 5. 3.2.2 and 5.3.2.5). In association with the sources of energy were the notions of there being different types of energy and the nature of the energy (Section 5.3.2.3 and Table 5.7). The notion of the regulation of body heat through its generation and the attempt to maintain a constant body temperature also showed changes with increasing student age (Section 5. 3.2.2 and 5.3.2.5).

During the following discussion a series of data sets will be referred to that are small in number and as such it was considered inappropriate to use separate tables each time. These results were combined into a single table which is found in Appendix 16. This table will be referred to when appropriate.

As suggested by Shymansky *et al.* (1997), students follow a saw-toothed path in their development of a concept with a number of researchers observing punctuated changes, regressions and changes of direction (previously discussed in Section 2.4.5). In this chapter a number of possible pathways are proposed which a student may follow in the development of a concept or aspect of energy. These pathways are the result of combining many students' notions and then attempting to link these together in some coherent from which could indicate possible pathways which could be followed in the development of a concept. How an individual student actually progresses towards an acceptable notion is unclear but potential pathways that may be followed become clearer through the use of the Figures 6.1 through to Figure 6.10 and these may follow a saw-tooth pattern. It should be noted these suggested pathways do not represent all possible pathways but are a set of possible pathways identified from the reasons given to the items found in Questionnaires 1 and 2. The pathway an individual student may follow could include any or all of the suggested notions but the sequence in which the notions are addressed could be in any combination.

In conjunction with the changing cognitive frameworks of the students and further analysis of the combined data from Part 2 of the questionnaires, a number of ontological changes which students may undergo as they progress towards holding scientifically acceptable conceptions are discussed.

In the figures presented in this chapter, an oval shape indicates an unacceptable notion while a rectangle indicates an acceptable notion. These acceptable notions may not necessarily be interconnected correctly by individual students, just that they are scientifically acceptable within the overall diagram. Similarly, arrows indicate possible connections between notions and further they indicate the possible pathway where one idea leads onto another.

The potential pathways proposed in the following discussion are based on real learners notions and are based on the combined evidence that many students hold and are the result of a number of these notions being combined into a possible series of paths students may or may not follow as they develop their own concepts. These pathways are by no means a complete set of notions but rather are a combination of notions held by a number of students.

It must also be remembered that student notions are formed through the interactions of many factors that may not include logical or rational factors. So these proposed pathways are tentative representations of potential pathways students may follow and one teachers can attempt to direct students learning towards and along. They provide possible starting points for the preparation of teaching materials which could cover these concept areas.

These proposed pathways are not intended to imply a student will start at the beginning and follow a pathway through to the end or an acceptable concept. Rather they represent a series of paths a student could take while developing a concept being in mind the discussion above on what previous researchers have discussed about student paths as they develop a concept (Section 6.1)

6.2 ENERGY AND FOOD

A number of external sources of energy that the body uses to enable it to adequately function were examined by the questionnaires and involved scientifically acceptable energy sources such as food, light and sound. The students held a number of other phenomena such as air, oxygen, sleep and exercise or activity which they thought were energy sources. A small number of students wrote that light and sound were not energy.

Further to these energy sources was the notion that energy with which the body was involved came in a number of forms which included energy that was good or bad, quickly or slowly available, useful or not useful, as well as needed or not needed. As well as these forms of energy was the notion that energy in food came as a number of different varieties each of which matched a specific use by the body and contrasts with there being only one variety of energy in food that the body can use, namely chemical energy.

In association with these forms and varieties of energy, was the notion of energy being particulate or not in its nature and if energy was viewed as particulate it was an ingredient of food found either within or between the food molecules. The responses relating to the particle nature of energy varied in the nature of the particles were they were seen as being, particles, bundles, packets atoms of energy or undefined in their nature but found between the particles of food. This particulate form of energy was not described or indicated as existing in any responses except where the item related to food and energy.

6.2.1 Sources of Energy Used by the Body

While all students agreed that food was a source of energy, a number of these students wrote that food was the only source of energy used by the body (Section 5.3.2.1). Despite this notion, students gave a variety of other energy sources. Air or oxygen was seen as a source of energy where students claimed either that air contains energy — *"we get energy from air all the time"* (8-84-1999) or — *"we receive energy from the air we breathe…"* (8-17-1999), that we use air to convert or burn with sugars to produce energy

— *“Oxygen in the air we breath is used to release the energy from food”* (11-60-1999), — *“oxygen from the air is involved in the chemical reactions that release energy”.* (11-38-1999) or — *“true, however we also need oxygen from the air we breathe to fulfil the equation of respiration”* (12-48-1999) or evidence was given which implied air supplied energy because if we do not breathe we die — *“because we will die if we do not inhale and exhale to keep our energy going”* (8-94-1999), — *“without air we would die or be weak so we must get energy from air”* (8-122-1999), — *“without it we would die”* (10-50-1999).

A small group of students wrote that they thought sleep produced energy and frequently gave evidence of a gain in energy as the reason for this notion — *“we can have drinks and vitamins to get energy too, and also sleeping”*(8-5-1999), — *“we absorb some energy through food and other through sleep and drink”* (8-103-1999), — *“you get energy from when you sleep”* (9-51-1999), — *“You get energy from sleeping* (10-94-1999). But, students in each year indicated that the body uses up energy while asleep — *“because when we sleep we store energy that hasn’t been used”* (9-27-1999), — *“I think energy levels may build up as we sleep because we’re not using any up”* (10-24-1999) while older students wrote that the body formed more energy than was used up and so replenished or recharged our energy supply —*“we use less energy to sleep while our body produces more than we require to sleep”* (11-21-1999), — *“when we sleep our body is using energy but not as much as we do when we’re awake therefore our body is conserving energy”* (12-5-1999). A number of students in each year-cohort simply wrote that sleep revitalises, replenishes or recharges our energy supply with no justification or any explanation given as to what these words mean.

A common notion that exercise or activity produces energy described by such authors as Nicholls *et al.* (1993) and Finegold and Trumper (1989) was also identified during the data analysis but only a very small percentage of students in any year used this as a reason.

The questionnaire items investigating the eye and ear showed that very few students held the notion that light and sound were not types of energy. The majority of students either responded as if they thought there was no energy involved or claimed if energy was involved then that sense organ used or converted this energy. The latter notion was not common in any year but was more prevalent in the higher age cohorts. From these data, the sources of energy that the body uses can be illustrated in Figure 6.1.

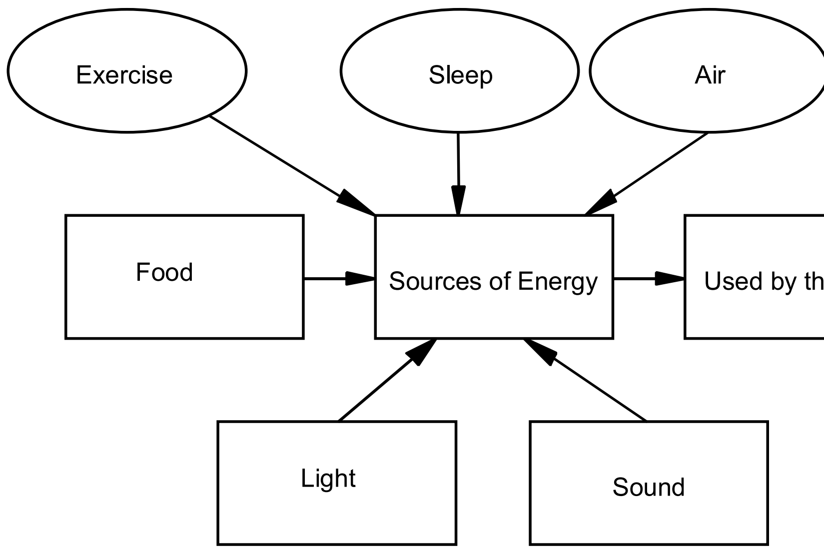

Figure 6.1: Student ideas about external sources of energy used by the body to function.

6.2.2 The Nature and Location of Energy in Food

As already discussed in Section 5.3.2.3, a large number of students wrote that energy was found as packets between the food particles (Table 5.8). Many of the Year 8 students (29.8%) held the notion that energy was in packets which are found between the food molecules, while a lesser percentage of Year 9 students held this notion. The notion of energy not being in bundles either between or in food molecules was definitely held by Year 10 students but many of the reasons given were of a general nature.

A parallel to the particulate notion of energy in food was of energy as an ingredient of food similar to sugars, fats or vitamins. Both of these notions had energy outside of the food molecules and so could be released during digestion. This particulate notion of energy declined with student age to be replaced by the concept of the energy being within the food molecules (Table 5.8). But some Year 11 and 12 students still retained the notion of packeted energy (n=8 in each year) while most of the students in these two years showed an increasing awareness of the role of the cell in converting energy into useful forms, that there were a number of reactions involved in obtaining energy from food and finally that respiration played a role in obtaining energy from food (Table 5.6). However, few students wrote where this energy is located within the food molecules with most students simply indicating the energy was in the food molecules — *"the energy is only found in certain molecules"* (11-47-1999), — *"in molecules found in small bundles. These are broken down for energy."* (12-46-1999). Three students in Years 10, 11 and 12 wrote that the energy in the food was in the chemical bonds.

The various notions held by students on the nature of energy can be represented diagrammatically in Figure 6.2.

6.2.3 Amount of Energy in Food

With the majority of students agreeing that food is their most important energy supply, the quantity of energy and which types of food possess the energy was an important concept. However, many students gave reasons that were of little use in establishing the notions held about the quantity of energy in food; the percentage of useful reasons for each year-cohort is shown in Table 6.1.

Table 6.1: The percentage of useful reasons in each respondent year-cohort.

Year	8	9	10	11	12
Useful Reasons	44.8	47.4	48.2	54.4	54.5

In each year-cohort, a number of students claimed the amount of energy in food was dependent upon the amount of food but in all year-cohorts a large percentage of students claimed the quantity of energy in food is dependant upon the ingredients or contents of the food. A separate claim to ingredients in general being a source of energy was that of the more specific food groups of sugars or carbohydrates. A number of students named

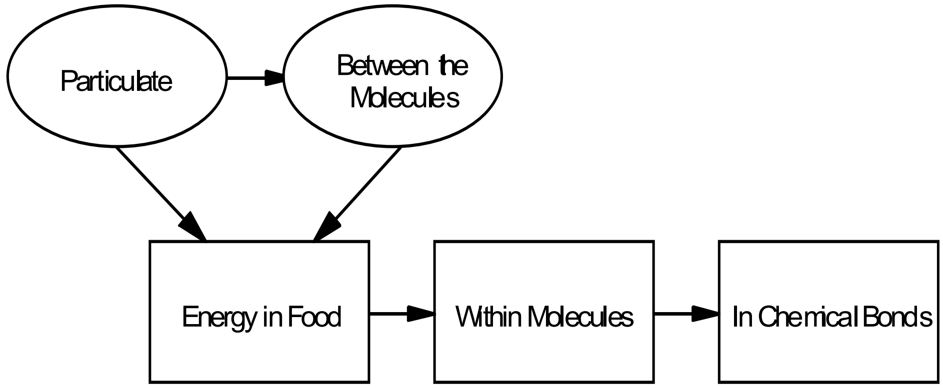

Figure 6.2: Possible conception pathways showing students' notions of the nature of energy found in food.

sugars as an example of an energy-source ingredient. The percentages of students who used ingredients and sugars as a specific example of ingredients as reasons for the variation in the amount of energy in food are shown in Table 6.2.

Table 6.2: The year-cohort and the percentages of students who gave that reason as a source of energy.

	Year				
Example Of Energy Found	8	9	10	11	12
Ingredients	11.8	19.2	10.7	11.7	9.1
Sugars	13.3	8.9	9.3	22	22.7

6.2.4 Types of Energy in Food

While some students thought energy was particulate and so would be found between the food or air molecules, some students thought that energy was found within the food molecules. Many of these latter students wrote that they thought there was a variety of types of energy found within the food and each food type had a different energy type and the variety of energy types matched particular functions of the body that required energy. For example, there was a type of energy to run, another type to think and yet another to supply heat for the body. This variety of types of energy in food persisted through all the year-cohorts but did decline with student age to be replaced by the notion of there being only one type of energy within the food.

A more generalised set of notions that centred on the useability of energy was held particularly by the Year 8 students. These notions held energy as being either good or bad, needed or not, useful or not and rapidly available or not. The use of these notions was most commonly found within the reasons given for items that examined the absorption of energy by the gut, the usefulness of energy and the different types of energy in food. (see for example, Questionnaire 1 Items 3, 4, 5, 9 and Items 4 and 5 In Questionnaire 2 respectively). Figure 6.3 uses a Venn Diagram to illustrate the types of energy in food and their inter-relatedness.

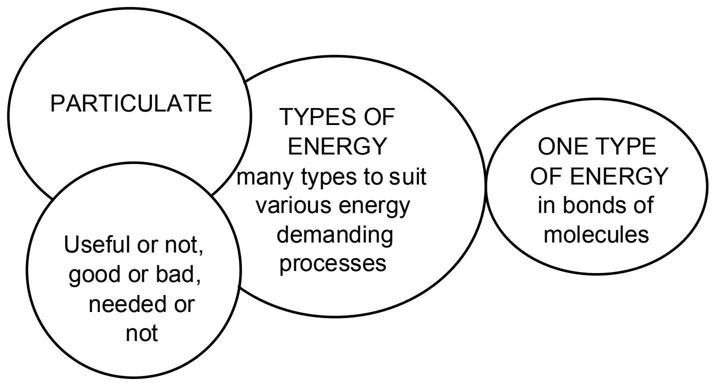

Figure 6.3: The relationship between the types of energy found in food

As student age increased, the notion of there being different types of energy persisted but declined greatly in use (see Table 5.8). Associated with this decline was an increasing awareness that there was only one type of energy in food (see table 5.5), that energy in food was found within the molecules and of the role of respiration. The concept of energy in food molecules was only written about by a very small number of students in each cohort, with only three students indicating the chemical energy was in the bonds of the molecules (see Section 5.3.2.3). These notions related to the types of energy found in food are summarised in Figure 6.4.

The items investigating the role of the eye and the ear revealed that a small number of students thought that sound and light were not forms of energy.

6.2.5 Obtaining Energy from Food

All students agreed upon food being the main energy source for the body (see Section 5.3.1.2) but the location of the energy within the food was uncertain. Although there was a trend to be more specific as to the location of energy within food and the manner of the release of this energy with increasing student age, many reasons given showed that the majority of students held few scientifically based or acceptable notions of where energy is found and how it is obtained from the food — *"different food have different amounts of energy because of the different molecules"* (9-31-2000), — *"the energy in our food is in tiny molecules that our body fluids break down"* (11-54-1999), — *"in molecules found in small bundles. These are broken down for energy"* (12-46-1999).

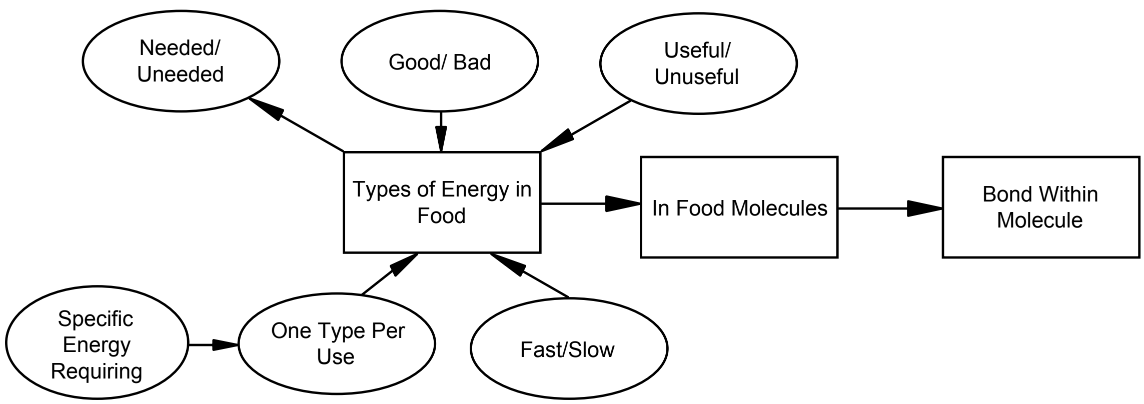

Figure 6.4: Possible conception pathways showing students' perceptions of the types of energy found in food.

If the students see energy as being particulate in its nature then the question to be asked is to see if this notion carries through and is used to help explain other conceptions such as heat being carried out in sweat. If energy is not held to be particulate but to be within the molecules itself then a different set of conceptions are needed to account for energy's transfer from food and its subsequent conversions and uses elsewhere in the body. The results of this research do not show any links between either of these two conceptions and other explanations or the reasons given by students. These connections may exist but were not tested for in this research.

Year 8 and 9 students had little knowledge of the role of digestion other than the misconception that it released the energy in the food — *"because digestion is the process used to break down food not respiration"* (9-24-1999), with some Year 10 and 11 students also holding this notion — *"because the food is transferred into energy through the process of digestion"* (10-137-1999), — *"energy is found after the digestion of food as energy"* (10-129-1999), — *"food releases molecules of energy during digestion"* (11-64-1999). This notion of digestion releasing energy was reported by Ross (1991). The more accurate process of digestion breaking up the food into smaller molecules, which are used elsewhere for energy, increased from the low percentages in Lower School to higher percentages for Upper School students (See Table 6.3). These percentages are still very low (except Year 11) and show a lack of knowledge about the role of digestion and respiration in the production of energy useable by the body or cells of a body.

Table 6.3: Percentage of students by Year cohort who gave accurate examples of the role of digestion.

Year 8	Year 9	Year 10	Year 11	Year 12
3	6.4	1.4	23.5	11.4

In Years 11 and 12, a number of students claimed that energy was released through a number of reactions that occur away from the gut (and digestion) and that the cell was involved in some way but the manner of this involvement was not specified. One or two students in each of Years 9, 11 and 12 wrote that the role of the digestion was to release smaller molecules such as sugars — *"because digestion is the process used to break down food not respiration"* (9-24-1999), which could be used in other reactions elsewhere in the body, or by the cells or in the process of respiration to release or produce utilisable energy —*"digestion is the breaking down of carbohydrates which is used by the cells"* (11-5-1999) — *"As digestion occurs and different enzymes break down/match up appropriate food properties. Sugar (carbohydrates) are broken down into simple sugars so that they can be absorbed into the blood stream and used by cells for energy"* (11- 51-1999).

The majority of students generally had little or no detailed conception of how energy is obtained from food. The notions held were disjointed and still at the formative stages of knowledge acquisition and understanding. From the information gleaned from the student responses about the nature and location of energy in food, its transfer to the cell and use by the cell in respiration, a number of pathways of the processes involved in obtaining the raw materials for respiration can be created. These possible pathways for the supply of energy for cellular respiration can be seen in Figure 6.5.

A diagram representing the notions held by students about the external energy sources used by the body, the nature and location of energy in food and types of energy was created and can be found in Figure 6.6. Essentially, this is a combination of Figures 6.1, 6.2, 6.4 and 6.5.

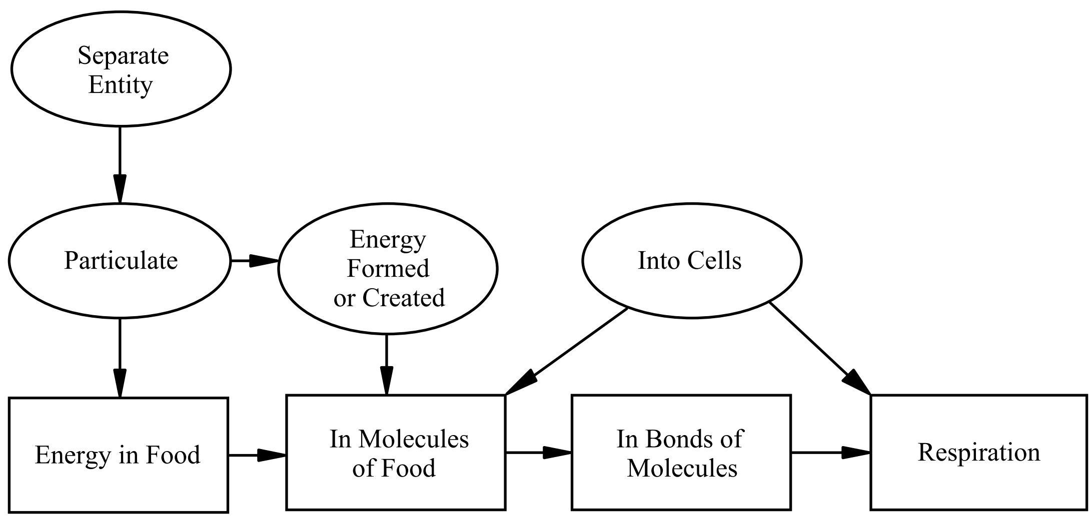

Figure 6.5: Possible conception pathways showing students perceptions of the processing of energy in food for use in respiration

6.3 ENERGY CONVERSIONS

While there are many energy conversion processes that take place in the human body, three of these were investigated, viz, respiration, and the roles of the eye, and the ear in producing nervous energy. Students showed that they had a number of unacceptable notions regarding a variety of energy conversion processes in particular with respect to digestion and sleep and had little knowledge of the process of respiration. A small number of students in each year level showed they understood the areas of energy conversions examined (see Section 5.5.3.2.2) and their responses revealed a dearth of knowledge about the eye and ear (see Appendix 16).

6.3.1 Role of Digestion in Energy Conversions

The role of digestion has been discussed in Sections 5.3.2.3 and 6.2.5 where it was shown students from all year cohorts held various views on the function of digestion with the actual role of digestion in the break up of the food to facilitate absorption increasing slightly with student age but still being very low in the number of students who indicated this notion. This scientifically accepted notion replaced the notions of digestion as either creating energy from the food — *"energy in food is changed into workable energy by digestion"* (10-136-1999) — *"and digesting food changes it into energy"* (9-27-1999*)* or releasing energy from the food so it can be absorbed in to the blood. — *"digestion breaks down food not respiration"* (9-24-1999) and — *"digestion releases this energy"* (9-18-1999).

6.3.2 Role of Respiration in Energy Conversions

While much of the discussion involving students' views of respiration occurred in Chapter 5 (Section 5.3.2.2) a brief summary follows. Across all year groups, the knowledge held about respiration was poor with students holding a number of incorrect notions which did decrease with student age. As illustrated in earlier studies, many students across all years thought respiration and breathing were synonymous and those who did not hold this notion held a set of notions some of which had become more scientifically acceptable as the student cohort's age increased (Section 5.3.2.2).

In Year 8, there were no valid notions about respiration shown in the written responses and this was despite the students having been taught the concept of respiration as being the process of combining food or sugars with oxygen to produce energy that the body can use.

Students from Years 9 to 12 showed an increasing awareness of the processes involved in respiration and where it occurred; the responses from these groups of students ranged from the general — *"we also get energy from respiration"* (9-40-1999) or — *"we use* *the food we eat for respiration"* (10-42-1999) to the very specific— *"enzymes break down the food releasing lipids, sacarides (sic) and amino acids. The mitochondria within the cells turn this into useable energy"* (11-14-1999). The responses that were scientifically acceptable were usually found in isolation and did not form part of a detailed response to a question. Some examples of these isolated responses can be illustrated in the following quotes — *"respiration involves oxygen",* — *" respiration uses fat"* (10-101-2000) or — *"within cells the mitochondria converts sugars into energy"* (11-50-1999) and the general equation for respiration — *" because the equation for respiration states:* $food + O_2 \dashrightarrow H_2O + CO_2 + energy$*"* (11-59-1999).

While the written answers varied in their precision from general to specific in nature and were in isolation, they formed the pieces of a jigsaw representing the whole process of respiration. No students in their written responses showed that they were able to place many of the pieces together to form a correct and detailed picture. But, it appears to be reasonably safe to assume that a student who can write such detailed information as the role of the mitochondria in respiration has a generalised grasp of the overall process of respiration. Reasons such as the following help support this assumption— *"enzymes break down the food releasing lipids, sacarides (sic) and amino acids. The mitochondria within the cells turn this into useable energy"* (11-14-1999), — *"within cells the mitochondria converts sugars into energy"* (11-50-1999), — *"The bits of food have been broken down by enzymes into smaller particles which include lipids, saccharides and amino acids. They then travel to the cells & mitochondria change it into energy."* 11-46-1999) — *"take energy as glucose then release it in cell cytoplasm then in mitochondria and used by cell"* (12-45-1999). These reasons were given in response to Item 7 of Questionnaire 1 'In the process of respiration, energy in sugars is converted into energy that the cell can use to do things.'

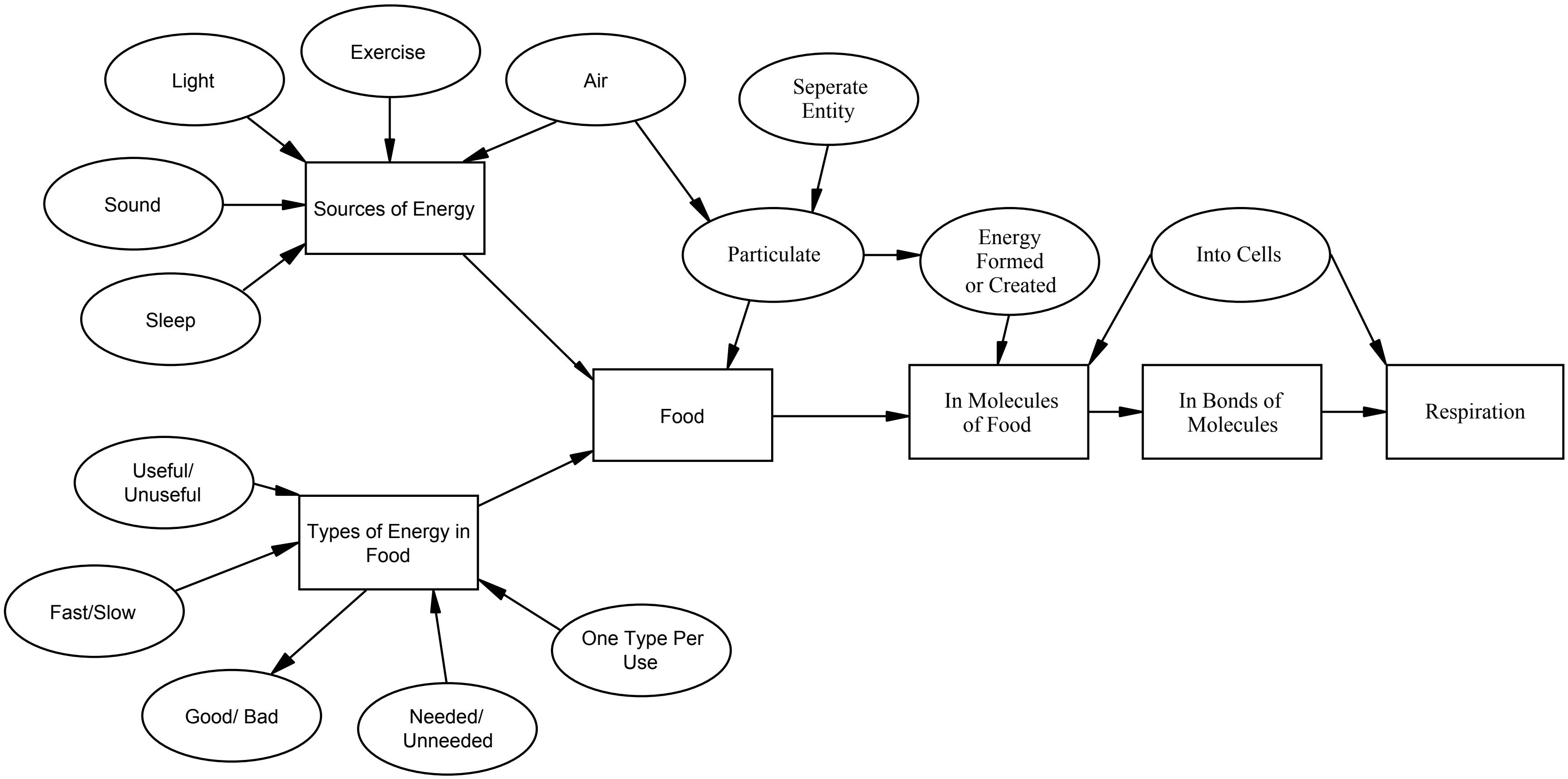

Figure 6.6: Possible conception pathways showing students' notions of the relationship between the sources, types, location and nature of energy in external energy sources used by the human body based on Figures 6.1, 6.2, 6.4, 6.5

Figure 6.6 shows one combination of the pieces of knowledge held by a number of students of different ages based on the responses to a number of the items on the questionnaires. These combined responses give an overall picture of the process of respiration. Part of this figure derives from Section 6.2.5 where the processing of food was discussed and could be joined onto the end of Figure 6.5.

Figure 6.7 shows a number of potential pathways that students' notions could take as they develop the conception of how the body obtains the energy in food. These pathways form a spectrum of notions that compose the overall student cohort's conceptions of how a person obtains energy from food. An individual student's position(s) in Figure 6.7 shows the accuracy of the notion(s) or overall conception held by that student and the progress being made towards the attainment of the scientifically acceptable conceptions of respiration. It also shows the conceptual development and changes needed for a student to form a more accurate conception of energy conversions and the ontological shifts required before obtaining as accurate concept of the place of energy in food through to

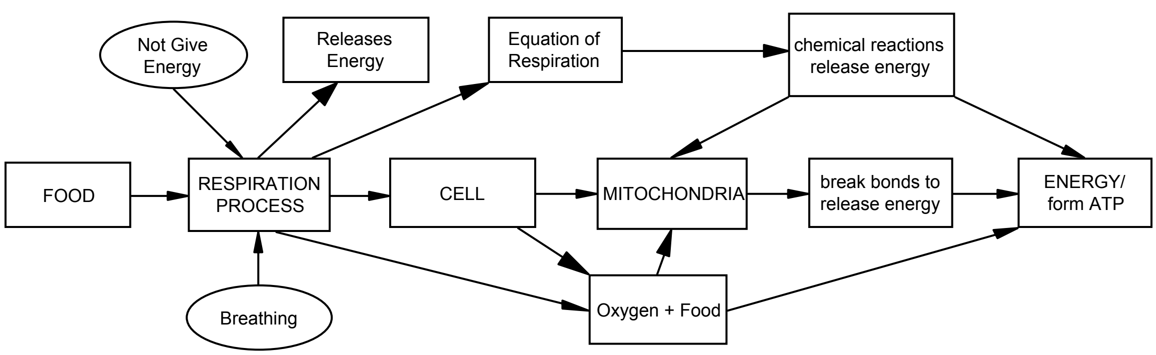

Figure 6.7: Possible conception pathways showing the notions held by students about respiration.

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the conversions which occur in the process of respiration. As student age increased, more students appeared to hold notions other than just food processing results in energy (see Table 5.6 and Section 5.3.2.2). But, no one student showed an accurate or detailed set of notions involving the breaking of the chemical bonds within the absorbed food molecules to release utilisable energy. (At the time the instruments were administered, it was not expected any student should know the role of ATP as this had not been taught in any science class in the schools surveyed.)

6.3.3 Role of Eye and Ear

The responses relating to the energy conversions of both the eye and ear were very poorly understood while a few students wrote that sound and light were not energy. Only 1.6 percent or 6 students from the total cohort discussed the conversion of the external energy by the sense organ into some other form of energy (electrical impulse) and that this energy was transferred to the brain where it was interpreted (See Appendix 16). The majority of students wrote that they thought the eye or ear collected the external energy and transferred this energy straight to the brain where it was interpreted. A small number of students thought the retina or eardrums were involved in this collection of the energy and its transfer to the brain for interpretation.

From the full set of written responses it is difficult to discuss a potential pathway of conceptual development for either the eye or ear and their role in energy conversions but this information does build on the data on vision discussed by such authors as Boyes (1991b), Collis *et al.* (1998), Guesne (1985) and Osborne *et al.* (1993).

6.3.4 Role of Sleep

Students wrote that they thought sleep was involved in energy production in a range of ways. An important notion was that sleep revitalised or recharged energy. What this revitalization meant was not made clear but during the interviews (Section 3.2.2.3 and 4) this notion was defined as the replenishing of the energy but no students who made this claim indicated that how this revitalization occurred.

Other students wrote that they thought more energy was used than gained during sleep — *"we lose energy when we sleep because we use energy to move and to breathe"* (9-18-1999), — *"we use energy when we sleep for example when we move and breath we do not get energy from this"* (9-25-1999), — *"when we sleep we use energy, not gain it* (10-42-1999), *when we sleep we burn energy not gain it"* (11-33-1999). Still other students thought more energy was created than used and so the supply of energy increased — *"because when you sleep to replenish your energy supplies you just do not use as much of it"* (8-91-1999*),* — *"because when we sleep we store energy that hasn't been used"* (9-27-1999), — *"we still burn food while we sleep therefore we still get energy even though we may not use it"* (10-39-1999), — *"we burn energy not gain it. Although the* *amount of energy burnt while sleeping is no were near the amount of anything such as running"* (10-40-1999).

6.3.5 Role of Air/Oxygen

A number of views on the role of air or oxygen were expressed in the written responses which ranged from the particulate model of energy, energy is in the air, air is involved in respiration to air/oxygen combines with sugars or fats to release useable energy.

The roles of the eye, ear, sleep and air/oxygen in the production of useable energy for the human body as revealed by the student year-cohorts are illustrated in Figure 6.8.

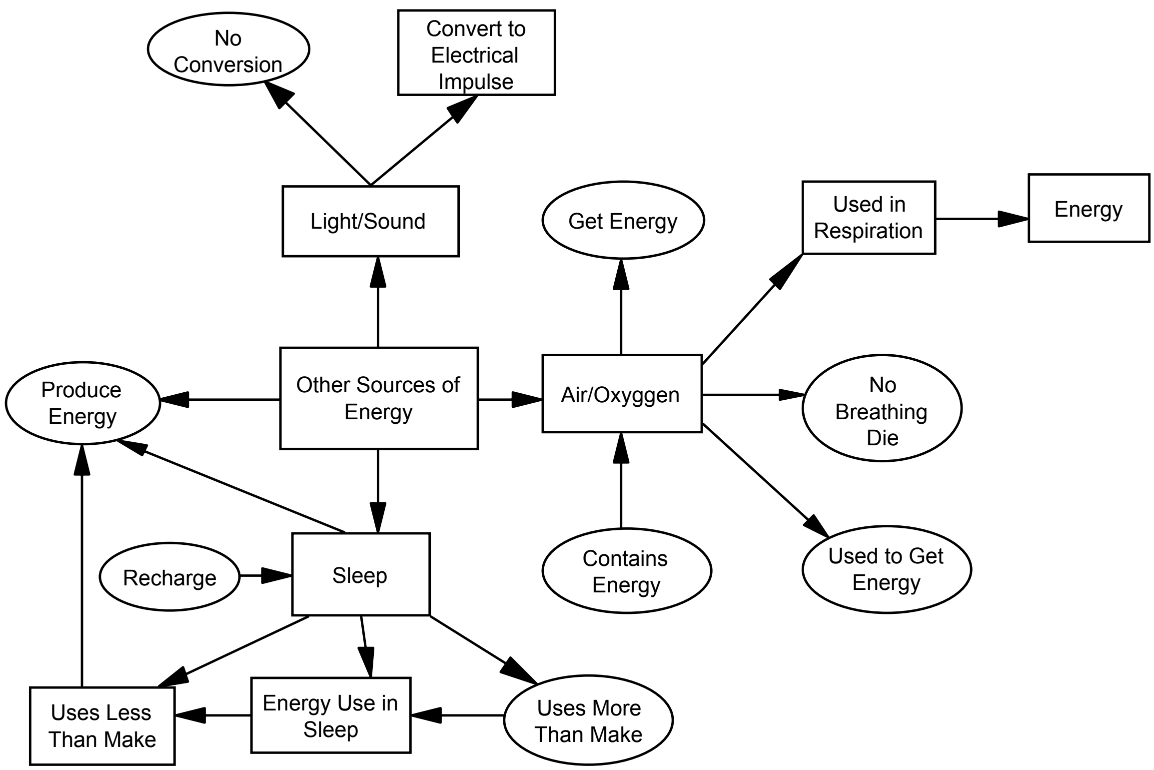

Figure 6.8: Possible conception pathways showing students' perceptions of the role of the sense organs, sleep and air/oxygen in the production of useable energy.

6.4 USES OF ENERGY

From the previous discussions on energy conversions, there were many misconceptions with respect to the types of energy present in food, the subsequent conversions of this energy, the role of the eye or the ear and of respiration in the conversions of energy into useable forms. This is apparent for many of the other energy uses by the body for example, the role of lipids, the use of energy to ride a bicycle and the utilisation of heat and the body's regulation of heat content which is more commonly referred to as temperature regulation.

6.4.1 Role of Lipids as an Energy Source

Across all year cohorts many students wrote that if excess energy is absorbed, it is stored as fats or in fats (See Table 6.4). There are two distinct meanings in this energy storage. Energy is stored as fats implies the energy is converted into lipids and stored while energy stored in fats implies the energy is transferred from the food into the lipid molecules.) A majority of Year 8 students wrote that the excess energy is permanently locked away in the fat but this changed in Year 9 when the energy was seen as being stored in the fat for later use (when needed). This has been further discussed in Section 5.3.2.1 and 5.3.2.5.

Table 6.4: Percentage of each Year cohort who claimed excess energy was absorbed and stored as fats.

Year 8	Year 9	Year 10	Year 11	Year 12
5	17.4	22.6	38.9	39.7
n = 79	n = 69	n = 119	n = 116	n = 68

Note: n is the total number of students who responded to the relevant items.

The role of lipids in energy conversions and conservation is shown in Figure 6.9.

6.4.2 Use of Energy to Ride a Bicycle

The use of a common experience such as riding a bicycle in the questionnaires was designed to investigate a situation familiar to the students who dealt with energy transfer. But it would appear many students of all ages had not thought about what was occurring when they rode a bicycle as a number of misconceptions about energy use were revealed.

These misconceptions included the problem of animacy, the bicycle making its own energy, the bicycle not needing energy as it made its own to move and all the energy is used up by the person's legs and so cannot be transferred to the bicycle.

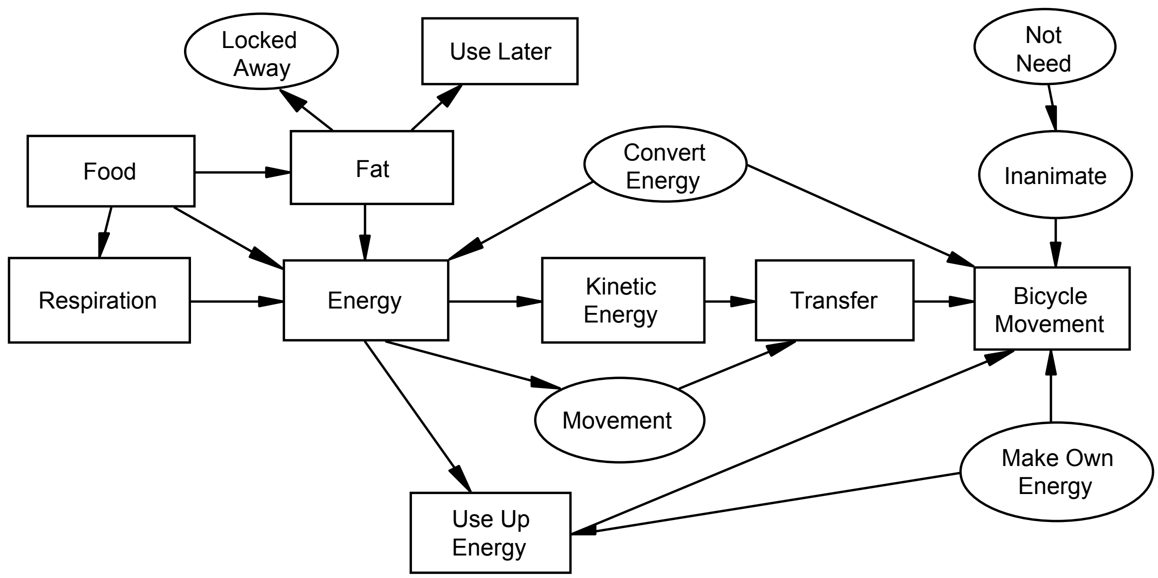

Figure 6.9: Possible conception pathways showing student perceptions of the energy conversions of excess energy and in riding a bicycle.

A small number of students wrote that they thought the bicycle received energy from the person while others wrote that the energy in the legs was transferred to the bicycle or more specifically the bicycle's pedals and so the bicycle moved. Other students claimed the person's energy was converted into the kinetic energy of the bicycle but no students discussed the kinetic energy of the legs being transferred to the bicycle although a few wrote that there was leg movement involved. Only a minority of students in Years 11 and 12 discussed kinetic energy as being involved with only four Students in Year 12 discussing this kinetic energy being transferred – "*human kinetic energy is transferred to mechanical energy so that the bike will move*" (12-4-1999). The use of kinetic energy as a reason was discussed in Section 5.3.2.2. This response reflected the students' better understanding of movement or kinetic energy and its transference. The younger cohorts of students may have been exposed to this concept but had not transferred this knowledge to a variety of situations outside those used in classes and were not able to provide a reason to this question.

The conversions of excess energy from food to lipids and the conversions and transfers of energy in the riding of a bicycle are illustrated in Figure 6.9.

6.4.3 Body Heat Regulation

Body heat regulation is more frequently referred to as body temperature regulation in everyday language because it is the temperature of the body that is measured as an indication of the heat content of the body. In the following discussion, I shall frequently use body temperature where appropriate since this was the fashion in which the questionnaire items were phrased and also this is the more commonly used terminology.

The concept of body heat regulation is composed of two major sections, one involving the obtaining of the heat energy and the other the regulation of this heat within the narrow temperature range required for correct functioning of the body.

6.4.3.1 Body heat formation

The manner in which the body obtains its heat and hence temperature revealed a number of misconceptions such as blood has a temperature and so the body gets its temperature, that heat is caused by blood circulating and heat comes from clothes of various types. Only three Year 8 and Year 9 students held these clothing-related notions of energy creation or formation while the role of friction as blood moves through the blood vessels as a cause of heat and hence temperature was used by five students in each year up until Year 10 (refer to Appendix 16).

Many students (in all years) held the more accurate concept of the body heat arising in some way from the chemical reactions occurring in the body. These chemical reactions included the body burns sugar to produce heat, energy is burnt to produce heat or that chemical reactions caused, created, transferred or released heat. These various notions are illustrated in Figure 6.10.

6.4.3.2 Body temperature regulation

The items that examined this notion did not investigate the exchange of heat with the environment through the agencies of convection, conduction and radiation; rather they investigated the role of sweating as one aid to temperature regulation. From these questionnaire items, students revealed a number of ways whereby sweat cooled the body. These ways ranged from sweat heating the body, having no effect at all and being helpful. Reasons given included the body cools because sweat or water comes out of the body or that sweat cools the body due to evaporation or when the wind or air contacts the sweat.

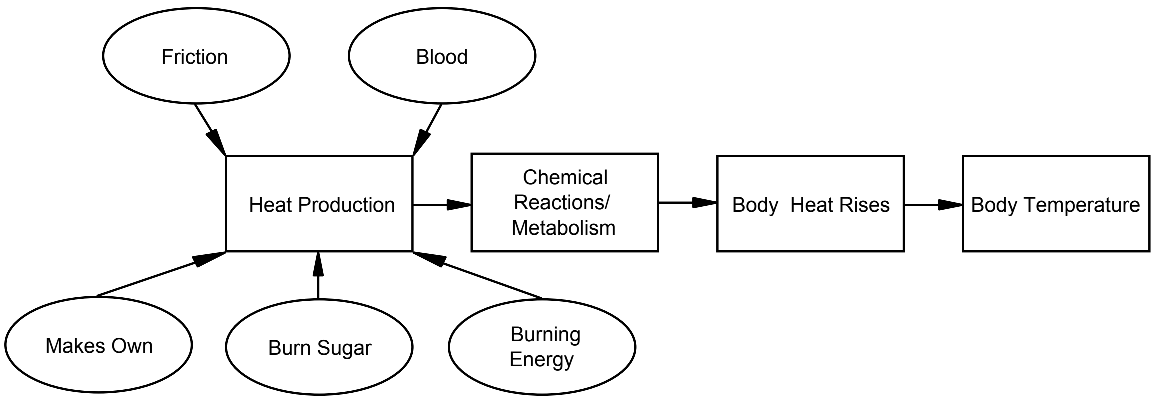

Figure 6.10: Possible conception pathways showing students' conceptions involving heat production by the body.

The role of evaporation was not accurately described until Year 10, while prior to this age any mention of sweating was to claim sweat does not cool the body rather it just makes the sweat disappear into the air. Even in Year 10, the idea of how the evaporation process acts as a cooling agent was not clearly indicated, just that it does cool the body. In Years 11 and 12, the need for heat to facilitate evaporation was recognised by only a few students with many students in these cohorts holding notions similar to the Year 10 cohort.

A popular misconception held by students of all years was that air or wind cools the body when it comes in contact with the sweat or skin. Other misconceptions involving sweat were that sweat was not involved in cooling at all while another conception of each year-cohort was that sweat takes heat with it as it leaves the body. — *" because sweating gets rid of our heat"* (8-91-1999), *the heat goes out through the water"* (10-135-1999), or that the heat leaves the body when it sweats — "*Even though the heat is leaving us…*" (8-93-1999), —*" the sweat still lies on our skin so only the heat goes away"* (9-50-1999), — *"the heat is reacting with the water in our skin which makes us sweat, to release the heat"* (10-89-1999) and — *"when sweat evaporates heat goes with it"* (11-6-1999). It is not clear whether this latter concept was claiming sweat carried heat away as it leaves the body or that the process of sweating requires heat for it to occur. It is possible that this latter notion could fit in with the substance-like nature of (heat) energy.

Figure 6.11 illustrates some of the more commonly held conceptions on the role of sweating and temperature regulation.

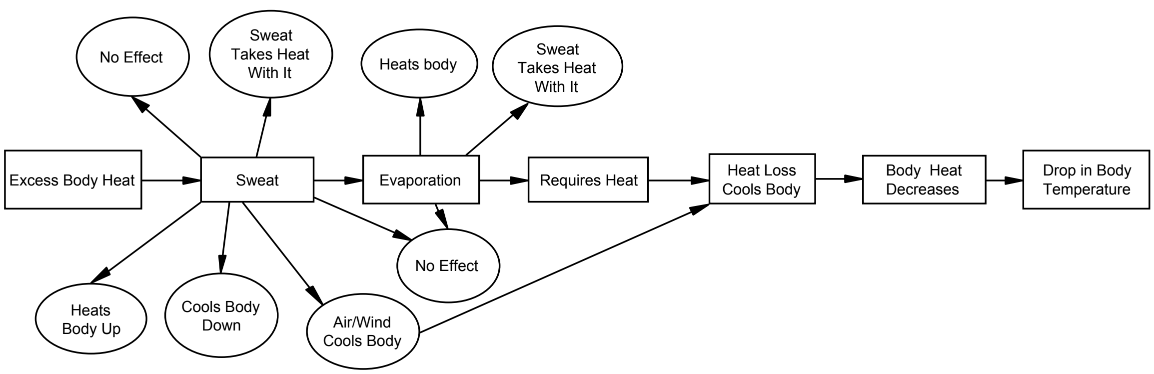

Figure 6.11: Various student conceptions of sweat and its role in body temperature regulation

6.5 SUMMARY OF CROSS SECTIONAL CHANGES IN STUDENT NOTIONS OF ENERGY

From the discussion above and in Chapter 5 on energy conversions and their uses by the human body it can be seen that the conceptions held by the majority of students in this study are not scientifically accurate. In addition, those conceptions that are close to accurate are not expressed in detail. Whether this is due to the manner in which students wrote their reasons in as short a fashion as possible or that this was all of the detail they could give is unclear. Nevertheless, it can be seen that a series of smaller conceptions are involved in the formation of a whole scientifically accurate conception. With a composite picture of the overall conception, it is possible to see the changes that need to be made for a student to develop a more scientifically acceptable conception. Through the use of the conceptual development pathways (Figures 6.1, 6.2, 6.4 to 6.11), the location of various pieces of the overall conception that are held by a student and what is needed by that student to develop a scientifically acceptable notion can be determined.

A number of notions have been shown to change with age and an increasing amount of formal education. Such notions as the amount and types of energy in food and how the body gets the energy from the food, energy conversions and the role of the eye and ear in energy conversions and energy transfers. How and why these notions change during the development of more acceptable notions has not been demonstrated but a series of pathways have been proposed which may indicate possible directions taken during the development of a concept.

6.6 AN ONTOLOGICAL PERPECTIVE OF ENERGY

This research did not set out to specifically study the ontological thinking of the students as have a number of researchers such as Chi and Slotta (1993), Chi, *et al.* (1994), Mariana and Ogborn (1991 & 1995) and Chittleborough, Hawkins and Treagust (2001). Consequently, the research items were not formulated to show trends or changes in conceptions as they developed in individuals. As well as not specifically targeting ontological changes, the following discussion is based upon data analyses for year-group results and not those of any individual. Nevertheless, it is possible to describe some ontological features of the students' conceptions that were studied. By following a set of consecutive age-cohorts (Years 8 to 12), a overview of some of the potential changes in cognitive frameworks can be observed. Teaching experience suggests that many students will follow sections of the pathways discussed previously in this Chapter and illustrated in Figures 6.1 through to 6.11.

For a person to understand energy and its involvement with the human body, a number of concept areas are required within that person's overall conceptual framework of energy. These would include such aspects as a functioning operational definition of energy, an understanding that energy is an abstract entity, the main types or forms of energy, various sources of energy and how conversions and transfers of energy occur. However, it is not necessary to have a physicist's understanding of energy. With a clear understanding of these general energy features it should be possible to transfer and apply the currently held knowledge to novel situations involving the human body. But in association with these energy concepts, a number of related phenomena need to be understood to form some further background knowledge, for example, evaporation, digestion and respiration as well as knowledge of the way the eye and ear work. Without this background knowledge, it would be difficult for any student to hold and show a scientifically acceptable knowledge framework of energy and the human body. Once this background knowledge is developed, it should be possible for an individual to apply the underlying general concepts of energy to situations involving the human body.

To have an understanding of what is happening with respect to energy in a given situation students need to be able to identify the type(s) of energy initially involved in the situation, what changes to the energy are occurring and what types of energy are finally present. For example, when lifting a ball what are the starting energies involved and as the ball is raised what are these energies being converted into and where are these energies being transferred? With this procedure on energy, it should be possible to apply student knowledge to specific situations.

From an analysis of the data collected from 610 students discussed in Chapter 5 and previously in this Chapter, a number of points were made about the quantity and quality of the subjects' knowledge of energy and the human body. Perhaps the most relevant points to bear in mind are the students' general lack of knowledge in the area of energy conversions, in particular the role and processes of respiration as well as the operation of the eye and ear with respect to their operating mechanics and the energy conversions involved in seeing and hearing. Also, many of the written reasons given by the students were of a general nature and did not have a lot of detail that could be used as evidence of concepts held by students.

As the students' age increased the percentage of responses which were of a general nature decreased which indicated the development of a more coherent and scientifically acceptable cognitive framework with respect to energy and the human body. This development was noticeable in a number of areas such as energy in food, the role of respiration and energy conversions and will be further discussed in this section on ontological changes.

To change or adjust any misconception within the conceptual domain of energy will require an ontological change, the degree of which may be revolutionary which according to Chi and her co-researchers would involve a change of categories while a evolutionary change would involve a change within a category (Chi *et al.* 1993). The data in this study have revealed conceptual changes as being both revolutionary and evolutionary in nature.

Figure 6.1 through to 6.11 are composites of all the students' conceptions and illustrate a number of possible pathways of conceptual development. By using the ten figures previously developed as guides, it is possible to locate where an individual is positioned within this proposed developmental framework and hence to identify what is required for him or her to form a more comprehensive and scientifically accurate conception of energy and the human body. From this knowledge of a student's position, the degree of change needed for better understanding of the concept by the student could be gauged and what is required to attain a scientifically acceptable concept can be found.

6.6.1 Nature of Energy

During the data analysis it was found some students did not have a conception of energy as an abstract phenomena, rather it was seen as being substance-like (particulate, bundle or an ingredient). This misconception makes student understanding and interpretation of many situations difficult when energy is transferred or converted. To explain conversion and transfer situations, many students having this concept would either hold the idea of energy being destroyed and created or that there was a specific energy for each energy-requiring activity. In either of these cases, a major change to the notion of what energy is will be required before many other energy-related phenomena could be explained or understood. This change is revolutionary in nature, as it needs a tree shift from substance/concrete to the process/abstract trees described by Chi *et al.* (1993).

Some students had a poor knowledge of the various types of energy as evidenced by the claim that sound and light were not types of energy and that there was good or bad, useful or not useful and needed or not needed (see Figure 6.4). The latter conceptions are very simplistic in their nature and require a change in the understanding of the meaning of energy types to include the various forms of energy and the removal of the idea of energy being either good or bad, needed or not needed useful or not useful.

All students made the claim that humans get energy from food but where the energy was located within the food led to differences of opinion (Chapter 5.3.2.3 and 6.2.5). Energy was seen by a number of Year 8, 9 and Year 10 students as being separate from the food molecules themselves (Chapter 5 3.2.3 and 6.2.5) and as being either particulate or an ingredient of the food (similar in nature to the food groups) (see Figure 6.2).

The nature of energy as substance-like or concrete in nature corresponds to the work of Mariana and Ogborn (1991) and early work by Piaget where these authors claimed that young people will ascribe concrete properties to invisible or abstract phenomena to better suit their mental development (Bliss, 1995). This view of energy places it in the tree of Matter (Chi *et al*., 1993) and requires a shift from this tree to that of Events. Evidence for placing energy into the substance tree was based upon the predicates of Slotta *et al*. (1995) which included terms such as moves, consumes, particulate, used up, accumulates, contains, stored, supply and absorbed all of which were found in the reasons written by students. This ontological shift from energy as concrete to abstract is a revolutionary change in conceptualisation since it is from the tree of Matter to an Event as described by Chi *et al*. (1994) or from Object to Cause of Mariana and Ogborn (1991).

From these matter-like conceptions of energy, the way the energy was made available to the body was through digestion releasing the energy from the food and so making it available for absorption and immediate use. In the Year 10, 11 and 12 cohorts, the idea of energy being within the molecules of specific food groups such as vitamins, minerals, carbohydrates, lipids, sugars and protein was common. No indication of where in the food molecules the energy is located was discussed except for three students in Year 12 who held the notion of the energy being in the molecular bonds of the food. This notion of energy within the food required a separate process to facilitate the availability of the energy to the body after the food was absorbed. This separate process took a number of forms, some of which included the general response that digestion changes the food or 'burns food for energy' or 'converts to energy' or involving the process of respiration.

With an understanding of the types of energy and the removal of energy as a substance, it is highly feasible that the notions of obtaining energy from such things as sleep and air will be deleted from the knowledge framework as these are inconsistent with the acceptable types of energy conception. Also, with an improved understanding of energy conversions and the role of respiration, the students could similarly delete their concept of energy gained from exercise.

6.6.2 Energy Conversions

The conversions of energy within the body are some of the more frequent occurrences that students may experience in life. Since these conversions are so frequent they are a key to an understanding of energy use by the body but many students failed to show an understanding of or failed to recognise energy conversions. It is difficult to tell whether the students either do not hold an understanding of energy conversions or that they are unable to transfer or apply their knowledge to novel situations. Since ontological development was not specifically studied, data supporting either of these views was not specifically gathered. But, from the data examined it would appear that many students do not have an understanding of energy conversions and those students who do show some understanding appear to be unable to apply this knowledge to new situations such as those the human body.

The students in Years 8 and 9 have been exposed to a number of formal lessons on energy conversions using physical science examples such as batteries, car engines and motors running. It would appear that with increased exposure to energy conversions many students had developed a better understanding of and ability to apply their knowledge to novel situations such as the energy conversions within the human body. This was evidenced by an increase in the number of older students (Years 10 to 12) showing an understanding of energy conversions (Referred to in Section 5.3.2.2). Whatever the case, an understanding of energy conversions is essential when thinking about energy and the human body, as there are numerous situations where these occur. Those students who understand that energy cannot be converted or hold the view there are a number of different energies each with a particular function require a large ontological shift in their conception of energy to be able to understand how the body uses energy. In particular, those students who think there are specific energies for each function need to change to the notion that energy can be converted from one form to another and that the body can use a small number of energy types to function the most commonly used being chemical energy.

In association with the weakness in energy conversions is the lack of knowledge of body organs and how they work, for example, the eye, ear, gut and also the cell. This lack of knowledge is likely to be detrimental to the facilitation of knowledge transfer to situations involving the human body.

With respect to respiration, as an example of both an energy conversion process and the details of the process itself, there was a paucity of accurate responses or information, which could be used to judge student-held concepts. Nevertheless a trend in possible student pathways to attain a set of scientifically acceptable concepts can be seen in Figure 6.7. It would appear that those students who do have some knowledge regarding the process of cellular respiration do not hold misconceptions but rather they lack detailed knowledge of the overall process.

Figure 6.7 shows a number of students' notions that require major changes, for example, the notions of no energy production and that respiration is another name for breathing. To understand the role of respiration as the process that supplies the body with the useable energy form or 'universal energy molecule' (ATP), it is necessary for a student to be able to distinguish between (cellular) respiration and breathing and that they are two separate entities with the unfortunate situation of having the same name (Mann & Treagust, 1998).

Other concepts in this figure require varying degrees of adjustment to held conceptions from a small alteration in the case of the general equation for respiration and the response of — *"oxygen + food gives energy"* (10-3-2000) or — *"oxygen + food → energy + water + salt"* (9-25-1999) to other conceptions which require a more detailed development of the idea of respiration releasing energy. None of these changes involve shifts across the Trees of Chi and her co-workers as all are within the same category (Changes). Rather, the change involves the addition of more information to the held conception. Students who did hold some of these smaller or partial concepts would need to further develop the missing areas and then combine their concepts to form a coherent whole (accretion of knowledge) rather than disband their held concepts and then develop new conceptions as would be required under a revolutionary shift.

The role of the eye and ear in converting energy showed that many students think the organ merely collects the external energy and transfers it straight to the brain where it is interpreted. Before the energy conversions which take place can be understood, the functions of the various parts of each organ need to be understood. Then the role that the organ plays in the converting of the collected energy into brain-interpretable energy can be understood. It would appear most students who have misconceptions about these organs do not know how they function and hence that they do convert energy from one form to another. To understand the energy involved in these functions requires the development of new knowledge and the removal of the unfounded material.

An energy conversion that showed a change in thinking was the role of fats in the body. Year 8 and some Year 9 students thought that fats are permanently locked away surplus energy while most of the older students explained that the energy in lipids is stored until needed later by the body (Chapter 5.3.2.1). The change from being locked away to being used later came about with the understanding that we use fats as an energy source and then linking this to the stored lipids in our body.

6.6.3 Body Temperature Regulation

As with the conceptual areas already discussed, this section requires knowledge of some related scientific principles before an understanding of the regulation of body temperature can be explained. An example is evaporation and the notion that chemical reactions in the human body are mostly exothermic. Without an understanding of evaporation, explaining the removal from the body of heat via sweating cannot occur and leads to inaccurate conceptions being expressed. These findings indicate a linking of an observation of the cooling effect to air or wind contacting the sweat. Similarly, explaining body heat (and temperature) is difficult without an understanding of exothermic reactions or more easily the fact that heat is evolved during chemical reactions which occur in the body.

6.6.3.1 Heat Gain

The gaining of body heat as a by-product of metabolism and the various student explanations of this heat gain are shown in Figure 6.10 which shows a number of misconceptions of where the heat comes from. While students of all year-cohorts had the notion of heat coming from chemical reactions, this became increasingly prevalent as the students' age increased. Many Year 8 and 9 students showed that they had little concept of the difference between temperature and heat and in fact used these terms synonymously as evidenced by statements such as — *"body temperature is due to chemical reactions"* (9-41-1999) and — *"body produces its own temperature"* (8-24-1999).

The role of friction as producing heat was held mainly by Year 8 students and reflects the recently taught concept of friction giving rise to heat. Students appear to have transferred the idea of friction in a physics context to the movement of blood causing friction and hence heat. While technically this is correct, it is an insignificant contribution to body heat. In this case to become more accurate about the main source of heat, it is necessary to introduce heat as a by-product of chemical reactions. This is an addition of new knowledge and does not involve the deletion of any concepts. Once again the conversion of energy (and the efficiency of this process) is required to explain heat production during exercise and its subsequent use or removal by the body.

Some students think the role of exercise is creating heat rather than heat being a by-product of the energy conversions required for exercise. This adjustment needs an understanding of energy conversions with the by-product being heat. In this case, the change is from the category of Events with a cause to the category of Process (Chi *et al.* 1994). The burning of sugar or energy to produce useful and useable energy is a result of misconceptions on both the nature of energy (as being substance-like) and the conversion of energy (previously discussed).

6.6.3.2 Heat Loss and Sweat

The method by which sweat cools the body showed a major problem with the conceptions of a majority of students since they did not understand the process of evaporation (and its requirement for heat) and this lead to a number of misconceptions about sweat and cooling.

The notions held were a result of casual observations that the body gets cool when a wind blows on sweat and a guess at explaining why the body may cool down when it sweats. To remedy this, it is necessary for the student to understand the process of evaporation and how heat is involved. Once this process is understood, the conversions and transfer of heat energy can be accurately employed to explain heat losses, but before this the student can only really guess at reasons for body cooling via evaporation of sweat.

The concept of energy being transferred to sweat and its subsequent removal from the body when the sweat leaves the body was held by a number of students in each year. This misconception can be possibly linked to the particulate nature of energy with the heat particles moving into the sweat or the heat energy transferring to the sweat from the body and thence leaving the body with the sweat. With a better understanding of the abstract nature of energy there should be a conflict in the student's mind between the abstractness of energy and the particulate notion of energy since the former fits into the Process tree and the latter the Matter tree. With reinforcement, this conflict could result in an acceptance of the scientifically acceptable notion.

Another source that would give rise to this problem and the other discussed misconceptions is the lack of understanding of the processes and role of evaporation and the energy transfers and conversions that occur. A closer understanding of the starting and finishing energy situations would reveal the changes that have occurred to the energy and hence the role of energy conversions rather than transfers taking place when evaporation occurs. The latter involves a change in energy location and the former involves a change in energy types in the case of evaporation both processes occur and ultimately leads to the body cooling.

6.6.4 Transfer of Energy

The common experience of riding a bicycle also showed-up a poor understanding of energy transfers, a general lack of knowledge or an inability to transfer knowledge to a new situation. Responses to this item about riding a bicycle also gave rise to a number of previously identified concepts such as the animacy conception (Bliss, 1985; Gilbert &

Watts, 1983; Kruger, *et al.* 1992; Nicholls & Ogborn, 1993) and energy possession or lack of transfer (Gayford, 1986b; Gilbert & Watts, 1983; Kesidou & Duit, 1993). Figure 6.9 shows a number of student concepts related to energy use in general and related to the involvement of energy when riding a bicycle.

There are two major misconceptions (bicycle makes its own energy and the animacy requirement for energy) which both require revolutionary changes to the possessor's cognitive framework before that student could hold more scientifically acceptable notions. There is a need to change the animacy concept to one involving energy transfers irrespective of the nature of the object receiving the energy. This is a conceptual shift from the Object or Matter tree to that of the Process tree.

The second concept of the bicycle making its own energy also involves the development of the energy transfer concept. This is an ontological shift within the Process category from an Event to the Constraint-Based Interaction (Chi *et al*., 1994) or the Acausal category of Mariana and Ogborn (1995). Once this process of energy transfer is understood, the old inaccurate concepts would then be relegated in status and eventually be deleted and forgotten. The application of the new concept (transference) to the riding of a bicycle should then be easier than with the old misconceptions.

From this investigation of the ontological changes needed for scientifically acceptable conceptions of energy and the human body, a number of areas in the domain of energy need to be developed before they can be applied to the human situation. Conceptual areas such as the abstract nature of energy, the ability to transfer energy and that energy can be converted into other forms needs to be formed and developed. Also, a number of associated concepts need to be understood, for example, evaporation, digestion and respiration and the way the eye and ear function. In conjunction with the development of these conceptions, the ability to transfer knowledge to novel situations needs to be developed.

This analysis of ontological frameworks and the changes to these frameworks that may be needed by students to have a scientifically acceptable understanding of energy and the human body show some changes to be revolutionary and others evolutionary. Many of these misconceptions need to be adjusted in a specific sequence such that the underpinning or foundation concepts are taught first so that the related energy concept(s) can be built upon these foundation conceptions. For example, the concepts of evaporation and types of energy precede the role of sweating as a cooling agent.

6.7 SUMMARY OF CHAPTER

In this chapter, a further analysis of the data collected from the administration of the two questionnaires previously analysed in Chapter 5 was performed. This cross sectional analysis revealed a number of changes to conceptions that occurred as student age increased from Year 8 through to Year 12. Further, these changes to conceptions were studied to reveal the ontological shifts necessary for the observed conceptual changes to occur.

While a number of possible conceptual changes were identified, a number of concepts that underpin much of the energy domain with respect to energy and the human body were also revealed. These concepts centre around the abstract nature of energy, students being able to identify when energy conversions take place, the process of evaporation, an understanding of how various body organs function and how energy is involved with these organs. The organs examined included the eye, ear and alimentary canal. The role of digestion and the role of the cell in respiration were other energy-related areas that created problems for many of the students. With an understanding of these various conceptual areas involving energy and the human body many of the misconceptions discussed in this and the previous chapter could be reduced or eliminated.

A perusal of the students' written responses revealed a change in the nature of these responses. Those from the Year 8 students were very general in nature, with few scientifically acceptable answers from Year 8 students, through to more specific and scientifically acceptable answers from the Year 11 and 12 students. The sense and words used and the notions held persisted across the five year-cohorts as did the notions as they related to food and energy, the role of digestion and of respiration, the role of the eye and ear, the types or forms of energy and body temperature regulation. But there was a gradual change to an increasing number of students writing more scientifically acceptable notions as the age of the cohort increased.

The types or forms of energy that the students conceived were many and varied and showed a lack of appreciation that energy was an abstract entity and not a substance. In association with this was the lack of understanding of there being a number of types or forms of energy and that the body utilises a number of these energies. Students felt energy was good or bad or as being useful or not rather than the chemical energy in food being a type of energy that the body used as one of its primary energy sources.

To rectify this types-of-energy misconception requires a student to undergo a number of ontological shifts, one of which was from energy as being concrete in nature to it being an abstract entity. In association with this shift was the change in the meaning of the term 'types of energy' from the everyday meaning revolving around its usefulness to that of the scientific notion of there being a number of forms, for example, chemical, light and sound energy. With an understanding of the term 'forms or types of energy' should come the ontological shift from light and sound not being viewed as energy, as well as the removal of such perceived energy sources as sleep, air/oxygen and activity and also the removal of the useful energy notion.

The conception of energy as an entity that has a number of forms that can convert to each other should also create dissonance in those students who think energy is a substance. This dissonance should lead to a different view of energy changes or conversions and also the view that energy is created from substances such as food or sleep and that energy cannot be destroyed only converted into other forms.

The concept of there being a number of types of energy, one of which is chemical energy would be the initial impetus to the development of the conception of the energy in food being within the food molecules and eventually to being in the bonds of the food molecules (See Figure 6.2).

The processes (examined by the two questionnaires) whereby energy is obtained from the environment and utilised by the body included digestion, seeing and hearing. In all of these areas, student-held misconceptions revolved around naïve notions such as the nature and location of energy in food and the process of digestion and the functioning of the eye and ear. The latter notions revealed most students had little understanding of how the eye or ear functions and that the initial energy is converted by the organ into the electrical impulses or action potentials of the nervous system.

The process of obtaining energy from food centred about how the students viewed the nature of the energy in food. If the energy was thought to be substance-like and an ingredient of the food, digestion was thought to release this energy from amongst the food molecules. As the student cohorts became older their view of the nature of the energy in food changed to it being located within the food molecules. In parallel to this notion was the concept of the processes of respiration being involved in making this energy available for the body to subsequently use.

While the energy conversion process of respiration was not well understood by the majority of students, it did become more accurate and detailed with ever increasing student cohort age. The initial or underlying conceptual change in this situation involved a change in the view of the nature of energy from being substance-like to being non-substance-like or possibly abstract. Once this ontological change had become part of the student's cognitive framework, information relating to the details of respiration could be incorporated. These incorporations were accretional in nature rather than a conceptual change involving the removal of a prior notion or its modification.

In general, energy conversions were poorly understood with a number of students from each of Years 8 through to Year 12 holding the view of energy being created or burnt to form another type of energy. There was a gradual change from these conceptions to that of energy being transformed from one type of energy to another. This change could be linked to students having developed an understanding of there being a variety of energy types or forms (and the abstract nature of energy) and their conceptions with each other.

A number of students in all years held the view that energy for body use could come from air, sleep and activity. These three ideas declined with age and the development of more acceptable notions on the nature of energy and energy conversions. Likewise, the involvement of energy conversions and transfers in riding a bicycle also improved with student age.

The regulation of body temperature also showed a more scientifically acceptable set of notions as the students age increased, with many students holding the concept of heat energy (or temperature) coming from chemical reactions (or metabolism) within the body. There was a major shift from there being a range of heat sources to this acceptable notion between Years 8 and 9. But while these heat sources declined in the frequency of their use as student age increased they persisted right through the student year cohorts.

The role of sweat and how it helps cool the body and the decrease in body temperature was poorly understood, possibly due to a lack of understanding of the process of evaporation and its role in this situation. As an understanding of evaporation improved so did the role of sweat and how it effects heat loss and hence the body cooling down.

Many of the conceptions identified and the changes necessary before students can develop a scientifically acceptable set of conceptions regarding energy and the human body are all inter-related and rest ultimately in the student's understanding of a number of basic underlying conceptions. Examples include the types of energy, energy conversions and transfers and a number of associated principles such as digestion, respiration and evaporation. Without these conceptions it is difficult for a student to identify what is occurring in a novel situation such as energy and the human body, which it is felt is infrequently covered in a classroom situation.

This Chapter has responded to the questions related to Objective 2 which has as its aim to look at the changes in student notions and how these notions change over time. This chapter has discussed the changes observed and has proposed a number of possible pathways that these changes could take as a learner develops an acceptable concept with regard to energy and the human body.

In Chapter 7 a series of two-tier true/false diagnostic items was developed. These items were based upon the unacceptable conceptions discussed in this and the previous chapter while in Chapter 8 an interventionist teaching strategy was developed and subsequently tested on a group of Year 9 students. This strategy involved the nature and location of energy in food, the digestion and absorption of this food and its subsequent processing through the process of respiration to yield utilisable energy.

CHAPTER 7

DEVELOPMENT OF A TWO-TIER DIAGNOSTIC INSTRUMENT

7.1 INTRODUCTION

The present study reported so far has involved an analysis of student conceptions in energy and the human body and their underpinning reasons (Chapter 5) and the changes in these notions with student age (Chapter 6). But for teachers to identify their students' conceptions and underpinning reasons by the methods used in this study to date (interviews and questionnaires) is extremely time consuming. To study the literature in the area of energy or even energy and the human body and then from this information to attempt to estimate the students' conceptions is not economical in time usage nor is it very informative since there are numerous conceptions reported in the area of energy. Few of these reports have the underpinning reasons for the conceptions identified. For these reasons, there is a need for a set of simple pencil and paper items which will facilitate the easy identification of student-held conceptions and their underpinning reasons for energy and the human body.

This chapter describes the development of such a set of diagnostic items that could be utilised by a busy classroom teacher as an aid to the identification of conceptions held by students and the underpinning reasons for these conceptions. The diagnostic items were combined to form two instruments. The items in the finished diagnostic instrument assess recallable student knowledge and misconceptions held by students in classes from Year 8 to Year 10 and possibly up to Year 12 in the area of energy and the human body. These items could be used as either a pre- or post-instruction diagnostic instrument to help a teacher or a student identify areas that need special attention or remediation.

Twenty nine diagnostic items were developed and trialed via two instruments titled *Energy and Your Own Body (Blue and White* versions*)*, followed by an analysis of the data collected from this trial administration. Subsequently 17 items, plus three supplementary items were selected for a pen and paper diagnostic instrument titled *Energy and the Human Body*. This instrument can be quickly administered and analysed to aid in the identification of conceptions and the underpinning reasons in the area of energy and the human body and could be carried out by either a teacher or a student

Due to the author going on leave immediately after the implementation of the interventionist strategy discussed in Chapter 8 and a mix-up by the substitute teacher, the wrong diagnostic instrument was used as one method for assessing the efficacy of the interventionist strategy. As a consequence of this mix-up, the diagnostic instrument *Energy and the Human Body* was not assessed for its effectiveness in diagnosing what it purported to. But, the method of determining which items should be included in the final instrument partially overcomes this problem by removing items which do not assess what they purport to diagnose.

Further, in response to a report by Griffard and Wandersee (2001) a series of 'think aloud tests' were administered to a number of students from Years 9, 10 and 11 in an attempt to discover the methods employed by students when answering the initial items trailed in the formulation of the final diagnostic instrument. These think aloud tests used some of the items used in the Two Tier Diagnostic Instrument (Blue) titled *Energy and Your Own Body* (Appendix 11). The data collected from these think aloud tests was analysed to identify the methods used by students when they were responding to the initial trial diagnostic items.

7.2 METHODOLOGY

7.2.1 Item Development

The development of this set of two tier multiple choice items is similar to that discussed by Treagust (1986; 1988; 1995) and since utilised by a number of researchers (Haslam & Treagust, 1987; Peterson & Treagust, 1986; Peterson, Treagust & Garnett, 1989) and modified by Mann (1994) and Mann and Treagust (1998, 2000). The modification by Mann and Treagust was to the first tier or content section of the item where instead of a set of answers being supplied to support the item stem, there is the statement to which a true or false commitment is required. Griffard and Wandersee (2001) called this part of the item "a traditional forced-choice question" (p. 1040). The second tier of each item consists of a series of reasons for this true or false commitment and a space where respondents may add their own reason(s) if the supplied reasons are not applicable to them.

7.2.1.1 Delineation of the Study Area

The purpose of this section of the research is to construct a number of items for inclusion in a diagnostic instrument that can be used to help identify student-held concepts and their underlying reasons in the area of energy and the human body. This is the same conceptual area reported on in Chapter 5 where student-held conceptions and the underlying reasons for these concepts were identified because the study areas are both within the overarching domain of energy and the human body. For example, respiration, energy in food, sources of energy, energy conversions and transfers and body temperature regulation, the propositions created for the initial study (Appendix 1) plus the associated concept map used in that study (Appendix 2) were reused to delineate this study area.

From the data collected through the administration of the two questionnaires described in Chapter 3 and the subsequent analysis of the collected data discussed in Chapter 5, a number of areas of weakness and problem areas were identified by the author. A list of these previously identified problem areas and underlying reasons for these problem area notions was compiled and were used as a guide in the identification of the propositions that were in need of diagnostic items. The underlying reasons given as reasons for the commitments for the items in the two questionnaires were used as some of the reasons in the second tier of the diagnostic items created.

7.2.2.2 Item Formation

From the list of propositions and the questions used in the two questionnaires described in Chapter 3, a series of statements were created which reflected the identified problem areas in student-held notions in the area of energy and the human body. Each of these statements covered a segment of the processes involved in energy and the human body. Some statements were discarded because they were considered to be of low importance to students at this stage of their educational career or to not involve a significant problem. Those remaining statements were then modified so they had features in them which students may find acceptable or not since these would appear logical or reasonable to a student if (s)he had a misconception (in this area of study) or if the statement were in fact true. An example of an identified problem area was that of obtaining energy from oxygen or air or while sleeping (Chapter 5) and has also been discussed by such researchers as Boyes and Stannisstreet (1991b) and Carr *et al.* (1987).

After creating the initial list of statements, a number of statements were further eliminated or recombined to arrive at a final list of 28 statements. Each statement then became the stem or content section of an item. Some of these item stems are true, some are partially true and others are totally false. Each of the stem statements examines a number of propositions that are related to the same part of a process in the body's energy processing. For example, White items 2, 9 and 12 and Blue item 6 are related to respiration while items White 3, 10, Blue 12 and 13 are all related to body temperature and its regulation. One statement was repeated in each test but had a different set of reasons and resulted in a total of 29 items.

To ensure the major processes of energy and the human body were covered by the 29 items a specification grid comparing the propositions and items was created and is found in Appendix 9.

Within the second tier or "reason" section of many of the items there are reasons that are true or partially true and represent commonly held misconceptions or the reason appears correct due to the incorrect interpretation of student observations of natural phenomena. Those respondents with partial or incorrect knowledge of the propositions being examined by that item would most likely select these last reasons as justification for their commitment to true or false.

The reasons, wherever possible, were taken from the data collected through the administration of the two questionnaires created in Chapter 3 and discussed in Chapter 5. There was also a blank choice provided for those students who could not find a reason which matched their own in the proffered choices. In this blank section, the students could write their own reason for their true/false commitment. An example of an item is included here to illustrate each item's format (Blue item number 1).

Food is a source of chemical energy for the body and this energy is found inside the food molecules.

TRUE/FALSE

A *energy is found as little bundles between the food particles*
B *energy is found as little bundles inside the food particles*
C *energy is in the chemical bonds of the food molecules*
D *energy is both in between the food molecules and inside the food molecules*
E *energy is transformed from the food molecules*
F ____

Research suggests that if the full set of 29 items were to be administered to students many problems could arise in obtaining valid responses (Hand & Treagust 1994). The primary concern of this author centred on the time it would take students to complete the instrument since this time would be inordinately long. If the test was too long the respondents would become tired and bored both of which could lead to inaccurate responses. It is also possible that the students could work out that the time required to complete the instrument would be long and hence they would not think carefully about their responses or would guess the reasons or just switch off and not respond at all.

Accompanying this concern was the possibility that the teachers whose classes were to be involved in this section of the research would object to the time to complete the instrument and so they may not be prepared to volunteer their classes for the research.

For these reasons, two instruments were developed from this set of 29 items, one instrument of 15 items will be referred to as the White Instrument (Appendix 10) and one of 14 items (Appendix 11) which will be referred to as the Blue Instrument (since these are the colours of the paper each instrument was printed on). This naming will help reduce the confusion in naming which may arise from these two instruments and the final diagnostic instrument. These 29 items adequately delineated the area of study as defined by the proposition statements and concept map discussed in Section 3. 2.1. From these 29 items a final set of items would be kept which best helped in the diagnosis of student held conceptions. The Diagnostic instrument titled *Energy and the Human Body* had 17 items plus three supplemental items.

7.2.2.3 Pilot Testing of the Items

The draft two-tier instruments were given to three very experienced Human Biology teachers with the request that they check for any problems in readability, comprehension or any other problems they detected in each item's construction. Adjustments were made as necessary according to the feedback received.

The two draft instruments were submitted to a group of 24 Year 9 students, comprising a class of middle ability students who were studying a general science course. The purpose of this preview was to assess (i) the instrument's readability and comprehensibility, and (ii) that the items elicited responses related to the propositions the items were purported to test. Students also had the chance to comment on and re-write statements if they found them to be unclear, unable to be understood or for any other reason they felt the items to be difficult to answer. Any such re-written statement was to be replied to in the same manner as the other statements on the instrument.

Results from this trial were analysed for the student conceptions identified, the underlying reasons for these conceptions and for each item's readability and comprehension. Particular notice was made of reasons which the students wrote themselves since these reasons could indicate problems and errors missed earlier in the research or deemed of low importance by the researcher and as such these reasons possibly should be included in the reasons section for that item.

This set of student responses revealed a number of problems that were subsequently addressed by modifying the statements or reasons. The new instruments were then submitted to a different group of 29 Year 9 students of similar ability to the previous class for them to answer in the same manner. Any suggestions from this group also were acted upon to arrive at the final two instruments (found in Appendices 10 and 11). This student re-assessment of the items further ensured that the comprehensibility of the items would not be so high as to lead to problems in students' understanding and responding to the items appropriately.

Using the Year 9 students who were all of middle science ability was designed to ensure that the instruments' readability and understandability was appropriate for the target age-group of the questionnaire, namely Years 8 to 10 students (and possibly to Year 12). Students in Year 9 have the reading and comprehension ability to ensure that students in higher years should be able to comprehend each item and yet they were not so old as to indicate the need for a reading ability level within the items which exceeds that of an average-ability Year 8 student. This age group (Year 9) had previously covered energy and the human body during their Year 9 General Science course and hence it was expected they would be able to respond better to each item than other age students.

7.3 ADMINISTRATION OF THE ITEMS

7.3.1 Student Profile and Numbers

All students used in this study were studying a general science course. None of these students had been involved in the research reported on previously in Chapters 5 and 6 of this thesis. They all came from the same school and matched both the academic and socioeconomic profile of the first study group (Section 3.3.1).

These 29 items were administered to 208 students in Years 8, 9 and 10 who attended the primary investigation school. The distribution of students across years and the two instruments is shown in Table 7.1 The Year 9 and 10 students did not include those students who were in the lower science achieving classes of this school for the same reasons discussed in Section 3.4.1, nor was any Year 9 who had proof-tested the instruments during their development. Some of the Year 8 respondents were lower achievers but were included in the analysis since it was not feasible to remove them from the classes or their responses due to anonymity of the respondents to the instruments.

Table 7.1: Distribution of Student Numbers Across Years and the Two Instruments

	Year 8	Year 9	Year 10
Blue Test	24	33	35
White Test	24	33	35

7.3.2 Administration of the Blue and White Instruments

The Blue and White Instruments were administered during normal science classes in the same room in which the students would normally be involved in their science lessons. The time allocated for attempting the instrument was set at 30 minutes but most students only required 20 minutes to complete the items. The slower responding students were not hurried along but given the time that they required to satisfactorily complete their responses, thus ensuring accurate detailed responses.

The instruments were distributed alternatively among members of the class with one student getting a White Instrument and the next student a Blue Instrument. (Students were told the two instruments were not only differently coloured but were different in the items they contained.) This alternating distribution was to remove the desire of students to collaborate with their immediate peers on their responses. Test-type conditions were adhered to so no talking would occur which further reduced potential collusion.

A set of instructions to supplement those already written at the commencement of each instrument was verbally given to each class of students by the researcher. These verbal instructions were for respondents to state if they did not understand an item as this would distinguish between a vacant response left out for some unknown reason and one that was not understood and hence unable to be answered. In addition, students were asked to respond to the true or false if they could do so, even if they could think of no reason for their response but to note in writing that they could not think of a reason for their commitment. Students were told it was very important to give a reason for their true or false commitment as this informed the teacher (and researcher) what the students actually knew (or did not know) about energy and the human body. Further, they were told the findings from these tests would be used to design better courses for future science classes in this school and would not be used for assessment purposes.

This approach was designed to have students responding to all items and to reveal an area that was not a misconception but still a problem in the student'(s) knowledge scheme rather than being filled in to do the right thing for the teacher. This manner of responding was also designed to reduce the incidence of students putting down true or false without any thought.

7.4 ITEM ANALYSIS

7.4.1 Data Analysis of True/False Commitment

Both the stem and the associated reasons for an item are important to a teacher, as they can be an aid to gaining information about the class or individual students' knowledge base on energy and the human body. For this reason, both the data for the true or false commitment and for the attendant reason was used in the assessment of each item's suitability in assessing that aspect of the students' knowledge of energy and the human body.

The true or false commitment was assessed for the usefulness of the statement. This usefulness was obtained by the calculation of a percentage of true or false commitments for each year cohort. This percentage would show the item's value in assessing each year cohort's notions and also could reveal any trends in knowledge differences over the three-year cohorts under study.

Since not all of the items have scientifically acceptable statements, each statement needs to be commented upon individually in light of the veracity of that item's statement. Any statement which had a percentage close to 50% committing to true or false would indicate the notions held by the cohort being studied were understood by only about 50 percentage of the cohort. The same caution on relying on the true or false commitment discussed in Section 5.3.1 also applies to these items in this analysis.

7.4.2 Data Analysis of Item Reasons

Percentages of student who made true or false commitments were calculated for each reason given independently of whether the commitment was for true or false as the reasons were intended to reveal notions held by students with respect to the propositions being investigated by that statement. There was no intention of assessing whether students held a particular notion for their commitment to the statement, rather that they held that notion with respect to the propositions being diagnosed. The study of the nature of students' notions is not the main issue in this section of the overall study; rather it is to create a set of valid diagnostic items. So the commitments and reasons are separate entities in many respects and as such could be treated independently of each other. In particular when using these items to diagnose notions held by students, the researcher would carry out a more comprehensive analysis of the reasons in particular to identify student conceptions.

To this end, the data from the two instruments were collated for individual items to show the number of students who responded that a statement was true or false or where there was just a reason without the commitment. For example, for a reason with a selection of three for true, two for false and zero for just a reason was recorded thus 3/2/- (Appendix 12). Further, each reason's raw score was converted to a percentage of the number of respondents in that year cohort for that reason irrespective of the true/false commitments made for that item (Appendix 13). Since some students chose more than one reason for their commitment to true or false, the total number of students responding and not the total number of reasons was chosen when calculating this percentage. Very few students gave no reason when they made a true or false commitment.

Where more than one reason was given for an item, all the reasons were scored separately since it was assumed the students thought a number of reasons supported their commitment. The instructions given to the students did not restrict the choice of reasons to only one. The use of multiple reasons was more common with the Year 8 students followed by the Year 9 students and lastly the Year 10 cohort.

From these data, the utility of each item was determined to assess whether or not it should be retained in the final bank of items for inclusion in the diagnostic instrument which could be utilised by a classroom teacher to determine their students' knowledge position on energy and the human body. In association with this determination was the potential to change items by either rewording, removing or adding to the reasons supplied. The addition of reasons would be determined by the number of written reasons chosen by respondents to a particular item. Since there were very few written reasons given it was deemed unnecessary to add more reasons to any item. Minor rewording could be made if it appeared that the language used in a reason selected was apparently confounding to the students.

Any reason that elicited below 12.5% for each of the three separate year cohorts would be considered a low priority reason from the student population's point of view. The value of 12.5% was used as it represents one in eight students who used that reason for each of the three year cohorts. As such that reason could be removed from the set of reasons for that item. But there may be other reasons why it is better left as a supplied reason. Such a reason may be that it does differentiate between student age cohorts or that by removing it there becomes a shortage of supplied reasons and the stem is important to help teachers assess current knowledge propositions of the students.

If respondents, as suggested by Griffard and Wandersee (2001), do employ test answer techniques, then it is possible that a reason could provide hints to the student on the selection of a more accurate answer. So the removal of the reason could actually benefit that item by improving its accuracy. However, it is difficult to easily assess the beneficial nature of a reason in aiding student selection without re-testing the items with this question in mind. A study was made of whether the students did use test answer techniques in their deliberations on reason suitability as argued by Griffard and Wandersee and discussed in Section 7. 8

7.5 INSTRUMENT ANALYSIS

With two instruments having been administered (Blue and White), the following discussion was based on each instrument separately with a summary of the findings at the end of each instrument's discussion.

No attempt will be made to explain why students chose particular reasons, as this is not the purpose of this analysis. Rather, the purpose of this piece of research is to discuss whether items are useful in gleaning information on student notions and any trends or patterns in these notions as indicated through the selection of reasons. Reasons the notions are held and the major trends as well as providing possible explanations for the holding of these notions were discussed in Chapter 5.

7.5.1 Blue Instrument Analysis

Item 1
Food is a source of chemical energy for the body and this energy is found inside the food molecules.

TRUE/FALSE

A *energy is found as little bundles between the food particles*
B *energy is found as little bundles inside the food particles*
C *energy is in the chemical bonds of the food molecules*

D *energy is both in between the food molecules and inside the food molecules*
E *energy is transformed from the food molecules*

Most correct response – True with reason C

Student responses

The greater majority of each year cohort (95.8%, 84.1% and 91.6%) said this statement was True (average of 90.5%)

Reason E was the main selection for a reason in Years 8 and 9 (41% and 41%), respectively, but showed a large decline (22.9%) in Year 10.

Reason C (most correct) showed a small increase from Years 8 to 10 but was still chosen by an average of 25.6% of all years.

Reasons A, B and D showed no pattern in their selection except A that was seldom selected and could be removed from the given reasons.

It could be reasonably expected that Year 8 students select reasons B and E as these could arise from general life or their formal education. While C is far more precise in its explanation, this level of explanation and hence student-held knowledge is not covered in formal lessons until at the earliest in Year 9. So Year 8 students may not use this reason because they are not expected to know where energy is precisely located.

Item 2
Digestion does not release energy the body can utilise for processes that require energy.

TRUE/FALSE
A *energy is released from food during digestion*
B *digestion converts food molecules into energy*
C *digestion filters the energy out of the food*
D *energy is produced elsewhere in the body*
E *energy in food is converted in the body cells but not by digestion*
F *digestion uses energy not produces it.*

Most correct response – True with reason E

Student responses

An average of 67% across all year cohorts selected the statement to be false (which is not correct).

Reason B was popular with Year 8 but not in Years 9 or 10 while reasons A and B (both covering digestion as the energy producing process involving food) accounted for 71% of all Year 8 reasons selected.

The rest of the reasons showed no patterns or trends in their selection.

Reason E is more accurate than D in that it specifies a more precise location where respiration occurs. For this it could be expected that some Year 8 students may be expected to select E even though they have covered respiration and its relationship to food in general in Year 8. The more precise link between food and respiration is covered in depth in Year 9.

Year 8 students should know useable energy is not produced during digestion but is produced elsewhere because they should have studied the process of respiration and digestion earlier in their science education.

Item 3
When we eat too much food the body only takes in the energy it needs and excretes the rest.

TRUE/FALSE
A *we absorb all the energy and the excess energy is excreted*
B *unused energy is destroyed*
C *not all the excess energy is destroyed some is stored as fat or excreted*
D *unused energy is stored as fat and used later if it is needed*
E *unused energy turned to fat which cannot be used later*
F *unused energy is turned into fat and used later*

Most correct response – False with reason D

Student responses

70 % of Year 8 students selected this statement to be true while equal numbers of Year 9 students selected true and a slight increase in true responses was showed in Year 10 (58.3%).

Reason A proved popular with Year 8 students but far less so with the other two years. At the same time, reasons C and D were frequently chosen by all years. B and E were very low in selection for all years and could possibly be removed from the list of reasons given for the statement, in particular reason B.

Reason E has a low frequency of selection and could be removed as could reason B which was chosen by 12.5% of Year 8 students and zero in Year 10. The only benefit for reason B remaining was to provide a reason that does attract a small number of Year 8 students.

A subtle difference in wording exists between reasons D and E which may have caused problems for the less able students or the less discriminatory readers in their selection of a reason. Reason D could be changed to read "... is stored in fats…". This would increase the reason's accuracy and possibly increase the discrimination between D and E.

General knowledge of some ways in which people can become obese should indicate that all age groups in this study should be able to select the statement as false which was not the case.

Item 4
Sense organs such as the eye and the ear convert the different types of energy into electrical energy (action potential) the brain can use.

TRUE/FALSE

A *the sound or light these organs receive goes straight from the ear or eye to the brain which then decodes the message*
B *light and sound are not energy so there are no conversions needed*
C *the eye or ear helps transfer the energy to the brain where it is translated*
D *the retina (eye) and cochlea (ear) convert the energy they receive into energy (action potential) which goes to the brain where it is translated*
E *seeing and hearing has nothing to do with energy transfer*

Most correct response – True with reason F (The energy these organs receive is converted by them into a form of energy (action potentials) the brain can interpret/use.)

Student responses

66% of all the student cohorts said the statement was true with less choosing it in Year 8 than in Years 9 and 10.

Reason A was the most frequently chosen in the three lower school year cohorts, with 65 % of Year 8 and 38% and 33% in Years 9 and 10, respectively. There is a big decline in the selection of this reason from Year 8 to Years 9 and 10. This is possibly due to both the ear and eye being covered in some detail in Year 9 prior to these results being collected.

Reason B elicited few respondents, with only 17 % of the Year 8 cohort and 6% for each of the other two lower school year cohorts. As such it could be removed from the provided reasons except that it does identify a number of Year 8 students who do not have an understanding of examples of energy (or what energy is).

Year 9 respondents were reasonably evenly spread in their selections of reasons C, D, and E and with few selecting B while no other trends were apparent across the year cohorts for any reason.

It is expected that Year 8 students may select A, C or D as all of these appear plausible because this area of knowledge has not been formally covered in the Year 8 class but are covered in depth in Year 9.

Item 5
Digested food is absorbed into the body and the body in a number of different processes can then use this digested food, one of which is respiration which produces useable energy.

TRUE/FALSE

- *A* *digestion produces the energy we need from our food and we absorb this energy*
- *B* *we only use food for energy nothing else*
- *C* *food is "burnt" with air to produce the energy our body uses*
- *D* *respiration is breathing and does not involve energy*
- *E* *respiration is breathing and this does not produce energy but uses it*
- *F* *food is changed into movement energy in the muscles*

Most correct response – True with reason C

Student responses

While an average of 57.5% of all respondents chose true for the statement, Years 9 and 10 were closer to 50%. From this result, this item would appear to be one about which many students do not have an acceptable understanding. This unacceptable understanding is also borne out by item 2 which similarly looks at the role of digestion and respiration and their roles in energy conversion in the human body.

Reasons A and E were the two most popular reasons chosen, in particular with Years 9 (36.4% and 34 %) and 10 (36.2% and 27.7 %). Year 8 students selected reason F but with a wide spread of choices.

Reason C was rarely selected by students except in Year 8 and showed a declining trend in popularity over Years 9 and 10. This reason could be removed from this item's provided reasons but should remain as it is the correct response. It is also debateable as to the value of reason D since it only elicited an average of 14.5% and this declined with student age and as such it could be used to discriminate the level of understanding by the different years and their ability to distinguish between respiration and breathing. In everyday language these two terms are often used interchangeably. But in the context of this item the process referred to as respiration is clearly differentiated from breathing.

The use of respiration and breathing as two very distinct processes is in accordance with what is taught in the school used for this study. In other schools, where this item may be used, the term cellular respiration could be substituted for respiration.

The choice of the word "burnt" in reason C is using a commonly used term which the students use to refer to combining with oxygen (See Chapter 4) and as such it is satisfactory in its application here. If the combining food with oxygen is taught as oxidation this word "burnt" could be substituted for oxidation (which is the synonymous meaning for the students).

A change to the stem of the item to read "… into the body where the body in a number of different processes can use this digested food, for example, respiration…" is suggested. With this change, the stem becomes less clumsy in its wording and is likely to improve its readability.

It could reasonably expect Year 8 students to select reasons A, B and F as these appear to be commonly held misconceptions (Section 5.3.2.2). The process of respiration is taught in Year 9 in detail. As such it would be expected that the Year 9 students would select the correct reason. The Year 10 students should be more accurate in their reasons than the Year 8 students but less than the Year 9 students due to forgetfulness and the reversion to previously held notions.

Item 6
Respiration is the set of chemical reactions, which result in the changing of energy in the absorbed food into chemical energy the cells can use.

TRUE/FALSE
A respiration is breathing and supplies oxygen not energy
B digestion produces the energy the body needs from the food we eat
C respiration uses energy it does not produce it
D respiration is when fats are converted into energy
E body turns food into energy
F respiration is the process for converting energy in food into useable energy

Most correct response – True with reason F

Student responses

The Year 8 students chose False (59%), while the Year 9 and 10 chose True (63% and 58% respectively), possibly due to this topic not having been covered fully in Year 8 classes.

Reason A was the most popular choice for all year cohorts but there was a decline in frequency of use as the student cohorts got older (50%, 43% and 35%). Other popular reasons were C and E.

Reason E had nearly double the selections in Year 10 than the other two years (33% compared to 18% in Year 8 and 11% in Year 9). Students select this reason when they know a little about respiration but with insufficient detail that food is involved and there is little knowledge of the energy conversions involved. As such, this item determines the level of knowledge held by those who select this reason.

Reason B and F were poorly selected and could be removed as given reasons except that F is the reason for the statement being true and so it should be retained.

The Year 8 students and those who are unclear about energy conversions could use E and that matter is not converted into energy in the body. The more detailed aspects of respiration are not covered in detail until Year 9, although the role of the mitochondria is discussed. In Year 10 one third of the students selected this reason.

This item covers similar information on respiration to that of item 5 with the added information on the role of digestion. As such, this item is a more useful one than item 5 for use in many schools where respiration is synonymous with breathing and cellular respiration is used for the chemical processes of respiration. Also, it is more readily adapted by changing respiration to cellular respiration. The role of digestion is also covered in items 1 and 2 of this instrument.

Item 7
Fats (lipids) are used by the body as an energy store and they can be used later when the body is running low on energy.

TRUE/FALSE

A *we store fat but we cannot use this fat for energy at some later time*
B *energy is changed into fat to be stored and used later*
C *excess energy is not changed into fat but is either destroyed or excreted*
D *we store the excess energy in the bonds of the fat for use later*
E *fat people are less energetic therefore they do not use it later*
F *there is no excess energy as we only absorb what we need*

Most correct response – True with reason D

Student responses

True scored very highly for Year 8 (86.4%) and to a lesser extent Year 9 (50%) then Year 10 where 60% chose true.

It appears that two reasons are true; reason D relates to and supports the stem and reason E is an observation by many students and may appear true for many people although it is not always the case. For example, for optimum performance a number of sports demand excess weight in their participants with Sumo Wrestling and shot put being two examples.

Two reasons show trends across the years. Reason A while averaging 28.5% showed an increase in choice from Year 8 to 10 while reason F was very low in popularity and there was a decline in its selection as the age cohort increased.

Reason B was very commonly chosen by Year 8 students (45.5%) but was low in Years 9 (12%) and 10 (30%).

Year 8 students are not taught about chemical energy being in the molecular bonds (reason D) and so they would not be expected to select this reason. Despite this fact, 27% chose this reason. The most likely explanation is that the energy is used at a later time and not that the energy is not changed into fat but that energy storage does involve fat (and so eliminates reason B).

Year 8 students have not learnt about bond energy, which is taught to Year 9 and 10 students. The latter two years could be expected to know matter is not converted into energy in the cells. As such, students not having this information in their knowledge schema could use B as a reason.

There is a similar item in the White Instrument (number 4) where the same sort of information is assumed except it deals with lipids. This item had similar percentages for the Year 8 cohort but higher percentages for Years 9 and 10 for the true/false commitment. With similar reasons giving results which are not as near to each other as would be expected with reasons which are very similar. For example, reason A in both items is identical but has different percentages (Blue are 22.7%, 31% and 31.9% and White 4 are 25%, 16.1% and 20.6% for Years 8, 9 and 10, respectively).

Item 8
When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE
A bicycles can't use human energy
B a bicycle is not living therefore it does not get or need energy
C we use energy up not transfer it
D the bicycle creates its own energy

E *the bicycle does not consume energy*
F *our energy makes the pedals etc move so the bicycle moves*

Most correct response – True with reason F

Student responses

More Year 8 (59.1%) and 10 (54.2%) chose false while 56.8% Year 9 students selected True.

Reasons A, C and D all showed trends of declining percentages as the respondent's age cohort increased.

Reason A showed a declining trend in its selection from Year 8 to 10 although this decline is small in percentage terms.

Reason D also showed a decrease in selection as the student age cohort increased with Year 8 (36%) and a large decrease for Years 9 and 10 (to 18.3%). By this stage of their education it appears the Year 10 group have learnt that the body cannot create its own energy but rather converts it into useable energy and that we do not use energy but transfer or convert the energy. This area of study is covered during Year 9.

Reason F has the highest selection rate for all choices (45%, 54% and 43%). This reason is an observation and not a complete reason but does cover the major energy transfers that occur, except for the transmission of the energy to the rear wheel of the bicycle. As such this reason does satisfy the statement.

A similar statement with some different reasons is to be found in the White Instrument (item 5). In that instrument, reason A is similar to B in the Blue instrument, F to C, C to D and E to F. Because of these similarities only one of the two items should be used in a single instrument. This will be further discussed under the section heading "Suitability of Items for Inclusion Into a Single Diagnostic Instrument" (Section 7.7).

Reason C may be utilised by Year 8 students who have not covered energy conversions in their formal lessons and/or who think energy is used up or destroyed when used to do some task.

Item 9
The ear converts sound energy into electrical energy (action potentials) the brain can use.

TRUE/FALSE
A *sound energy is transferred straight to the brain which uses this to "hear"*
B *the sound energy is converted into electrical energy (action potentials) which are transmitted to the brain.*
C *eyes don't receive energy from our surroundings*
D *seeing has nothing to do with energy transfer because sound is not energy*
E *ears don't receive energy from our surroundings*
F *hearing has nothing to do with energy transfer*

Most correct response – True with reason C

This item is a very poor item as it includes too much irrelevant material

This question has major problems with its wording due to a misprint. Consequently, the results of this item will not be discussed. It should be noted there is a similar item on the eye in item 15 and on the other instrument (item 6) and so with rewording could be useful in diagnosing student notions on the ear since these other items proved to be useful in diagnosing their propositions.

Item 10
A number of regions of the body receive energy from the environment. Some of these regions are the eyes, ears, skin, lungs and gut.

TRUE/FALSE
A *we only take in energy in our food*
B *we get energy from food, air and sleep not the others*
C *these are only some of the ways our body can get energy into it, there are more*
D *we only get energy when we are exercising or being active*
E *we do not get energy from our surroundings*
F *we only get energy from respiration*

Most correct response – True with reason C?

Student responses

The selection of true and false were close to evenly selected (52%, 48% and 52%) and shows no trend or pattern over the three year cohorts studied.

Distribution of reasons selected was fairly consistent with no trends or favouring of any reason except in Year 9 where the selections of B, E and F were low to very low.

This item shows the confusion held by students over the ways that energy impinges upon, enters or is detected by the body and that students have little idea of energy receptors associated with their body.

Year 8 respondents have been taught the role of respiration in energy conversions within the body. No other energy receptors have been covered, so it is conceivable the students may select reason F. Other reasons (A, B and D) are misconceptions identified earlier in the research (Sections 2.2.5 and 5.3.2.1).

Item 11
During sleep our body produces more energy than it uses up and so our energy levels are restored back to normal.

TRUE/FALSE
A we do not get any energy when we are asleep
B we do not use as much energy as we produce when we are sleeping
C we do not digest food when we are asleep so we get no more energy
D because we relax we restore the energy levels in our body
E we use energy when we are asleep so we do not restore our energy levels
F we are not active and so do not get or use any energy that we can store

Most correct response – True with reason B (this is a partial restating of the statement)

Student responses

In all Years, in excess of 70% of students selected true for the statement (85.7%, 79.15% and 70.8%).

There is a reasonably even distribution of the reasons chosen in support of the students' claim that the statement is true with no apparent trends across the years.

Many Year 8 students (57.1%) gave the correct reason for their commitment. This was the highest percentage for any reason in this item with Years 9 and 10 far lower in their choosing of this reason (16.1% and 32.4%)

The gaining of energy from activity (reason F) agrees with reason D in item 10 and percentage of students selecting it were similar (Year 8, 14%, Year 9, 29%, Year 10, 8%).

Item 12
We have an average body temperature of about 37°C which is often higher than our surroundings. This body temperature is due to the heat released from all the chemical reactions of the body.

TRUE/FALSE

A	*we get heat energy from the chemical reactions in our body and this gives us our body temperature*
B	*the blood flowing (friction) and heart beating give us our body temperature*
C	*viruses raise our body temperature*
D	*energy is burned to give heat and hence our body temperature*
E	*we get our heat from the clothes we wear; for example, jumpers*
F	*we are not hotter than our surroundings*

Most correct response – True with reason A (this is a restating of the stem of the item.)

Student responses

The average of 60% who said the statement was true showed no trend over the year cohorts only that it was less popular with Year 9 students.

Year 8 students favoured reasons A and B with nearly half this number in Years 9 and 10. Many of the Year 8 students who chose A also said the stem was true (70%), while Years 9 and 10 had an approximately even division favouring true or false.

Reason C showed a decline in use from Year 8 (34%) to Year 9 (23.1%) and Year 10 (10.6%). (While viral infection can and does lead to elevated body temperature this is not the major reason for body temperature throughout the majority of a human's life.)

Reason D had a very similar percentage (25%) of students selecting it in all years.

Reason E was selected by a large number of Year 8 students (30%) but only 22% of students in Years 9 and 10 chose it.

Reason F was not a popular reason with very few selections (below the 12.5%) from all the years and as a consequence could be removed from the supplied reasons.

Item 13
The evaporation of sweat cools the body down.

TRUE/FALSE

A *the air or wind coming in contact with the water in sweat cools us down*
B *sweating does not cool us down (it just disappears into the air)*
C *sweat cools us down by taking the heat with it as it leaves the skin surface*
D *heat energy is taken from the body so the water can evaporate*
E *heat particles are removed along with the water when we sweat*
F *air passing over our skin cools us down not evaporation*

Most correct response – True with reason D

Student responses

While there was an average of 73% favouring true there was an obvious trend of decreasing popularity (with age) for the true response with 87% in Year 8, 70% in Year 9 and 62% in Year 10.

Most students (65%) in Year 8 gave reason A with a large decline in this choice for the other two years (20%, 31% respectively). The Year 8 students studied evaporation during the year but it was not directly related to the cooling effect of evaporation but as a process of a separation technique. The other two years of students have studied cooling and evaporation in general terms and so the transfer of knowledge may not be occurring or the knowledge simply has been forgotten.

Reason B is an observation in that we do not cool down quickly when sweating and often we feel hot while sweating.

Reason C is looking at the particular notion of heat as particles (as is reason E) and showed a slight decline in frequency of choice with increasing age from 34.8% to 30% and 25%, respectively, or a decrease of 5% per year cohort.

Reason D declined in popularity as students became older, from 26% in Year 8 to 8% in year 10

While reasons C and D showed a decrease in selection as age increased, the reverse is seen for reason E although this is very low in selection percentage for any year. (8.7% to 14.6%)

Item 14
When we eat too much food the body only takes in the food energy it needs and excretes the rest.

TRUE/FALSE
A unused energy is absorbed and is turned into fat and can be used later
B food that is not needed goes straight through the gut and is excreted
C some energy is stored, we use some and the rest goes out of the body
D excess energy is stored as fat which is a reserve supply of energy
E unused energy is passed out as waste
F energy does not pass out of body but is stored and turns to fat

Most correct response – False with reason D

Student responses

56.8% of respondents said the statement was true but there were a number of students in each year who only gave a reason without the commitment to true or false.

Two reasons showed trends over the years. Reasons were D and E; with E decreasing in frequency of choice with increasing age and D marginally increasing as the student cohort became older. There was no trend in either of these reasons as to favouring true or false for the statement.

Reasons A (59%) and C (45%) were very popular with Year 8 students but less so with the other two years which both had a reasonably even distribution of the choice of reasons.

Reason D would be better worded if it was to be changed to "…stored in fat…" from "…stored as fat…". This reason is a far more accurate portrayal of what occurs.

This item has a very similar stem to item 3 but with different reasons. Item 3 concentrates on the absorption of energy across the alimentary canal while the reasons for this item cover the storage of the absorbed energy.

Item 15
The eye converts light energy into electrical energy (action potentials) the brain can use to help us see.

TRUE/FALSE

A *light energy is transferred straight to the brain which uses this energy to "see"*
B *light burns an image on the retina which then transfers this image to the brain*
C *light is reflected onto the retina and transmitted to the brain for use*
D *the reflected light from the object is converted by the eye into electrical energy which is transmitted to the brain.*
E *eyes don't receive energy from our surroundings*
F *seeing has nothing to do with energy transfer*

Most correct response – True with reason D

Student responses

True was selected by a very high percentage of Year 8 students (86%) and was popular with other years (59% and 64%) who also chose true.

Reason A had a very high percentage of Year 8 respondents choosing it (63.6%) with Years 9 and 10 using this reason far less frequently (20.5% and 29.8%).

Reason D showed an increase in frequency with student age (18%, 23% and 29%).

While all of the given reasons were utilised to support the commitment to true or false, Year 9 students did not favour reason B and Year 10 students do not use reason F.

Item 4 assesses similar aspects of energy to that of this item but item 4 also involves energy and the ear.

This item covers an area studied extensively in Year 9 by this cohort of students. As such one would expect Years 9 and 10 to select reason D with a high frequency. While it does show an increase, it was still low in selection priority for both of these two years.

7.5.2 Summary of Results of the Blue Instrument Pilot Study

Generally the results from these 15 items indicate that they can be used as diagnostic tools to help identify problem areas in either student-held alternative conceptions or to identify areas of weakness in student knowledge of concepts held in energy and the human body. This is with the exception of item 9.

The low numbers of respondents used in this study for the identification of items that could be used to diagnose student-held notions on energy and the human body would make any claims of identifying misconceptions extremely tenuous. This was not the purpose of this study; rather it was to validate the items to ensure each item does test the knowledge it purports to. The results above show that the items on the Blue instrument do fulfil this purpose.

Hence, the results of this study indicate that the items can be used as diagnostic tools. The responses to the statement section of each item can be utilised to identify student-held beliefs while the reasons can be used as guides to identifying the underlying reasons for these knowledge claims. Each item does identify similar problems to those major areas of concern identified in Chapter 5 and supported in this research. These common problems are shown in Appendix 9. That these two pieces of research should identify similar areas of concern is not surprising since the diagnostic items were derived from problem areas identified in the earlier piece of research. The main purpose of this latter research is to verify that the items do in fact test for and can be utilised to help identify problem areas identified earlier in this research program and reported on in Chapter 5.

The validity of the items discussed in this Chapter are derived from the reasons given to the instruments and the reasons discussed in Chapters 4, 5 and 6 and through the analysis of these items which follows. Many of the reasons supplied for the items being used in this chapter came from the reason supplied by students when they made responses to the items developed in Chapter 4 and subsequently discussed in Chapters 5 and 6. Further, the checking of the student answering techniques discussed in Section 7.8 is an attempt to indicate that the methods students use to respond to these items do not utilize the reasons supplied but rather the students think of their own reasons and then select the one which most closely matches their own reasons for choosing agree or disagree.`

7.5.3 White Instrument Analysis

Item 1
Blood transports molecules of food around the body so the cells can take these molecules in and use them as a source of energy.

TRUE/FALSE

- *A* *we absorb the energy produced by the digestion of food and the blood carries this energy around our body to where it is needed*
- *B* *blood circulating gives us energy*
- *C* *blood is unable to support or carry excess energy*

D *blood carries oxygen around the body not the energy*
E *blood carries the sugars around the body for the cells to absorb which they can then use to make energy*

Most correct response – True with reason E (a reiteration of the stem statement)

Student responses

The greater majority of students selected true (Years 8, 9 and 10, respectively, were 60.8%, 75.7% and 74.2%)

A high percentage of Year 9 students (54.5%) chose reason A which was also well chosen by Years 8 (34.8%) and 10 (37.1%).

Few students selected reasons B and C and so these could be removed as they are below the nominated 12.5% cut-off for selection. Even though these two reasons were from the literature discussed in Chapter 4, the students choosing these two reasons were too low in both the earlier study (Chapter 5) and in this study to warrant continued use as a reason.

Reason D was frequently chosen by Year 8 (43.5%) students but much less so by Year 9 and 10 students.

Reason E was used frequently by Year 8 students and 10 students (43.5% and 48.1%) but not Year 9 students with only 18.2% selecting this reason.

Item 2

Respiration can use food molecules such as glucose (and other sugars), fats and proteins to produce useable energy (ATP).

TRUE/FALSE
A *respiration is breathing*
B *fats are unable to be used for energy but sugars are*
C *energy is released by digestion not respiration*
D *we get our energy when we are active (like exercising) not from food*
E *respiration burns energy not create it*
F *respiration is the process of making all food components into useable energy*

Most correct response –True with reason F

Student responses

With the exception of Year 9 students, the selection of true for this statement was low (12.5% and 35.2% in Years 8 and 10 compared to 60.6% for Year 9).

Very few students in any year group selected the correct reason (F) which indicates an area of weakness held by the students.

For the other reasons there was a reasonable spread within each year level except in Year 8 where many students (62.5%) selected the reason (A) that respiration is the same as breathing.

Year 9 students had a low percentage for all reasons except A and F.

All three year cohorts have studied this aspect of respiration and as such would be expected to have the necessary knowledge to respond correctly. Also, the differentiation between respiration and breathing has been emphasised in all science classes at the school where the research was conducted. Despite this result, Year 8 students have persisted with the synonymous meanings of respiration. Year 9 students who have had further study of respiration have selected the correct reason more often. Year 10 students who have covered the topic in Years 8 and 9 have failed to select reason F, instead favouring a number of alternative conceptions. Since respiration is covered in all years of formal high school education, there is no expectation of a year group selecting one reason over others.

Item 3
The heat released from the chemical reactions in our body is a waste product that we can use to help regulate our body temperature.

TRUE/FALSE
A *chemical reactions contribute to the heat production*
B *our body temperature is from the heat we produce when we exercise only*
C *the chemical reactions produce heat as a waste product and we convert this heat into temperature*
D *heat is from the flowing of blood through our veins and arteries not the chemical reactions*
E *energy is "burned" to give heat for the body*
F *the body makes its own heat, it is not from chemical reactions*

Most correct response – True and reason C (chemical reactions release heat which the body uses to help maintain the constant heat (temperature) level required for optimal functioning.)

Student responses

Most Year 8 students chose True (70.8%) while the other two years had lower selection rates of True (51.5% and 60.6%).

Reason A, which is a reiteration of the stem, was used by many Year 8 students (54.2%) but far fewer Year 9 students (24.2%) and 10 students (9.1%). This reason may be popular with Year 8 students as they do not appreciate the subtle meaning of "contribute" and think this is the contributing factor to body heat. Also the reiterative nature of the reason may be a contributing factor to the selection of reason A. Nevertheless this reason does discriminate between year groups.

Reason B was a very unpopular choice for a supporting reason with a high selection being only 8% Year 8 students. This reason could safely be removed from this question.

The other reasons had a good spread of students selecting them with no trends or patterns apparent apart from reason A and B.

Item 4
Energy may be stored in the body for later use. Fat (lipids) is one such chemical that is used for energy storage.

TRUE/FALSE
A we store fat but we cannot use this fat for energy at some later time
B energy is changed into fat to be stored
C excess energy is not changed into fat
D we store the excess energy in the bonds of the fat
E respiration does not convert fat into energy
F there is no left over energy as we use all we take in

Most correct response –True with reason D

Student responses

All three year groups chose true in large numbers (83.3%, 74.1% and 76.4% respectively for Years 8, 9 and 10 with an average of 77.9%)

Reasons C and E were not popular choices in support either the True or False commitment. For this reason they could be removed from the reasons given although it is possible to retain reason C since in two years (8 and 9) it was a reasonably well selected reason.

While reason B is close to being correct, the correct reason D is more accurate and shows a better understanding of the reason for the commitment to True. Reason B shows the common notion of energy changing into a substance and that energy is stored as or in fat but not exactly where or how it is stored. The difference between B and D may be too subtle for many students. This subtlety was further discussed with items 3, 7 and 14 of the Blue Instrument.

Generally there was an even selection of all reasons across each year level with the exceptions of reasons E and F.

This item is very similar to item Blue 7 where results were similar to these in the patterns they showed while the actual percentage values were different.

Item 5
When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE
A *the bike is not living and so cannot use or have energy*
B *we use energy up not transfer it to the bike*
C *bike makes its own energy*
D *use energy to move the pedals but no energy is transferred to the bike*
E *our leg movement energy is transferred to the bike and then becomes movement energy of the bike*
F *we push on the pedals which makes the bike move but there is no energy transferred to the bike*

Most correct response – True with reason E

Student responses

While Year 8 only chose 47.6%, Years 9 and 10 chose 63.6% and 58.8%, respectively.

Reason A shows a declining trend with age from 43.5% to 5.9% in Year 10.

Most Year 8 students chose reasons A, B and D for their commitment(s) to false.

Reason B was chosen by 39% of Year 8 students with 9% of Year 9 students and no Year 10 students electing this reason.

Reason C had 25% or Year 8 students selecting it but 3% (or one student) in Year 10.

Another trend was found in reason D which showed a decrease in popularity from 48% in Year 8 down to 20.5% in Year 10.

Reason E showed an increase in popularity with increasing age from 17% to 24.5% and 50% respectively. This may be due to more coverage and accumulation of experiences about energy transfer and its applications in Year 10 than in Years 8 and 9. Both of these latter years' students have covered energy transfers in formal lessons.

Item 8 in the Blue instrument has the same stem but slightly different reasons and has revealed similar problem areas as identified here. Due to the similarity of a number of reasons across these two items, only one of these items should be retained or both sets of reasons are combined to form one single item.

Item 6
When we hear a sound, the sound comes from the object into our ears where it is converted into electrical energy which the brain can interpret.

TRUE/FALSE

- *A* *we convert sound energy into electric current and the brain interprets these electrical signals*
- *B* *sound passes to brain where the sound waves (energy) are interpreted*
- *C* *vibrations move the eardrum and then the vibrations pass into the brain*
- *D* *sound waves pass through the ear to the brain*

Most correct response – True with reason A

Student responses

The statement elicited 67% (Year 8), 62.55% (Year 9) and 79.4% (Year10) of true responses.

Reason A was the most popular reason selected for all years with a slight decline in popularity with increasing age (45%, 37% and 35%, respectively).

Reason E was poorly utilised by all years (below 10%) and as such could be removed with little effect on selection choice. This reason did show a decreasing trend in frequency of choice as the students got older.

No other patterns within the reasons were observed except the low percentage in Year 9 for all reasons other than A.

Similar items are found in the Blue version of the instrument (items 9 and 4).

Item 7
Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE
A all food has the same energy but in different amounts
B different food groups have different amounts of energy with the same type of energy in foods
C each food has a number of different types of energy in it and each of these is in different amounts
D we carry out different types of activities and so these activities need different types of energy to occur

Most correct response – False with reason A or B

Both reasons A and B are very similar in meaning with the only real difference being in the wording where B is more specific in nature through the use 'type of energy'. For this reason, either one could be removed and have no effect on the reasons chosen.

Student responses

True was very highly chosen with an average of 70%, and where 62% Year 8 students chose true (compared to 75% and 73.5% in Years 9 and 10.

Since reasons A and B are so similar, their results can be combined with 54.1% (33.3% + 20.8%) of Year 8 choosing these and 31.3% (12.5% + 18.8%) Year 9 and 29.4% (8.8% + 20.6%) of Year 10. With Years 9 and 10, reason B was more popular while for Year 8 students it was reason A.

Due to the low number of reasons, poor use of reason E and the similarity of A and B, this item is better left out or completely revamped. It is suggested that it be reworded as discussed in detail in the section headed “Summary of Results of White Instrument Pilot Study” (See Section 7.5.2.1) immediately following this White item analysis.

Item 8
We get energy the body can use from a number of sources. Some of these sources are food, sleep, air, light, sound and heat

TRUE/FALSE
A we only get useable energy from our food
B we get useable energy from food, air and sleep not the others that are listed
C these are only some of the ways our body can get useable energy into it
D we only get useable energy when we are exercising or being active
E we do not get useable energy from our surroundings
F we only get useable energy from respiration

Most correct response – False with reason C (sleep and air are not energy sources, they are only involved in energy replenishment processes).

Student responses

66.7% of the Year 8 cohort chose false and with this commitment selected reason C (45.8%) followed by reason B (33.3%) with the other reasons all being chosen but at much lower percentages.

With 68.8% of Year 9 students choosing false there were only two reasons - B and E - which were relatively frequently chosen but both were below 30% while reasons A, C, D and F were below 10% but reason C needs to be retained as it is the most correct reason.

Year 10 saw a change back to the claim that the statement was false (51.5%) and the reasons given by many were either B and C, both of which have commonly held alternative notions embedded within them.

Reason B was popular with three commonly held misconceptions on what gives the body energy. This reason omits sound and light as energy types the body uses.

While C was very popular with Years 8 and 10 students and showed an appreciation of some methods of energy entering the body, it also reveals the misconception of energy coming from sleep and air. Both of these two reasons have partial truths in them but have also commonly held alternative notions.

There were no other apparent trends or patterns across years.

Item 9
Respiration is the process in which the energy in food is converted into useable energy.

TRUE/FALSE
A respiration is breathing and has little to do with energy
B respiration is the taking in of energy from food during its passage through the gut
C respiration is the filtering out of bad energy and storing and using good energy
D digestion is how we get energy not respiration
E respiration is where the energy in food molecules is converted into useable energy

Most correct response – True with reason E

Student responses

Most students claimed this statement was false with an associated decrease in this claim as the student cohorts became older (83%, 53% and 45%, respectively).

Reason A was chosen by 71% of Year 8 students with this number declining to 31% in Year 9 and 39% in Year 10. This reason reflects the dual use of the term respiration and how students are unable to use the same term in a number of different contexts (breathing and cellular respiration). This is despite respiration being taught as being the same as cellular respiration and not being involved in the breathing process. (See similar discussion in item 2.)

The most correct reason E, had no Year 8 students selecting it while some Year 9 (21.9%) and 10 (12.1%) students used it (two Year 9 students said the statement was false).

Reasons B and C had increasing percentages of students selecting them in the older cohorts although only low numbers of students chose these two reasons in any of the three age groups.

Similar results where respiration and breathing are used interchangeably or create confusion are found in item 2 on this instrument and items 5 and 6 in the Blue Instrument.

Year 8 students should know the overall process of respiration (cellular respiration) and as such were expected to successfully respond to the stem and give the best reason. This was not the case as only 12.5% chose this and no reason was selected. Year 9 and 10 have re-covered respiration and have done so in more detail in Year 9 and so would be expected to select the correct reason.

Item 10
Heat is released as a by-product of all chemical reactions that occur in the body.

TRUE/FALSE
A *we only get hot when we do exercise or we are active not at other times*
B *we only get hot when we sweat*
C *we get heat from our surroundings because that is hot*
D *heat is a type of energy and when we are active we use up this energy so no energy is left*
E *get the heat from jumpers and clothes*
F *heat is from the friction of the blood flowing around the body*

Most correct response – True with reason C (the reason should be a rewording of the restatement).

Student responses

56% of both Years 8 and 9 chose True and there was an increase in this number to 67.6% for Year 10 respondents who said the statement was true. Only one Year 10 student gave his or her own reason in favour of the statement being true.

A trend was seen for reason A where 30% of Year 8 respondents chose this with a decrease to 20% and 14.7% in Years 9 and 10. The other trend was seen in reason C where 30% of Year 8 chose it followed by 16.7% and 14.7% of Year 9 and 10 respectively.

Reason D had nearly the same percentage of students selecting it in all three years (22%, 23% and 21%).

Of the other reasons no patterns could be found.

This item is similar to item 3 on this instrument and item 12 on the Blue Instrument. Item 12 has a more detailed stem which not only incorporates this item's stem but adds something about body temperature.

Item 11
Excess heat in the body needs to be removed, this occurs in a number of ways one of which is by the evaporation of sweat.

TRUE/FALSE

A	*heat particles are removed when we sweat*
B	*heat is removed from the skin by convection currents and radiation not evaporation*
C	*it is the air moving over our skin that makes us cool*
D	*heat is evaporated away from the skin*
E	*the process of sweating cools us down not evaporation*

Most correct response –True with reason B (The process of evaporation requires heat and this heat comes from the skin which becomes cooler and so eventually the body is cooled down).

Student responses

Most students said the statement was true (58.3%, 54.85 and 61.8% in Years 8, 9, and 10).

Reason A showed an increase over the three years (21%, 26% and 35%) and reflects the particulate nature of energy held by many people as does reason E which also was a popular reason, particularly with the Years 8 and 10 cohorts (17.4% and 20.6% respectively).

Reason B showed an increase in popularity but from very low percentages to a slightly higher one (8%, 10% to 17%).

Reason D only elicited acceptance from 9.7% of Year 9 students. This reason could be removed with little if any affect on the selection of reasons.

Very little in the way of trends or patterns could be seen in any other reasons.

Year 8 students have been taught about evaporation as a separation process in a Chemistry unit. The example of sweating as a cooling agent through the evaporation of the water is rarely covered because of the purpose for which evaporation is taught.

Item 12
Respiration occurs within the cells and results in the production of useable energy.

> *TRUE/FALSE*
> *A* *cells change food into energy*
> *B* *respiration is breathing and supplies oxygen not energy*
> *C* *it is digestion that produces the energy the body needs from the food we eat*
> *D* *respiration is where "food" molecules are broken down to release energy*
> *E* *respiration is taking the energy from the digested food*

Most correct response – True with reason D (respiration is the process whereby the energy in "food" molecules is converted into useable energy (ATP) in the cell)

Student responses

Year 8 students claimed this statement was false (73.9%) while 50% of Year 9 and Year10 respondents thought it was true.

A number of reasons showed trends over the years. Reason A decreased from 21.7% down to 11.8%. Similarly reason C decreases from 26.15% down to 11.8%. These decreases were not large nor was the percent of students who used these reasons.

Reason B was the most popular reason chosen in each year (56.5%, 36.7% and 41.2%, respectively).

Reasons D and E are vague and generalised and are the closest to being correct of all the reasons. Reason E increased in popularity from Year 8 to 10 (8.7%, 16.7% and 23.5% respectively) while reason D had variable rates of selection over the three years and lacked a trend or pattern. Retain D as it is the closest to correct reason but with the possible addition of the word digested in front of food so that the reason reads "digested food".

This item investigates similar aspects of energy and the human body as items 2 and 9 in this instrument and items 5 and 6 in the Blue instrument. All of these items had a high percentage of students choosing reasons indicating respiration is breathing and is not involved in energy transformation.

Item 13
When we see an object, light comes from the object into our eyes where it is converted into electrical energy which the brain can use.

TRUE/FALSE

A	*light energy transfers the image to brain*
B	*the eye captures the image and then the brain receives that image*
C	*eyes can't receive energy from the surroundings*
D	*energy goes into the eye, to the retina and then to the brain via the optic nerve*
E	*the eye focuses on the tree and its image is passed to the brain*

Most correct response – True with reason D (light energy is converted, by the eye, into electrical impulses which the brain can interpret).

Student responses

A decreasing number (with age) of students thought the statement was true (77.3%, 62.1% and 50%, respectively).

Trends were observed in reasons B and C, with B showing a decrease in popularity (27.3%, 20.7% and 5.3%) while C increased in use with student age (4.5%, 20.7% and 26.5%).

No other trends were observed.

Year 8 students showed a lack of understanding of the energy conversions involved by many selecting either A, B or D. Year 9 students similarly showed this lack of knowledge of energy conversions but they showed no real favouritism in reason choice with a fairly even choice of A, B and C, with D and E infrequently selected.

The processes involved in vision and the eye are not covered in formal science lessens until Year 9 where it is dealt with in detail. There was an expectation that Years 9 and 10 students should select the correct reason and the commitment.

This item is similar to Blue item 15.

Item 14

Any excess energy in the food we eat is destroyed.

TRUE/FALSE

A *we don't absorb the excess energy but excrete it*
B *energy is taken into the body and stored in fat for use later*
C *unused energy is absorbed and then it is destroyed if there is too much of it*
D *we cannot destroy the energy we absorb so we store it in the body as fat so it is out of the way*
E *there is no excess energy as we use it all up*

Most correct response – False with reason B

Student responses

While the majority of students in each year claimed this was false, there was a decline in this commitment with increasing age (86.4%, 73.3% and 63.6%).

Reason A induced a high percent of each year choosing it (34.8%, 54.5% and 37.1% for Years 8, 9 and 10, respectively).

The most correct reason (B) showed an increasing selection with age (13.6%, 33.3% and 42.4%)

There were a number of reasons (A, C and D, E) which were popular with Year 8 students but far less so with Year 9 and 10 students. The apparent trends for this item from Year 8 to Year 10 is due to one or two students selecting each reason and so the trend is minimal.

This item is similar to items 3 and 14 in the Blue instrument.

7.5.4 Summary of Results of the White Instrument Pilot Study

An analysis of each item has revealed that a number of items have problems and as such should be reworded (item 7) or they can be left out since they test the same conceptual area that a similar item covers, for example items 9 and 12, and 3 and 10.

Item 7 examines an area with a commonly held misconception (there being different types of energy in different types of foods). As such this item is valuable and should be retained but there is a problem in the wording of the first and second reasons. These two reasons are the same in meaning. It is the wording of reason A that needs to be changed so that the item now reads:

Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE

- *A* *each food has the same type of energy and the same amounts of this energy*
- *B* *different food groups have different amounts of energy with the same type of energy in foods*
- *C* *each food has a number of different types of energy in it and each of these is in different amounts*
- *D* *we carry out different types of activities and so these activities need different types of energy to occur*
- *E* ____

This wording will now mean the most correct reason would now only be reason B. This rewording would now differentiate between those students who think there are different types of energy and the amount of these energies in the food eaten.

Items 3 and 10 are similar in their stem wording with item 3 incorporating item 10 and then extending the stem to relate this heat by-product to body temperature. As such, this is a more comprehensive stem. But both sets of reasons assess different aspects of heat and body temperature. Only reason A in item 3 is similar in meaning to reason B in item 10. With these major differences between the two items, both can be used to test heat production in the body with item 3 linking heat to temperature. As such both items could be retained within a diagnostic instrument.

Further, item 3 has a very low percentage of students using reason B and consequently it could be removed. This would mean the two items are more different in what they diagnose for. That is, item 3 links heat production and body temperature while item 10 assesses knowledge about heat production.

Items 9 and 12 share very similar stems and a number of reasons. Therefore these can either be removed or combined to form one item. It is considered better to combine them using item 9 and reason A from item 12 to form the following item:

Respiration is the process in which the energy in food is converted into useable energy.

TRUE/FALSE

A	*respiration is breathing and has little to do with energy*
B	*respiration is the taking in of energy from food during its passage through the gut*
C	*respiration is the filtering out of bad energy and storing and using good energy*
D	*digestion is how we get energy not respiration*
E	*respiration is where the energy in food molecules is converted into useable energy*
F	*we get heat energy from the chemical reactions in our body and this gives us our body temperature*
G	______________________________

The rest of the items have all shown they do assess what they were designed to. Items 3, 48 and 12 all had reasons selected by less than 12.5% of each year cohort and as such these reasons could be removed from the lists of provided reasons.

7.6 GENERAL SUITABILITY OF ITEMS FROM BOTH INSTRUMENTS

Blue Instrument item 5 may be of limited value in schools other than the study school, because confusion could arise due to the use of the term respiration. In many schools and science textbooks, respiration has the dual meanings of cellular respiration and breathing. In this item, the term respiration means the chemical processes involved in transforming chemical energy in food into useable energy in the form of ATP. If cellular respiration is substituted for respiration it makes little sense to have reasons D and E.

Blue Instrument items 5 and 6 both test digestion and respiration as processes involved in energy production. They test for where the energy conversions actually take place and the name of the process involved. It is better to remove item 5 since item 6 covers the same area and is better worded (See Section 7.5.1). In item 6, of the reasons given, respiration could be more easily substituted for the words cellular respiration and hence better match the dual meaning of that term.

The fact that very few students actually chose to write their own reasons could be used as a gauge of the validity of the supplied reasons and that these supplied reasons were the reasons held by the majority of students. Care is needed with this claim since it could be counter claimed that many students could not be bothered to write their own reasons or as Griffard and Wandersee (2001) claim the respondents used “multiple choice test answering techniques” to help select their reason(s) for their true or false commitment.

To assist in identifying which of these may be the case a number of students who had completed one diagnostic instrument previously were requested to do the other instrument while "thinking aloud". These think aloud tasks were tape-recorded and the data transcribed and analysed to identify if they did use test-answering techniques while attempting the diagnostic instrument. The results of this assessment of the techniques students used to answer these items is reported in Section 7.8

7.7 SUITABILITY OF ITEMS FOR INCLUSION INTO A SINGLE DIAGNOSTIC INSTRUMENT

7.7.1 General Analysis of Items for Suitability

The suitability of items in each of the White and Blue instruments showed that most items could be retained in the instrument in which they appeared. Only Blue item 9 was deemed totally unsuitable due to wording problems. But when all 29 items were combined a number of overlapping items were found. This was anticipated when the original 29 items were created. For example, White 13 and Blue items 4 and 15 test the area of vision but item 4 also covers an aspect of hearing while items 13 and 15 only cover vision. For this reason, all three items are of value but not together in the same instrument. It is more economical, item-wise, to use item Blue 4 as it covers both sight and hearing. If only sight or hearing is being assessed, then the more specific item (White 13 or Blue 15 for vision and White 6 for hearing) is a better choice.

To help assess the suitability of each item for retention within the respective instruments and for their potential inclusion in a diagnostic instrument, a grid of the major subsections of energy and the human body, as set out in the Proposition Statements (Appendix 1), against the items was created (Tables 7.1, 7.2 and 7.3). From these grids, items assessing the same area were readily revealed. From these common assessment items, the suitability of each item for inclusion could be ascertained. The suitability for inclusion into a single diagnostic instrument was evaluated by comparing the selection of reasons as previously discussed under the heading Blue or White Analysis (Sections 7.5.1 to 7.5.4). Also, the similarity of reasons and the actual propositions being diagnosed were compared. Once commonality between the items and what they assessed and the usefulness of the items was decided upon, items were eliminated from the list of potential inclusions. In this section, discussion on the items for inclusion in a single diagnostic instrument is performed

When assessing the suitability of the items in the Blue instrument, a specification grid of the items against the subheadings found in the list of Propositions (Appendix 1) was created (Table 7.2). A similar specification grid was formed for the White instrument (Table 7.3). These (two) grids would reveal where the items from the same instrument cover the same aspect(s) of energy and the human body. These common items in an instrument were then assessed for their effectiveness in assessing the subsection they purported to investigate. From this subjective assessment, a number of different items were identified which did overlap and should not be kept in that instrument

This assessment process resulted in a number of items being removed since they were considered the least suitable of the similar items. That is, Blue items 5, 9, 10 and 15 and White items 9 and 12 were removed and White item 7 was reworded to make it a more suitable item in assessing what is was designed to do.

Further to this, the items remaining would be considered for inclusion in a single instrument made up of items from both the Blue and White instruments. The final instrument being a single set of items any of which could be used in isolation or in conjunction with other items to help a teacher obtain information about student-held notions with regard to energy and the human body. Each set of remaining items was then combined and a similar grid created to those in Tables 7.2 and 7.3 to show the areas covered and which items were investigating the particular subsections. The elimination process as outlined above was then repeated to form a set of items which were considered the most suitable for inclusion in a single instrument to diagnose student notions with respect to energy and the human body (see Table 7.4).

Despite the creation of a single diagnostic instrument, the items initially retained within the Blue and White instruments could be used either on their own or in various combinations to help diagnose student-held notions with respect to energy and their own body. The combination of items used would depend upon what was being investigated

Table 7.2: Grid Showing Item Numbers Against Proposition Areas for Blue Instrument

	Energy Sources	Intake	Reception	Digest/ Absorption	Transport	Reaction	Respiration	Eye/ Ear	Sleep	Temp. Regulation	Uses/ Conversions	Storage
All Items	1	1, 3, 14	4, 10, 15	2, 5			6	4, 9, 15	11	12, 13	7, 8	7, 14
Items To Leave In	1	1, 14	4, 10	5			6	4	11	12, 13	7, 8	7, 14

Table 7.3: Grid Showing Item Numbers Against Proposition Areas for White Instrument

	Energy Sources	Intake	Reception	Digest/ Absorption	Transport	Reaction	Respiration	Eye/ Ear	Sleep	Temp. Reguation	Uses/ Conversions	Storage
All Items	7, 8	7, 8	8		1	3, 10	2, 9, 12		6,13	3, 10, 11	3, 5, 14	4
Items To Leave In	7(New) 8	8	8		1	3, 10	2	6, 13		3, 10, 11	3, 5, 14	4

Table 7.4: Grid Showing Item Numbers Against Proposition Areas for Both Instruments

		Energy Sources	Intake	Recep-tion	Digest/ Absorp-tion	Trans-port	Reac-tion	Respir-ation	Eye/ Ear	Sleep	Temp. Regul-ation	Uses/ Conver-sions	Storage
All Selected Items	Blue	1	1, 14	4, 10	5			6	4	11	12, 13	7, 8	7, 14
	White	7(new) 8	8	8		1	3, 10	2	6, 13		3, 10 11	3, 5 14	4
Final Items To Leave In	Blue	1	1, 3	4	2			6	4	11	12	8(new)	
	White	7	8	8		1	3	2			11	14	4 (new)

Note: The final items to be left in are a result of the discussion in Sections 7.5.1 to 7.5.4, 7.6 and summarized in Section 7.7.1.

and by whom. Tables 7.2 and 7.3 or 7.4 could be used to help a teacher decide the items for inclusion in a customised diagnostic instrument.

Where multiple items assess a similar area they were re-examined for their suitability to remain in the instrument in which they are currently found. Since items which are not part of a group of items assessing the same group of propositions have already been discussed they are not looked at in the following discussion. Only items assessing a common subsection are compared to determine their suitability for retention and use in the final diagnostic instrument.

It should be remembered that each sub-section within the propositions will have a set of propositions and hence a number of possible features which can be investigated. Hence some items may appear to assess a common subsection but in reality assess different aspects within that subsection.

7.7.2 Suitability of Blue Instrument Items to Emphasise Consideration for Retention in the Final Instrument

The following discussion has as its central purpose the task of selecting items from groups of items which cover the same sub-sections of the propositions outlined in Appendix 1. The selected items will be considered suitable for inclusion in the final diagnostic instrument.

Items 1, 3 and 14. These items assess the intake of energy.

Item 1 is very different in the propositions it investigates to the other two items and as such it should be retained.

Items 3 and 14 assess the same aspect of excess food and/or energy intake and what happens to this excess energy. Both these items have identical stems with the some reasons being the same (3A and 14 C, both D reasons match as do 3F and 14A), with item 14 covering a different aspect of energy and its location within the food. Item 14 is further discussed where it is similar to Item 7. Since there is this further commonality it should be retained before item 3.

Decision: Retain items 1 and 14

Items 4, 10 and 15. These items assess the receivers of energy such as the eye, ear and other body regions.

Item 4 investigates the conversion of energy received by the ear and eye into an energy form the brain can interpret. Item 15 is included within item 4 and so can be eliminated.

Item 10 only looks at energy receivers and its reception into the body. As such it is different to items 4 and 15.

Decision: Retain items 4 and 10.

Items 2 and 5 look at digestion and the absorption of food and its subsequent conversion into ‘useable’ energy.

Item 5 involves respiration as the process of energy conversions from chemical energy in food into useable energy while item 2 deals only with the digestion of the food. Item 5 incorporates item 2 within it and so is a better item.

Decision: Retain item 5.

Items 12 and 13 cover temperature regulation.

These two items investigate different aspects of temperature regulation with item 12 investigating a source of body heat while 13 covers the role of evaporation in cooling the body.

Decision: Retain items 12 and 13

Items 7 and 8 cover the general use or conversion of energy.

These items assess vastly different aspects of energy conversions with item 7 covering storage and item 8 energy conversions and the transfer of energy.

Decision: Retain items 7 and 8.

Items 7 and 14 cover excess energy and what happens to this excess.

Different aspects are covered with item 14 investigating the intake of energy into the body while item 7 investigates the fate of excess energy once it is inside the body. These have similar reasons (14A and 7B, 14D and 7D, both Cs are similar) although these similarities are sufficiently different to warrant retention unless a small number of items are desired in an instrument. (If this is the case retain item 7.)

Decision: Retain items 7 and 14.

From this analysis of the items found in the Blue Instrument, item numbers 5, 9, 10 and 15 have been removed from this instrument with the remaining items being considered for inclusion in a single diagnostic instrument.

7.7.3 Suitability of White Instrument Items to Emphasise Consideration for Retention in the Final Instrument

From Table 7.2, the following items were identified as diagnosing within similar sub-sections of the propositions and are to be considered for retention in a single diagnostic instrument.

Items 7 and 8 cover the intake of different types of energy.

Item 7 needs rewording as discussed earlier for the suitability of items for retention in the White Instrument. Considering the reworded item, both items 7 and 8 assess energy intake but both have different aspects and propositions covered. Item 7 investigates food while item 8 covers a number of sources of energy and includes food. Since both cover different aspect of energy intake, both can be retained but with item 7 reworded to have the following wording:

Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE

A *each food has the same type of energy and the same amounts of this energy*
B *different food groups have different amounts of energy with the same type of energy in foods*
C *each food has a number of different types of energy in it and each of these is in different amounts*
D *we carry out different types of activities and so these activities need different types of energy to occur*
E ____

Decision: Retain reworded item 7 above and item 8.

Items 3 and 10 cover the attaining of body heat from metabolism.

Item 3 incorporates item 10 in the stem but each has very different reasons. Because of the different reasons both can be retained, as they will when combined for analysis, give a good coverage of sources of heat used by the body as an aid to maintaining body temperature.

Decision: Retain items 3 and 10.

Items 2, 9 and 12 all deal with respiration.

Item 12 is generalised in its wording and probing and only distinguishes problems at a very elementary level of knowledge or understanding of the process of respiration and is very similar to items 9 and 2. It also shares a reason with both items (Reason A is common to all items). This item can be removed with no loss of investigative power of the instrument.

Item 9 uses conversions of food while item 2 covers the same things as item 9 but specifically mentions three food groups and as such assesses the value of food groups as sources of energy for respiration. Thus this item may detect misconceptions involving the value of different food groups as energy sources for respiration. For this extra probing, it is desirable to retain item 2 over item 9.

Decision: Retain item 2

Items 6 and 13 cover aspects of hearing and vision and the conversions of energy by these sense organs.

Both items deal with one of these two sense organs with item 6 covering the ear and item 13 deals with vision. So both items could be retained.

Decision: Retain items 6 and 13.

Items 3, 10 and 11 cover propositions dealing with heat as a by-product of chemical reactions which occur in the body and body temperature.

Items 3 and 10 were discussed earlier with both being retained.

Item 11 covers the area of heat loss from the body and because it covers a different aspect of heat and the body it should also be retained.

Decision: Retain items 3, 10 and 11.

Items 3, 5 and 14 cover energy conversions and uses.

Item 3 has already been discussed and was to be retained. This is supported in this comparison.

All three items cover different aspects of energy conversions so all could be retained.

Decision: Retain items 3, 5 and 14

Items 9 and 12 are to be removed from the set of items found in the White instrument while item 7 is to be reworded with the remaining items being retained and considered for inclusion in a single diagnostic instrument.

7.7.4 Suitability of All Items for Inclusion in a Single Diagnostic Instrument

Figure 7.3 shows which items remained after the comparative analysis of the Blue and White instruments. In a number of cases, these retained items cover similar aspects of energy and the human body. To this end a further comparison between items follows a similar to the discussion on retention of items within the Blue and White instruments. But before this discussion, it should to be pointed out that there are a number of items that do not have closely associated items on the other instrument. These items need to be retained and include White 1, 10 and Blue 2, 7, and 11 and as such will not be discussed in the following comparisons.

Items Blue 1 and White 7 (re-written) both investigate the area of food intake (and hence energy). Both items look at different aspects of energy and food intake. Blue 1 examines food as a source of energy and the location of energy within the food while White 7 examines at the types of energy and its quantity in different foods. The reasons for both items are different and so there is no overlap in the areas covered by these two items.

Decision: Retain both items Blue 1 and White 7 (with item 7 being the reworded version shown in section 7.7.3).

Items Blue 1, Blue 3 and White 8 all investigate the involvement of food and energy. But each is entirely different in which propositions are actually investigated.

Decision: Retain the three items of Blue 1, Blue 3 and White 8

Items Blue 4 and White 8 investigate sources for energy intake into the human body. Blue 4 investigates sense organs and their energy conversions (reception and conversion) while White 8 investigates energy sources rather than energy reception.

Decision: Retain items Blue 4 and White 8.

Items Blue 6 and White 2 investigate the process of respiration to form useable energy and the initial sources of this energy.

A number of reasons are shared by both items (reasons A and F in both, Blue 6 B and White 2 C, while there is a similarity between Blue 6 C and White 2 E). With the similarity between reasons, there is enough commonality between the items for the removal of one item.

The stems of both items are also similar, with White 2 specifying which food groups are used while Blue 6 is general in its use of the word food. For the reason that White 2 is more specific as well as using the word food, it could indicate students who think only one food group is responsible as an energy source. This is a documented misconception (Chapter 5) and as such makes this reason more useful than item Blue 6.

Decision: Retain White 2.

Items Blue 4, White 4 and White 13 investigate either or both vision and hearing and the energy conversions which take place in both processes. Blue 4 covers both sight and hearing while White 6 covers sound and White 13 covers the process of vision.

Each of these items have common reasons. With Blue 4 including sections of items White 4 and 13 it is proposed to retain item Blue 4 because it covers both senses.

Decision: Retain Blue 4.

Items Blue 12, Blue 13, White 3 and White 11 all investigate different aspects of body temperature and the regulation of this temperature. Each looks at a different section of temperature regulation.

Items Blue 12 and White 3 are similar in what they investigate and use the by-product of chemical reactions to contribute to body heat and hence body temperature. Blue 12 actually mentions a temperature (approximately 37^{o}C) while White 3 concentrates on the source of heat for body temperature.

Further argument against the retention of White 3 is that Reason B in White 3 is very low in the percentage of students who selected it and it has been suggested this reason be removed. Reason C in the same item tests not only the heat source but also goes further and investigates the relationship between heat and temperature. Reason C could be removed, as it is not directly related to the defined area being studied; that of energy and how it relates to the human body rather investigating the differentiation between heat and temperature.

With both reasons B and C removed it is of little value to retain item White 3.

Decision: Retain item blue 12.

Items Blue 13 and White 11 both deal with temperature regulation through the use of sweating. White 11 indicates there are other processes involved in temperature regulation and as such is a better item for diagnosing body temperature regulation. Retain White 11.

Decision: Retain items Blue 12 and White 11.

Items Blue 8, White 3, White 5 and White 14 investigate energy uses by the body.

White 3 and White 14 study very different aspects of energy "use" by the human body and as such each should be retained. But, prior discussion of White 3 resulted in this item being removed in favour of item Blue 12 since 2 reasons are not effective in White 3.

Blue 8 and White 5 use the riding of a bicycle as an example of this use or transfer of energy. Previous discussion of these two items has been carried out in Sections 7.6.2.1 and 7. 5.1.1 which resulted in the suggestion that both these items be combined to form one item with 8 reasons.

Decision: Retain item White 14 and combine items Blue 8 and White 5 to form a new item with reasons provided from item 8 as follows:

When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE

A *the bike is not living and so cannot use or have energy*
B *we use energy up not transfer it to the bike*
C *bike makes its own energy*
D *use energy to move the pedals but no energy is transferred to the bike*
E *our leg movement energy is transferred to the bike and becomes the movement energy of the bike*
F *we push on the pedals which makes the bike move but there is no energy transferred to the bike*
G *bicycles can't use human energy*
H *we use energy up not transfer it*
G ____

Items Blue 7, Blue 14 and White 4 investigate what happens to excess energy in the body.

Blue 7 and White 4 investigate the storage of energy in lipids while Blue 14 investigates the storage and excretion of excess energy which is a different aspect of energy storage.

The stems of Blue 7 and White 4 are very similar in meaning and in the way they probe the area of knowledge on energy storage. Two of the reasons are identical (A and D in both items) with B and C having minor differences but with White 4 going further in its span of time and processes of what happens to the excess energy (after storage). The other two reasons in each item are both different. With little difference between these two items except for two reasons, there is little to choose between them. Either White 4 should be retained as it probes in greater depth with its reasons or it is better to combine the two items to create the following item.

This following item is derived from the stem of item White 4 and the reasons from this item except reason E which is substituted for Blue 7 reason F.

Energy may be stored in the body for later use. Fat (lipids) is one such chemical which is used for energy storage.

TRUE/FALSE

A	*we store fat but we cannot use this fat for energy at some later time*
B	*energy is changed into fat to be stored*
C	*excess energy is not changed into fat*
D	*we store the excess energy in the bonds of the fat*
E	*there is no excess energy as we only absorb what we need*
F	*there is no left over energy as we use all we take in*
G	____

Decision: Retain items Blue 14 and the newly created item.

While a number of items have been rejected for a variety of reasons, some should be left as supplementary items since they cover specific areas within their respective subsections of the propositions. These items include White 6 and 13 and Blue 13. Both of the White items are subsumed within Blue 4 but are very specific in the reasons they contain and these reasons are not fully covered by item Blue 4. Similarly Blue 13 covers the specific role of the evaporation of sweat as part of the body's cooling processes and assesses the process of evaporation rather than the role of sweating.

7.7.5 Final Item Selection

To ensure the set of items used in the final diagnostic instrument do investigate a wide range of topics covered under the umbrella of energy and the human body, a specification grid was created (Table 7.5). This specification grid shows the major sub-sections as defined by the propositions found in Appendix 1 and shows the final set of items to be used in the diagnostic instrument "Energy and The Human Body" which can be found in Appendix 14 and comprised 20 items.

Table 7.5: A specification grid showing the items against the main sub-sections within the area of energy and the human body.

	Energy Source	Intake	Reception	Digestion/ Absorption	Transport	Reaction	Respiration	Eye/ Ear	Sleep	Temp. Regulation	Uses/ Conservation	Storage
Item Number	1, 2, 3	2, 4	10	6	7	8	9	10, 1s, 2s	11	8, 13, 14, 3s	12, 17	5, 15, 16

Note: 1s, 2s and 3s are supplementary items that have specific diagnostic functions and should be used for assessing these specific propositions.

7.8 ANALYSIS OF ANSWERING APPROACH BY STUDENTS TO ITEMS

It was anticipated that when students are responding to two-tier items, they will decide on the veracity of the statement first and then look in the set of supplied reasons for a reason which parallels that of the respondent's reason for the commitment. This answering technique was the method assumed by the constructors of two-tier items to be the same as that used by respondents. But Griffard and Wandersee (2001) argue that this assumption may not be valid. They argue, from data they collected during some recent research, that respondents may use test-answering techniques when giving their responses. In other words, students use the responses to help guide their selection or elimination of answers or in the case of these items the reasons rather than the reverse where-by a response is made and then the parallel reason(s) to those used to arrive at the commitment, are searched for within the reasons supplied. To this end, a second stage of testing the validity of the responses was carried out in two parts. Firstly, four students were given a think-aloud test during which they were tape-recorded and secondly, a larger group of students were assessed by their peers through the use of a check sheet to determine the process(es) used by students when responding to an item. These four students who participated in the think –aloud test volunteered to a request from the author to participate.

7.8.1 Response Method Instruments

Four students from Year 9 (n = 2) and Year 11 (n = 2) were asked to re-sit one of the White or Blue instruments during which time they were required to think aloud while making their responses. This thinking aloud was tape-recorded and analysed for evidence of the test answering technique(s) was being utilised.

A check sheet of possible approaches to answering a two-tier item was created by the author, with a number of possible student approaches derived from this author's experiences with student test-answering methods and the methods of the four student volunteers used. This check sheet is found in Figure 7.1. To ensure no obvious answering methods were left off this check sheet, five experienced science teachers were asked to read through it to see if it did cover the more common methods of responding to a multiple choice type of test item. This check sheet was then used to gather more information on the methods employed by students when responding to two tier items.

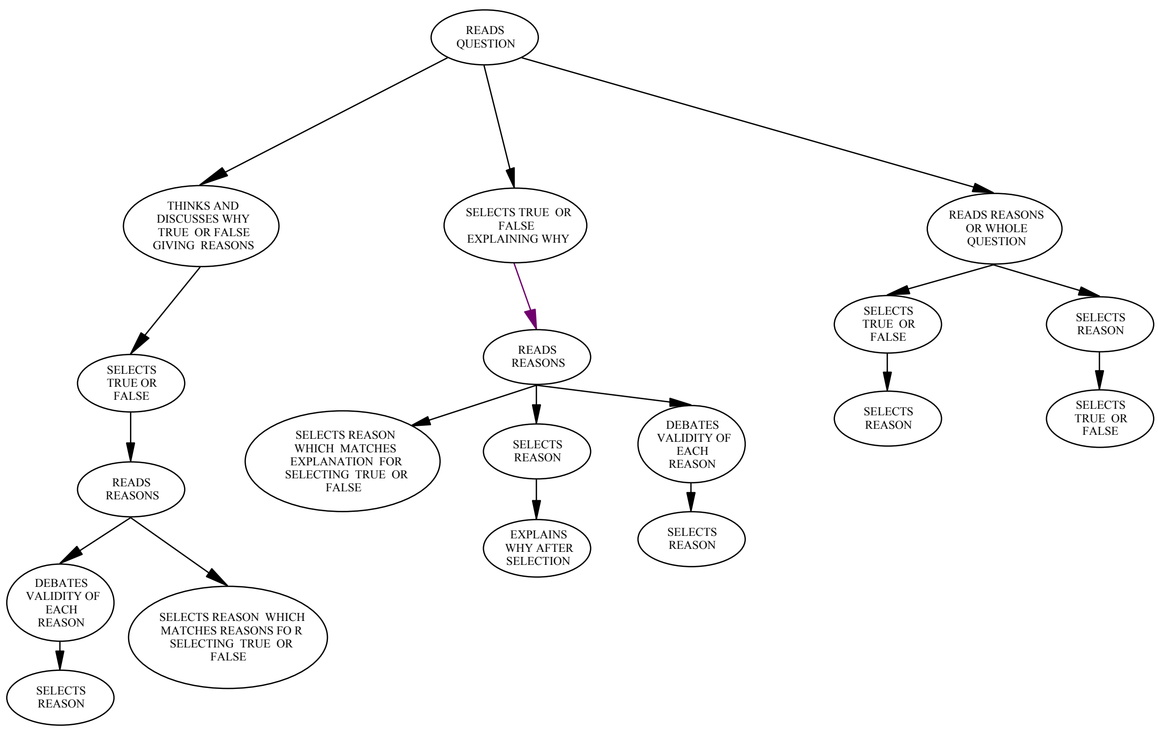

Figure 7.1: Check sheet used to map student-answering techniques when responding to a two-tier item.

Two classes each of Year 9 and 10 were asked to participate in a think-aloud test situation while responding to four or five items from one of the Blue or White instruments. The instrument used by each participant was the instrument that the students had not seen in earlier situations. This ensured the items were unfamiliar to the respondent. In each of the classes, students involved in this test situation were divided into pairs. One of each pair was to do the test while the other person was to assess the method in which the respondent answered the set of items. A partner using the check sheet assessed the manner in which the respondent responded to the items.

The assessors were verbally instructed on what was expected of them and how they were to monitor their partner's answering techniques. This instruction was done in a different room well away from the responding group.

These instructions were for the assessor to mark each step of any of the supplied pathways followed by the respondent while the items were being answered. If no path on the check sheet was followed, the assessor was asked to write down each step used as it happened. When an apparent pattern of responding appeared, the respondent was asked to stop their answering items. This process usually took four or five items.

The respondent group was then given their instructions in the presence of their partners. The whole class was told to answer four or five items at random from within the instrument they had in front of them but to think aloud while answering and that only the assessor could ask questions of the respondent.

The procedures used by the student-pairs were monitored by this researcher to ensure that the students did in fact carry out the required procedures with no digression from the instructed methodology. Any digression would be dealt with as it occurred through the intervention of the researcher. There was no need for intervention during this assessing procedure.

7.8.2 Results of the Tape-recorded Methodology

Each tape-recording of the students thinking aloud was analysed for the methods used while the four students responded to one of the Blue or White instruments. In each case, the students followed the same pattern of answering. Three of the respondents read the stem and debated the veracity of it and then chose true or false. To identify the supporting reason, they read the reasons supplied to find the one that fits the reason for choosing true or false. The fourth student chose the reason because it looked right. This later student did not explain why she selected true or false and when asked why these were chosen replied —*" not know how to explain it, it just is"*.

7.8.3 Analysis of the Peer Checked Responses

Analysis of the peer-assessed methods of answering the items showed each student employed a variety of methods. A total of eight students used more than one method in their answering the items. Table 7.6 shows the percentage of response methods used by students when responding to the items. A total of 52 questions were answered by Year 9 students (n = 13) and 54 questions by Year 10 students (n = 16).

The first three choices on the check sheet are ones where the respondent does not use any clues from the item itself, rather the student debates the veracity of the stem and then selects a reason from those supplied which matches the reasons in the debate. Methods two and three are very subtle in their difference and for this argument they will be combined as they do not involve using the item to gain clues.

Table 7.6: Percentages of students who used each process to chose true/false and to select the reason(s) for true/false.

	Year 9	Year 10
Discuss and debate item sections	26.9	22.2
Read reasons for answers	42.3	46.2
Read whole question first	30.7	31.5

The other four answering techniques on the check sheet involve reading the reasons and these methods could supply clues as to the most suitable reason for the stem being true or false. Methods three and four involve reading the reasons and then selecting a reason but not the one that matches the argument used for the statement being true or false. The last two methods involve reading the whole item through and then answering it. These methods could supply clues to the respondent that could aid in the selection of answers.

A percentage of respondents did debate the veracity of the stem of each item (26.9% of Years 9 and 22.2% of Year 10) while by far the largest percentage of students read the reasons before selecting the reason which they feel supports the stem's veracity. Of the students who do read the reasons, over 40% had already chosen true or false and then were looking for a reason which best fitted their choice. It could be argued that these students are most likely looking for a reason which matches their own reason(s) for their selection of true or false. But these students were not obtaining any hints to aid in their responding to the item. Only methods 6 and 7 could provide any sort of clues as advocated by Griffard and Wandersee (2001).

If Griffard and Wandersee (2001) were to be supported by this brief survey of answering techniques employed by students, there would be a high percentage of students using reasons 6 and 7. Approximately 30% of those surveyed did use either of these methods while the rest of the students used a variety of other methods for arriving at their responses. From this small survey, it would appear the majority of students did not use the item to gain clues to help in their responses but rather made up their mind as to what was their response and then looked for the best match in the reasons. From this it can be claimed that two-tier items may be used to supply clues for a significant percentage of students but for the majority this is not the case.

It was felt that the fact that these students had already responded to a similar set of items would not adversely influence the method by which the students would use to respond to the items. Rather, familiarity with the format would make the students more at ease and so they would respond in their normal test answering manner and hence this would have a beneficial effect on the outcome of this method for checking the validity of the items as they would be responding in their natural manner.

7.9 SUMMARY OF CHAPTER

This chapter has discussed the development and subsequent administration of a number two tier multiple choice items for potential inclusion in a diagnostic instrument created to identify conceptions held by students in the area of energy and the human body. This diagnostic instrument is designed for use by classroom teachers to help identify conceptions held by students and to also gain an insight into the underpinning reasons for the holding of these concepts.

Student conceptions and their underpinning reasons identified in Chapter 5 provided the source of information for the reasons use in each of the two tier items and resulted in a set of 29 items. The 29 items were divided into two separate instruments which were subsequently administered to 208 students in Years 8 to 10 who attended the school in which the author works.

The items were analysed individually and as a group for their overall inclusiveness in assessing student-held conceptions within the area of study. From this analysis, a set of 17 items was identified for inclusion in the diagnostic instrument "Energy and the Human Body". As well as these 17 items, three supplemental items were retained for assessing specific propositions within the area of energy and the human body.

Further to the creation of the diagnostic instrument "Energy and the Human Body", a brief study of the methods students use in answering two tier items was carried out in response to a report by Griffard and Wandersee (2001). This analysis found many students in responding to items formulated their own arguments as to the validity of the stem for an item and from these arguments chose a reason from those supplied or wrote their own reason. But a significant number of respondents did use the item to gain clues to aid them in formulating their response.

This Chapter partially achieves the goals of Objective 3, namely to develop a diagnostic instrument which could be used by teachers and students in the identification of student held notions and their underpinning reasons. The assessment of the effectiveness of this instrument in describing student held notions was not carried out due to the researcher going on leave and the substitute teacher administering the wrong instrument, namely '*What do you Know about Energy and Your Body? Questionnaire1'*.

CHAPTER 8

THE INTERVENTIONIST STRATEGY

8.1 INTRODUCTION

This chapter involves the design of an interventionist strategy developed in an attempt to overcome a number of problems identified and described in Chapters 5 and 6. Subsequently, this strategy's effectiveness was tested through the use of the instrument *'What do You Know about Energy and Your Body? Questionnaire 1'* found in Appendix 4 and an open-ended essay item (Figure 8.1) which were both used as pre- and post-strategy instruments, with the essay item re-administered five months after the completion of the strategy. The data collected from these instruments were analysed to investigate the effectiveness of the interventionist strategy both in the short and the longer term.

The analysis of the data reported in Chapters 5 and 6 revealed a number of problems in student knowledge concerning digestion, energy location within food, how absorbed food is converted into utilisable energy via respiration and energy's subsequent conversions and transformations by the body or its cells as they carry out their normal functions. It is the first three of these identified problems, which the interventionist teaching sequence to be discussed here attempts to address.

All subjects from the initial data collection and discussed in Chapters 5 and 6 indicated that they knew food was a major source of energy for the human body. But, after this point of agreement there is divergence in the notions held by students with respect to where in the food energy is found and what happens to that food for it to become utilisable energy. As Ausubel (1968) and many other researchers on teaching strategies point out, a teacher should start a lesson at a point where the students currently hold knowledge. In this situation, it is also a logical starting point as this is where the food energy enters the human body. It is for this reason that the interventionist strategy starts at the ingestion of the food and progresses through how it is digested, absorbed and the once inside the cell, how the process of respiration converts this energy into a useable form.

8.2 UNDERLYING BACKGROUND FOR STRATEGY

8.2.1 Requirements for learning strategy

A number of criteria based upon a broad constructivist paradigm were required before a model for use in teaching this sequence of work could be developed. These requirements included the active involvement and participation of the learners in the lesson (Gorrell, 1991; Glynn & Duit; 1995, Symons, 1994) through the learners being made aware of their own conceptions about the material to be covered (Beeth, 1998; Flavell, 1976; Glynn & Duit, 1995). Once aware of their own conceptions, the students would interact with new information through their involvement in a range of activities that would challenge student held misconceptions and attempt to redirect these. During these activity processes, the students would be required to carry out “reflection on the content of conceptions themselves” (Thorley, 1990, p. 116) and to think about these ideas and to use them in a number of situations (Hewson, 1996). This involvement should ideally be in small groups where the exchange of ideas could be readily accomplished (Beeth, 1998; Fleer, 1991). In these groups, the students can discuss their evolving ideas, elaborate and justify them and then modify them in light of the information and feedback received during this interaction (which is one of five conditions for meaningful learning of Glynn and Duit, 1995).

To develop more scientifically acceptable notions, the students need to be involved with a number of activities that are challenging to both old and newly developing notions. This involvement is best achieved through the use of models of phenomena and situations which are real to the students (Fensham, 1996a & b; Gabel, 1992; Gilbert, 1998; Linjse, 1990). These models and situations should involve concrete objects representing abstract or invisible things such as molecules and energy, and to go from the macro to micro situation (Gabel, 1998; Gilbert, 1998; Johnson, 1993). In the lesson sequence involving food and energy, models of molecules and a simulation of digestion and respiration were to be developed.

Through the gradual development of ideas which derived from the students pre-existing notions and through the student's involvement with phenomena real to them, the intention was to develop a gradual change in a student's cognitive framework (Trumper, 1993b). At the same time, it is necessary to be cognisant that students' pre-conceptions are resistance to change, as discussed by such researchers as Posner *et al*. (1982), Shrigley (1990), Kaper and Goedhart (2000) and Pedro (2000).

Based upon these requirements, the model of Driver and Scott (1996) appeared to meet these requirements for a learning strategy and so was chosen and subsequently modified to better suit the requirements outlined above.

8.2.2 Interventionist Strategy Model

The interventionist strategy utilised in this piece of the research was based on a modified lesson format outlined by Driver and Scott (1996). This modified lesson sequence did not involve the teaching of the nature of scientific theory and theory-making as this was not feasible in the allocated time and it was not considered vital to the students' learning the material being covered in this interventionist strategy. Rather, the students formulated their notions that were then tested in the last three steps of the sequence.

The six steps employed in this teaching sequence were as follows: orientation and eliciting of ideas, a treatment of the problems identified in the first section through experimentation and manipulation, the students made their own theories which was then followed by review, reflection and evaluation of the theory being developed. The final step of consolidation was via discussion with peers where ideas were presented and if necessary defended. This process is circular as the student's progress through the lessons and they constantly reflect back on what they have adjusted in their cognitive framework and then employ these new notions in the next cycle of the lessons.

During the orientation section, students were made aware of their ideas with regard to the relevant phenomena by use of a questionnaire and an open-ended essay question. The questionnaire used was the instrument *'What do You Know about Energy and Your Body?'* (Appendix 4), the development of which was discussed in Chapter 4. Concurrently, an open-ended question was given for homework (Figure 8.1) which required students to write as much information as they could on how a cell obtains food. The only instruction was not to use any help from textbooks or any other sources.

> Describe in detail how a cell obtains energy so it can carry out its function(s). For example, explain how a muscle cell gets the energy needed so it can contract and so help us move. In this description start with getting the energy into the body.

Figure 8.1: Pre and post-test open-ended essay question

The open-ended essay was worded to allow all students to write as much information as they can on the subject of how a cell gets energy and not feel directed or restricted in any way in the response they give. A student who has much information would be able to demonstrate this while a student who knew little would similarly demonstrate this point. The type of knowledge, whether accurate or not, was not indicated in the question and so it was anticipated that students would reveal both inaccurate and accurate notions.

Both the open-ended essay question and diagnostic instrument were to supply data to both the student and this researcher on what the students knew about the overall area to be studied and to encourage the students to start thinking about the area being covered during future classes. The responses to the pre-strategy test and the post-strategy tests (diagnostic instrument and essay) would also supply data that could be used to examine any changes in the notions held by the students as a result of the interventionist strategies to be discussed in this chapter.

Step two involved the learning sessions in which the students progressed through a programmed sequence of activities that would enable them to develop a more scientifically acceptable set of notions about energy and their body. It was during this phase that the students manipulated models of the phenomena related to energy in molecules, digestion and the process of respiration. These developing notions commenced with the location of energy within food molecules, the processing of food from its ingestion through to absorption into the body and the subsequent transfer of the food energy to ATP (or the universal energy molecule) via the process of respiration. This teaching sequence for the interventionist strategy is located in Appendix 16.

While the students were progressing through the lesson sequence, a series of questions were posed as part of the lessons and are designed to raise student awareness and to encourage them to record their current ideas about the next steps in the conversion of the ingested food into utilisable energy. After these questions had been responded to, class work was carried out which related to that idea. This activity was followed by the students reviewing their previously given answers. This process corresponds to the theory creation step of the model, where the students could modify and record any changes to their previous responses such that they would have a written record of their newly developing notions. Any changes to notions would be in light of the new information they had gained from the activity just carried out and the subsequent cognitive adjustments resulting from it. This step is similar to that of Driver and Scott's reflection, revision and development step, as there is no theorising via the development of patterns in the data that students create. Rather, there is reflection on the new information that would not confirm the old patterns based on previous knowledge. This would be followed by a revision of the knowledge base in light of newly discovered information and should facilitate the adjusting of the prior knowledge to better fit this new information.

As students developed a mental picture of the processing of the ingested food they were challenged to review and reflect upon their old ideas and adjust the notions they may have held prior to the modelling of the processes of digestion, absorption, and subsequent respiration process of the absorbed food. This reflecting and reviewing of held and developing notions was further refined during the group discussions that took place within the working group (the student belonged to) where notions were tested and defended. This peer interaction led to these new ideas being reinforced or readjusted and subsequently being applied during the next stage of the circular process.

The penultimate step of this teaching scheme was where the students applied their current (newly formulated) ideas on energy gain, retention and conversion. This event was via a repetition of the open-ended essay question given during the orientation session. Each student was involved in a discussion with a group of students from within the same class but who had not worked together during the lesson sequence. During this final discussion, students had to defend their notions and if necessary further modify them in light of any new or conflicting information which arose at this stage of the lessons. It is during this social interaction process that the final stage of consolidation was expected to occur.

8.2.3 Anticipated Outcomes

It was anticipated that during the lesson sequence students would have to become aware of their current notions and then, by working through the lessons, to adjust these notions as the older notions become unfruitful and so leading to dissatisfaction with them. Continual revision and chances to adjust notions and the subsequent application of the adjusted notion(s) in new situations would reinforce the student's cognitive framework as it developed.

The intention was that this lesson sequence would lead to a more scientifically acceptable set of notions which would remain as the set of notions foremost in the student's mind. This cognitive behaviour would be in line with the work of such researchers as Demastes, Good and Pebble (1996) and Dawson and Lyndon (1997), who claim it is not possible to totally remove a previously held notion, only to make it fade into the background so it becomes rarely if ever used rather than be replaced by the older conceptions.

8.3 DEVELOPMENT OF THE INTERVENTIONIST STRATEGY

8.3.1 Planning the Strategy

From the analysis of data collected from the administration of two questionnaires discussed in Chapter 5, a number of areas of weakness in the students' knowledge were identified. These weaknesses included the location of energy in food, the role of digestion especially with regard to energy, the role of absorption of the digested food and the general lack of knowledge about respiration. From the sequential nature of these problem areas it was possible to develop a sequence of lessons which could address most of the areas of identified weakness. Since the school in which the author is employed covers these areas in the general science course taught to all Year 9 students, it was decided to develop a lesson strategy which would attempt to address these areas of weakness for this year group. The lesson plan would be a sequence covering all the areas nominated so students could follow the passage of the food from its ingestion through to the conversion of the chemical energy in the food molecules into the 'universal energy molecule' or ATP.

It was necessary to cover most of the topic areas to a limited depth due to the age and background ability of the students. To this effect and with the areas of weakness identified, a set of statements was developed which delineated the coverage and depth for each study area (Figure 8. 2). These statements also helped define the sequence of lesson coverage, such that the students would follow the normal passage of the food from its ingestion through to it being used in respiration.

8.3.2 Creating the Strategy

Using the statements and the criteria discussed in section 8. 2.1, a set of instructions was constructed for students to follow when participating in this lesson sequence. This lesson sequence was then given to three teachers teaching the Year 9 general science course (one teaching physical science and two teaching biology in Years 11 and 12). These teachers were requested to check the lessons for their logicality of the sequencing, the scientific accuracy of the instructions and their expected outcomes. In addition teachers were asked if the lessons could be followed, and to comment on the reading and comprehension levels of the material and any other problems which they might find. From this feedback, the lessons were modified and then rechecked by these assessors.

Subsequent to this teacher check, a class of Year 10 students were asked to further check the material. Year 10 students were involved since it was felt they should have some degree of background knowledge (however small) of what the lessons were aiming to achieve and cover. Hence it was intended these Year 10 students would know if there were any problems with the material in terms of not being sure of what was expected or could not understand a direction given. In this case, the check was that the students could follow what was to be done without actually physically carrying out the whole process and answering the questions in detail. Any suggestions were considered and acted upon. The resultant lesson-sequence which was given to the students can be found in Appendix 16.

Structure of Molecules

- components of a molecule include atoms and chemical bonds
- examples of members of each food group include glucose, lipids, proteins, vitamins, minerals and water.
- structure of some food molecules including glucose, a generalised lipid and a generalised protein

Digestion

- ingestion of food involves the intake of various food groups via the mouth
- digestion is the process of breaking down large molecules into smaller absorbable sized molecules
- products formed from digestion of food include amino acids, glucose, (glycerol and fatty acids)

Absorption

- what is absorbed is small molecules from food digestion
- digested material is absorbed by diffusion
- lipids are reconstituted before absorption into the lymph

Transportation (of absorbed food)

- blood carries the absorbed food molecules to the liver first then around the body
- absorbed carbohydrates and amino acids molecules are transported in the blood
- lipids are transported around the body via the lymphatic system.

Cellular Absorption

- cell membrane selectively allows molecules to move across it
- absorption of 'food molecules' across the cellular membrane is by diffusion and active transport

Respiration

- respiration occurs in the mitochondria
- respiration involves the breakdown of molecules from absorbed food (glucose and a generalised lipid are examples)
- the word equation for respiration is only a summary of the complex process of respiration
- respiration results in the formation of ATP ('universal energy molecule')
- respiration is the process in which the energy in chemical bonds is transferred from glucose or other food molecules to help in the formation of ATP
- chemical bonds are the source of chemical energy used in the process of respiration

Figure 8.2: Statements related to the processes involved in the transfer of energy from food to ATP

8.3.3 Administering of the Strategy

The interventionist strategy was given to a Year 9 class of average science ability who were being taught by the researcher. The class comprised 33 students of whom 19 were females. The class had formed a number of working groups during the year which ranged in size from pairs to four with the majority of groups being four (with three being mixed sex groups). It was originally planned for the strategy to take five lessons but this time had to be extended to eight lessons hence time was lost due to the library research work and the class work being carried out more slowly than expected by the students. (The students stayed on task for the majority of each lesson.)

At the commencement of the lesson sequence, it was verbally explained by the researcher what was going to happen, how the lessons would be worked through as well as the various assessment instruments and their purposes. This discussion included the role of the students as individuals and in their groups and also indicated that the teacher's role was to facilitate rather than to teach from the front of the class and that the teacher would be as a guide and a source of help should a problem arise. This was not a new teaching procedure to the students; rather the length of the lesson sequence was longer than normal. Discussion also took place about the reasons for this sequence of lessons, both for the students and their knowledge growth and also for the research program that was intended to help other teachers and students, if it achieved what it was designed to do. At this time, it was pointed out that at no stage would students be identifiable in any reports written on this strategy.

Each student's name was required on all diagnostic instruments for future identification as the open-ended essay item and the diagnostic instruments served two purposes; one to show the students what they had learnt during the ensuing two weeks of the strategy and secondly that the researcher could collate all the responses from each student.

After this introductory session and prior to the students commencing the interventionist strategy, an open-ended essay was given for each student to do during a science class (see Figure 8.1). Clear instructions were given verbally that the essay was to be attempted by the student and that no help be sort from other students, family members or resources and the purpose of this essay was clearly explained. This essay was re-administered immediately post instruction and again after a period of five months. The latter was to assess the long-term retention of material covered by this teaching strategy.

At the commencement of the strategy all the students completed the diagnostic instrument *'What do You Know about Energy and Your Body?'* during class time.

Both of these instruments should raise the students' awareness of their own knowledge on the topic area of how they get energy into their body and how the energy is converted into useful energy forms. From this raised awareness, students could then work through the lessons and make adjustments to their knowledge framework in light of what they are aware of already being in their knowledge framework and also be aware of what was new to them.

8.3.4 Problems Which Arose During Administration of the Interventionist Strategy

During the first section where the students needed to use the library to research molecular structures, the majority of students could either not find the required diagrams or there were insufficient books available for student use. This section of work was subsequently altered so that the teacher used a set of overhead slides of various molecules and briefly discussed each molecule and what was to be done with these required diagrams of various molecules. When this modification was employed the following year, students had little trouble in understanding the rest of the procedure.

The other problem was the length of time required for the class to satisfactorily finish the lesson sequence. Since the students remained on task for the majority of the time spent in class, very little could be done to remediate this problem except to allow the extra time for learning.

No other problems arose once the students realised they had time to become fully engaged in the lessons and that it was not expected that they rush through the lesson sequence and finish it in one or two lessons, but that they could take their time and fully understand what was going on.

8.3.5 Judging the Effectiveness of the Interventionist Strategy

Two methods were used to assess the effectiveness of the interventionist strategy - the open-ended (Figure 8.1) essay item and the questionnaire *'What do You Know about Energy and Your Body? Questionnaire 1'*.

For the open-ended essay instrument, the number of individual points made in a response was calculated and the quantities of these points for each of the three assessment stages compared. A point was a single piece of information that could stand on its own and still be relevant as a response to the item. It is thought that the use of each of the points made by a student in their response to the item would be an indication of the amount of knowledge that a student can recall, since students were asked to write all they could on energy conversions from food intake to using the energy. Each new point should indicate a different idea held that is readily recallable by the students.

More importantly though is the need to compare changes in the number of correct points written by each student as it is these acceptable notions which are ultimately the desired outcome of any learning situation. Of particular interest were changes which persisted over the longer term rather than the immediate post-test results as these are the notions effectively incorporated into each student's mental framework. That is, the long-term post-post-test assessment, when compared to the immediate post-test and pre-test assessments, indicate the effectively incorporated ideas and the degree of retention of recallable acceptable ideas over a period of time. The pre- and immediate post-test comparison of data indicate material readily recallable as a result of the interventionist strategy. This information may be held in the memory for a short time and then be forgotten if it is not used again outside the class.

The post-test was that test which immediately followed the interventionist strategy while the post-post-test was the test which was administered five months after the administration of the post-test. In this intervening five months, the students studied alternative energy sources which dealt with energy derived from wind, solar, tides and waves chemistry. The chemistry covered topics centred around acids and bases, metals and non-metals and chemical formula writing which were all unrelated to energy and in particular were unrelated to any notions covered in the post-post-test. Further, the students were not warned about this later test and so could not study or prepare for it.

The diagnostic instrument *'What do You Know about Energy and Your Body? Questionnaire1'* was used to assess the pre and post-strategy knowledge that each student possesses about particular aspects of the interventionist strategy covered by the instrument. (Items not related directly to the interventionist strategy were not used in this assessment process.) Comparison of the pre and post strategy data was carried out firstly on an individual student basis and was followed by changes revealed for the class as a whole. It is felt the effectiveness of the strategy may be satisfactorily judged using this instrument if each individual's data were used as some students may resist change to their notions. However, changes to the set of combined class-notions may not reveal the effectiveness of the strategy because improvements made by some students could be cancelled out during scoring by inaccurate notions given by other students.

8.4 RESULTS

8.4.1 Open Ended Item Analysis

The data for students who attempted at least two of the three open-ended tests are shown in Table 8.1. A total of 22 students responded to at least two of these tests. 18 students attempted both the pre- and the post-tests, 18 students attempted the pre-test and post-post-tests while 15 students completed all three assessments. Consequently, each discussion to follow on the comparison between tests only took place between students who completed both of the tests used for that comparison.

After a quick perusal of the data it was felt that there was a difference in the strategy's effectiveness for each of the two sub-sections within the strategy of digestion and also on respiration. So further analysis of the data was carried out with respect to the two main sections of the strategy.

Many students gave a number of different pieces of information in a response. Each of these pieces of information was scored individually and is referred to in the following discussion as a point. For example, the following response has two points – *"In the food there are molecules which contain a form of energy. When we eat the food this energy is released through many processes"* while *"energy had to be small for the body to absorb it"* has only one point.

8.4.1.1 Pre-test and Post-test Comparison

The pre-strategy test initiated a range of written responses varying from two to 15 points with the majority falling below 10 points. Many of these points were irrelevant to what the item was investigating and these irrelevant points had a range of one to 13. These results indicate that the study cohort's knowledge prior to the interventionist strategy was poor with regard to the aspects of the energy processes involved when the human body obtains and uses energy.

The relevant responses (that ranged from zero to five accurate points with a mode of one point correct) showed few students could create accurate or detailed notions with respect to the processes involved in the body obtaining energy and its subsequent use. Of these accurate responses, the majority involved digestion. While many students accurately mentioned the process of respiration, there were few more detailed points made on this process.

In the post-strategy test responses, students who responded to both of the tests (n = 18) not only had written more points overall but they had more relevant points in their responses (from 6 to 24 points compared with 2 to 15 in the pre-test responses). The post-test responses had more accurate points with a range of 2 to 20 points compared to a range of 0 to 5 points in the pre-test responses and associated with the increased number of responses were fewer irrelevant points. The smallest improvement in accurate points for a student was an increase of one point while the largest increase was 19 points and 55.5% of the student cohort (n = 18) showed an improvement of 10 or more accurate points over their pre-test responses.

Further, only one student in the post-test situation made more incorrect points than in the pre-test which could be due to an increase in minor errors in the responses or it could be due to an increase in the quantity of the responses where small errors could be easily created.

The irrelevant points (as distinct from incorrect points) indicate that students do not accurately know material related to the topic but have learnt material that is either not understood or is incorrectly linked to the accurate information they have in their cognitive framework. A decline in irrelevant response points is an indication that this material has been adjusted within from the cognitive framework through the learning processes and hence this could be an indication of the effectiveness of the learning or teaching strategy. The number of irrelevant points made in the post-test responses

Table 8.1: Results of data from the administration of a diagnostic essay to assess the effectiveness of the interventionist strategy

	Pre-Test (n=22)			Immediate Post-Test (n=18)			Delayed Post-test (n=18)		
	Number of Related Points		Number Made Points	Number of Related Points		Number Made Points	Number of Related Points		Number Made Points
	Correct	Incorrect		Correct	Incorrect		Correct	Incorrect	
Nat	5	0	10	10	1	13	4	1	6
Phil	3	0	4	6	0	8	6	1	9
Rach	0	3	9	15	1	22	5	1	10
Liam	3	2	9	20	0	24	11	1	13
James	1	0	5	18	0	21	4	0	5
Rachel	0	1	8	17	3	21	3	3	8
Lucy	1	0	4	8	3	13	7	2	10
Lele	1	2	6	18	1	24	6	2	9
Nissa	1	2	8	11	3	17	5	2	8
Tammi	0	0	2	19	0	20	0	0	3
Adam	2	1	3	9	3	13	0	0	4
Ash	2	0	11	17	2	22	1	0	6
Tani	2	0	6	16	1	17	1	1	4
Dean	1	1	4	2	3	6	6	1	9
Callum	1	0	4	10	2	16			
Cam	2	2	8	11	1	20			
Lia	1	0	4	15	0	17			
Mich	0	2	2	3	3	8			
Nic	3	1	11				3	0	6
Zoe	2	1	15				2	1	10
Kath	4	0	9				1	4	6

showed a large decrease with 55.5% of the students having less irrelevant points and also could indicate the strategy's effectiveness. Examples of such irrelevant points are — *" All of the foods plus many more contribute to the growth, strengthening and reproduction etc of the cell".* (Rachel) —*"Red blood cells drew in oxygen from the blood stream and send it to the lungs. This is a good example of cells working together, and collecting nutrients."* (Zoe) — *" Most carbohydrates in the human diet is mainly sugars, starch and cellulose"* (James).

It would appear from these data that the interventionist strategy did have a positive effect on the quantity and quality of knowledge the students had gained during the interventionist procedure. Not only was there an increase in the number of responses overall but, these responses were composed of more accurate points and there was also a decrease in the number of irrelevant points made in these responses. So, not only had the students gained in the quantity of knowledge but they had also been better able to make points related to the areas being inquired about. A decrease in irrelevant points indicates an improvement in the quantity of new knowledge and shows a change in the quality of knowledge. This improvement has possibly come about through a better understanding of what was required by the question which also indicates a change in an individual's knowledge framework as well as an increase in knowledge because it is an indication of the organisation of that knowledge. In this case the strategy had a two-fold effect in that it had led to an increase in knowledge and also its organisation within the cognitive framework of the students.

8.4.1.2 Pre-test and post-post-test comparison

A period of five months elapsed between these two assessments during which the students did not cover topics related to the items n this test. The results of the post-post-test showed that the strategy did appear to have a long lasting effect on some students' retention of the material covered during the interventionist strategy.

Nine students had an increase in the total points made, while four of these students had an increase in excess of four points in the post-post-test over the pre-test. Of these four students, two (Lucy and Phil) had a small increase to the number of incorrect points, Dean had no change to the incorrect points, and Liam student had a decrease. Conversely, four students (Zoe, Nic, Ash and Nat) had a decrease of four or more total points made and of these one student (Nat) also had an increase in errors, Nic a decrease in errors and Zoe and Ash each had the same number of errors in both tests with the number of errors only increased by one

A comparison of the results of these two tests showed that of the correct points made by the students who completed both of these tests (n=18), 50% had an increase in the number of correct points made, with five of these students increasing the number of correct points made by at least five. But at the same time, there was a decrease in the number of correct points made by 33% of respondents and 17% had no change.

Of the students who had a change in the number of incorrect points made (n=11), seven of these students had a maximum increase of two incorrect points. Four students had a decrease in incorrect points and seven students had no change in the number of incorrect points.

It would appear that there was a long-term effect of the interventionist teaching strategy for some students as is shown through the decline in the number of incorrect points made and that some students had an increase in the number of correct points they made. However, not all students showed this improvement which is in agreement with Grayson (1994). There was no testing of reasons to explain how this benefit arose or why so many students did not show any long-term benefit. However, this latter finding is in accord with such authors as Hewson (1981), Kaper and Goedhart (2000), Kesidou and Duit (1993) and Odom and Barrow (1995) who also found poor results following an interventionist strategy.

Within the total number of points written is the number of relevant points made (whether accurate or not) by the students with respect to the question posed. (Relevant points are those points which do relate to the item while irrelevant points are ones which have no apparent relationship to the item.) Eleven students showed an increase in relevant points, three students (Nic, Ash and Adam) had a decrease in relevant points made in the post-post assessment and four students (Nat, Tani, Zoe and Tammi) showed no change. Of those students showing an increase in points made, six (Rach, Liam, Lucy, Lele, Nissa, and Dean) had an increase in correct points made and one student (Adam) had a decrease in accurate points.

Of particular importance is the decrease in irrelevant points written, as this decrease shows students had altered the material incorporated in their mental framework with respect to the assessment question posed. There was a decrease in irrelevant points made by 14 students, three had an increase and one had no change in irrelevant points. The change to the knowledge framework may be either through the removal of irrelevant material (from the cognitive framework) or by that material being relegated to a lower degree of importance as suggested by Bliss *et al.* (1994), Garnett *et al*. (1995), Gunstone, (1994) and Solomon (1993). These data imply that students had retained the adjustments that they had made to the irrelevant material in their initial conceptions and had maintained these adjustments for at least five months.

8.4.1.3 Post-test and post-post-test comparison

The comparison between the pre-strategy responses and both the post-strategy and post-post strategy diagnoses showed there was a benefit derived from the interventionist teaching strategy which persisted up until the last of the diagnoses was performed. Despite there being less responses overall in the post-post-strategy than in the post-strategy responses, the benefit of the strategy is shown through an increase in accurate responses made in both of the post-strategy diagnoses over the pre-strategy situation. There was an overall decline in the number of accurate responses given between the post-strategy and post-post-strategy responses (n = 12) with only one student giving more correct reasons in the post-post strategy diagnosis and one the same number of reasons.

Twelve students had a decline in total points made and these students also had a decrease in the total accurate points they made while seven of these students had increased the number of irrelevant points made. This result indicates a degree of forgetting of the material learned during the implementation of the strategy by approximately 50% of the students. But, there were seven students (Nat, Rach, Liam, James, Lucy, Lele and Nissa) who had less irrelevant points in the post-post set of responses than the post-strategy test and one student (Phil) who had no change in these points which indicates these students had retained the adjustments they made to their cognitive framework knowledge gained as a result of the interventionist strategy. So, the strategy seems to be effective in the longer term for nearly 50% of the study group.

There was a decrease in the overall number of students (from 13 to 10) who made inaccurate points in the post-post-test responses with six students having no change in the number of inaccurate points made and five had a decrease in inaccurate points made. This retention of accurate points and further, the persistence of the decreased number of inaccurate points appears to indicate that a number of students had retained over the longer term some of what they had incorporated into their cognitive framework as a result of the interventionist strategy.

From this analysis of comparisons between the three sets of responses to the essay question (pre- post and post-post tests), there is an improvement in the knowledge gained by all students and on the whole this knowledge is retained for the short term, although this retention was not to the same extent in the longer term. This result could lead one to assume that the strategy had a beneficial effect in the two areas it addressed, viz, digestion and respiration. A further analysis of the data by way of examining these data from the two sub-sets based on the two areas covered by the strategy reveals that there was a smaller improvement of knowledge in the area of respiration than was found in digestion.

8.4.1.4 Effectiveness of digestion and respiration strategies

All students had more total points made in their responses which related to digestion than they had made on respiration (Table 8.2). A more detailed breakdown of the total points shown in Table 8.2 can be found in Tables 8.3 and 8.4 where the total points are divided into correct or incorrect points.

Digestion

An analysis of the data related to digestion shows there was an improvement in student knowledge. The improvements, gained as a result of the interventionist strategy, closely mirrored those of the complete data previously discussed in Sections 8.4.1.1 to 8.4.1.3. The results for the comparisons between the three tests are found in Tables 8. 3 and 8.4.

The pre-test data revealed that a small quantity of scientifically correct knowledge was held by many of the students in conjunction with a lot of irrelevant points, and the quantity and quality of this knowledge increased as a result of the implementation of the interventionist strategy. The improved quantity of the responses is illustrated by an increase in the number of correct points made and the decrease in the number of incorrect points as shown in Table 8.3. Further, the number of irrelevant points made can be an indication of the quality of the responses.

In Table 8.4, negative values indicate fewer points in the latter of the two tests being compared. When comparing the pre-test and post-post-test irrelevant points in this table, there are more negative points in the comparison between and in the post-test and post-post-test which shows a decline in the irrelevant points made for the latter of each of the two tests.

The improvement in the quantity and quality of the knowledge gained, as a result of the strategy, declined over time but still remained greater than the knowledge held prior to the strategy's implementation.

Respiration

Analysis of the data based on the sub-area of respiration (see Tables 8.5 and 8.6) showed that there was little knowledge of respiration present prior to the application of the interventionist strategy. Only two students from the sample of 18 students who did both tests provided two or more correct points while 13 students made no correct points. However, immediately after the strategy there was an improvement in correct points, with 13 students improving their number of correct points while two students (Nat and James) had a decrease and three students (Phil, Dean and Mich) still made no correct points.

Also, there were six students (Rachel, Lucy, Ash, Tani, Mitch and Callum) who made more incorrect points in the post-strategy response than the pre-strategy response but for five of these there was only one point increase. At the same time there were five students (Rach, Liam, Lele, Nissa and Adam) who had a decrease in the number of incorrect points made.

Table 8.2: Total score correct for each student for the sub-sections of digestion and respiration from each of the three essay tests

	Pre-Test (n = 22)		Post-Test (n = 18)		Post-Post-test (n = 18)	
	Digestion	Respiration	Digestion	Respiration	Digestion	Respiration
Nat	10	10	13	13	6	6
Phil	4	4	8	8	9	9
Rach	9	9	22	22	10	10
Liam	9	9	24	24	13	13
James	5	5	21	21	5	5
Rachel	8	8	21	21	8	8
Lucy	4	4	13	13	10	10
Lele	6	6	24	24	9	9
Nissa	8	8	17	17	8	8
Tammi	2	2	20	20	3	3
Adam	3	3	13	13	4	4
Ash	11	11	22	22	6	6
Tani	6	6	17	17	4	4
Dean	4	4	6	6	9	9
Callum	4	4	16	16		
Cam	8	8	20	20		
Lia	4	4	17	17		
Mich	2	2	8	8		
Nic	11	11			6	6
Zoe	15	15			10	10
Kath	9	9			6	6
Matt	3	3			4	4

The increase in incorrect points coincided with a large increase in the total number of correct points made and as suggested earlier (Section 8.4.1.1) this increase in errors may be due to an increase in points resulting in more minor errors being made. Another possible explanation for this increase is that for many students, the material covered in class was new and so adjustments to old conceptions had not been fully possible due to insufficient elapse of time. The new conceptual material had been encountered too briefly for it to be fully tested in a number of situations to ensure its accuracy and to facilitate any necessary and further cognitive adjustments. There were two students (Nat and James) who made fewer correct points after the strategy than before.

While comparing the post-post-test and pre-test scores (see Table 8.6), eight students made one or more correct points (with the largest number being 6 points) and of these eight students three (Rach, Liam and Tammi) had made at least one correct point in the post-post-test while in the pre-test they had not made a point, and one of these students (Tammi) had increased her correct points score by six points. But, in the post-post-test, there was a decline in student performance over the post-test (as indicated by the number of correct points) with the exception of two students (James and Tammi) one of whom had no change in the number of correct points (Tammi). As well, in comparing the pre-test and post-post-test responses five students (Nat, Lucy, Lele, Ash, Kath) made more correct points in their pre-test with two of these students (Nat and Kath) having a difference of five correct points while nine respondents (Phil, James, Rachel, Nissa, Adam, Tani, Dean, Zoe and Matt) had no change in scores to their score. This would indicate students had learnt some material but that in most cases it was soon forgotten.

The number of incorrect points made in each of the tests was generally low with all except two students (Liam and Rachel) having either one or two incorrect points in the two post strategy tests while five students (Rach, Lele, Nissa, Nic and Kath) had more than two incorrect points in the pre-test situation. Four students (Ash, Rachel, Tani and Mich) showed an increase in the number of incorrect points in either of the two post-tests and this was from zero to two points in the final test with three students (Liam, Rachel and Kath) giving incorrect points in the post-post-test. This would indicate that students had remembered the problems they had adjusted and not reverted to the older conceptions.

While the interventionist strategy did have an effect for a number of students over the short term, there was little long-term retention of the material that had been initially incorporated into the students' memory as a result of the strategy. Once again, possibly due to the short time allowed for reinforcement of the newly adjusted concepts, this could have led to the new material's fruitfulness not being fully established for the learners. One benefit of the strategy was that misconceptions that had been challenged and adjusted as a result of the interventionist strategy were retained over the longer term by

Table 8.3: Break down of correct and incorrect points per student for digestion on the three tests administered.

	Pre-Test (n=22)			Post-Test (n = 18)			Post- Post-test (n=18)		
	Number of Related Points		Total Number Points Made	Number of Related Points		Total Number Points Made	Number of Related Points		Total Number Points Made
	Correct	Incorrect		Correct	Incorrect		Correct	Incorrect	
Nat	1	0	10	9	1	13	6	1	6
Phil	4	0	4	4	0	8	3	2	9
Rach	1	1	9	5	0	22	4	1	10
Liam	4	1	9	13	0	24	9	1	13
James	1	0	5	15	0	21	2	1	5
Rachel	1	2	8	8	1	21	4	0	8
Lucy	0	1	4	3	3	13	5	2	10
Lele	1	1	6	8	0	24	5	2	9
Nissa	2	1	8	9	3	17	3	2	8
Tammi	0	0	2	4	0	20	3	0	3
Adam	1	1	3	5	1	13	0	1	4
Ash	2	0	11	6	1	22	0	0	6
Tani	6	0	6	6		17	0	0	4
Dean	3	0	4	2	1	6	4	2	9
Callum	3	0	4	6	0	16			
Cam	7	1	8	11	2	20			
Lia	1	1	4	11	0	17			
Mich	2	1	2	5	1	8			
Nic	3	0	11				2	0	6
Zoe	1	2	15				2	1	10
Kath	1	0	9				0	2	6
Matt	1	2	3				2	0	4

Table 8.4: Breakdown of results for the three essay tests related to digestion

	Total Points Made			Correct Responses			Incorrect Response			Irrelevant Response			Relevant Points		
	pre/post (n=18)	pre/p post (n = 18)	p/p post (n = 14)	pre/post (n = 18)	pre/p post (n = 18)	p/p post (n = 14)	pre/post (n = 18)	pre/p post (n = 18)	p/p post (n = 14)	pre/post (n = 18)	pre/p post (n = 18)	p/p post (n = 14)	pre/post (n = 18)	pre/p post (n = 18)	p/p post (n = 14)
Nat	3	-4	-7	8	5	-3	1	1	1	-6	-10	-4	-6	-10	-10
Phil	4	5	1	0	-1	-1	0	2	2	4	4	0	4	4	4
Rach	13	1	-12	4	3	-1	-1	0	0	10	-2	-12	10	-2	-2
Liam	15	4	-11	9	5	-4	-1	0	0	7	-1	-8	7	-1	-1
James	16	0	-16	14	1	-13	0	1	1	2	-2	-4	2	-2	-2
Rachel	13	0	-13	7	3	-4	-1	-2	-2	7	-1	-8	7	-1	-1
Lucy	9	6	-3	3	5	2	2	1	1	4	0	-4	4	0	0
Lele	18	3	-15	7	4	-3	-1	1	1	12	-2	-14	12	-2	-2
Nissa	9	0	-9	7	1	-6	2	1	1	0	-2	-2	0	-2	-2
Tammi	18	1	-17	4	3	-1	0	0	0	14	-2	-16	14	-2	-2
Adam	10	1	-9	4	-1	-5	0	0	0	6	2	-4	6	2	2
Ash	11	-5	-16	4	-2	-6	1	0	0	6	-3	-9	6	-3	-3
Tani	11	-2	-13	0	-6	-6	0	0	0	11	4	-7	11	4	4
Dean	2	5	3	-1	1	2	1	2	2	2	2	0	2	2	2
Callum	12			3			0			9			9		
Cam	12			4			1			7			7		
Lia	13			10			-1			4			4		
Mich	6			3			0			3			3		
Nic		-5			-1			0			-4			-4	
Zoe		-5			1			-1			-5			-5	
Kath		-3			-1			2			-4			-4	
Matt		1			1			-2			2			2	

Note: Where a negative result in a cell indicated that there was a higher response number in the earlier of the two tests being compared while a positive result indicates there was a larger score made in the later test over the earlier test.

Table 8.5: Breakdown of results for the three essay tests related to respiration

	Pre-Test (n=22)			Post-Test (n= 18)			Post- Post-Test (n=18)		
	Number of Related Points		Number Points Made	Number of Related Points		Number Points Made	Number of Related Points		Number Points Made
	Correct	Incorrect		Correct	Incorrect		Correct	Incorrect	
Nat	5	0	10	0	0	13	0	0	6
Phil	0	0	4	0	0	8	0	0	9
Rach	0	3	9	7	0	22	1	0	10
Liam	0	1	9	3	0	24	1	1	13
James	1	0	5	0	0	21	1	0	5
Rachel	0	0	8	1	1	21	0	2	8
Lucy	1	0	4	2	1	13	0	0	10
Lele	1	2	6	2	0	24	0	0	9
Nissa	0	3	8	1	1	17	0	0	8
Tammi	0	0	2	6	0	20	6	0	3
Adam	0	1	3	4	0	13	0	0	4
Ash	2	0	11	3	2	22	1	0	6
Tani	0	0	6	4	1	17	0	0	4
Dean	0	0	4	0	0	6	0	0	9
Callum	0	0	4	6	1	16			
Cam	0	1	8	1	1	20			
Lia	0	0	4	2	0	17			
Mich	0	0	2	0	1	8			
Nic	1	4	11				2	0	6
Zoe	1	1	15				1	0	10
Kath	5	2	9				0	1	6
Matt	1	1	3				1	0	4

Table 8.6: Table showing a break down of the correct and incorrect responses for respiration on the three essay tests administered.

	Total Points Made			Correct Responses			Incorrect Responses			Irrelevant Responses			Relevant Points		
	Pre/Post (n=18)	Pre/P Post (n=18)	P/P Post (n=14)	Pre/Post (n=18)	Pre/P Post (n=18)	P/P Post (n=14)	Pre/Post (n=18)	Pre/P Post (n=18)	P/P Post (n=14)	Pre/Post (n=18)	Pre/P Post (n=18)	P/P Post (n=18)	Pre/Post (n=18)	Pre/P Post (n=18)	P/P Post (n=14)
Nat	3	-4	-7	-5	-5	0	0	0	0	8	1	-7	8	1	1
Phil	4	5	1	0	0	0	0	0	0	4	5	1	4	5	5
Rach	13	1	-12	7	1	-6	-3	-3	-3	9	3	-6	9	3	3
Liam	15	4	-11	3	1	-2	-1	0	0	13	3	-10	13	3	3
James	16	0	-16	-1	0	1	0	0	0	17	0	-17	17	0	0
Rachel	13	0	-13	1	0	-1	1	2	2	11	-2	-13	11	-2	-2
Lucy	9	6	-3	1	-1	-2	1	0	0	7	7	0	7	7	7
Lele	18	3	-15	1	-1	-2	-2	-2	-2	19	6	-13	19	6	6
Nissa	9	0	-9	1	0	-1	-2	-3	-3	10	3	-7	10	3	3
Tammi	18	1	-17	6	6	0	0	0	0	12	-5	-17	12	-5	-5
Adam	10	1	-9	4	0	-4	-1	-1	-1	7	2	-5	7	2	2
Ash	11	-5	-16	1	-1	-2	2	0	0	8	-4	-12	8	-4	-4
Tani	11	-2	-13	4	0	-4	1	0	0	6	-2	-8	6	-2	-2
Dean	2	5	3	0	0	0	0	0	0	2	5	3	2	5	5
Callum	12			6			1			5			5		
Cam	12			1			0			11			11		
Lia	13			2			0			11			11		
Mich	6			0			1			5			5		
Nic		-5			1			-4			-2			-2	
Zoe		-5			0			-1			-4			-4	
Kath		-3			-5			-1			3			3	
Matt		1			0			-1			2			2	

Note: A negative result in a cell indicates there was a higher number of points made in the earlier of the two tests being compared while a positive result indicates there was a larger number of points made in the later test over the earlier test.

the majority of students as few students had increased scores for incorrect answers and so had not reverted to previously held notions or new incorrect notions.

A comparison between the number of correct points made for both digestion and respiration shows that, for the majority of students, there are more correct points made for digestion in all three of the tests than were made for respiration (See Table 8.7). Also, there are more incorrect points made for respiration than for digestion. In both of these comparisons, the improvement in points made for respiration had a maximum of five points, while two of the score differences was three or less points.

While each post strategy test had less written points for each of the two subsections being examined than the previous test, the trend of more points being written for digestion than for respiration is consistent across all three tests and also there were less errors made in digestion than respiration.

Summary of digestion/respiration comparison

In summary, the interventionist strategy appears to have been of value in that it did increase the knowledge base of the majority of the students and that much of this knowledge remained in place, albeit to a lesser degree, for a period of at least five months. When the results were re-examined in terms of responses made by students for the digestion and respiration sections, prior to the interventionist strategy students had less knowledge of respiration than of digestion and this pattern continued for the other two tests. This result could be expected in view of the exposure of students to more information relating to digestion than respiration both in their formal schooling and also in informal situations.

The open-ended test item analysed in this section of the Chapter should be a good indication of student knowledge because there was no prompting or hints given in the item that may trigger or prompt a student's memory. A second instrument was administered during the lesson following the administration of the open-ended test. This diagnostic instrument was the item bank *'What do You Know about Energy and Your Body?'* which was developed and analysed in Chapter 4. The data from the relevant items on this test are now analysed to collect further information as to the effectiveness of the interventionist strategy.

Table 8.7: Difference between the points made for digestion minus those made for respiration.

	Pre-Test (n=22)		Post-Test (n=22)		Post-post-test (n=22)	
	Number of Related Points		Number of Related Points		Number of Related Points	
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
Nat	-4	0	9	1	6	1
Phil	4	0	4	0	3	2
Rach	1	-2	-2	0	3	1
Liam	4	0	10	0	8	0
James	0	0	15	0	1	1
Rachel	1	2	7	0	4	-2
Lucy	-1	1	1	2	5	2
Lele	0	-1	6	0	5	2
Nissa	2	-2	8	2	3	2
Tammi	0	0	-2	0	-3	0
Adam	1	0	1	1	0	1
Ash	0	0	3	-1	-1	0
Tani	6	0	2	-1	0	0
Dean	3	0	2	1	4	2
Callum	3	0	0	-1	0	0
Cam	7	0	10	1	0	0
Lia	1	1	9	0	0	0
Mich	2	1	5	0	0	0
Nic	2	-4	0	0	0	0
Zoe	0	1	0	0	1	1
Kath	-4	-2	0	0	0	1
Matt	0	1	0	0	1	0

Note: A positive result indicates more points in the digestion section of the answer than in respiration while a negative value indicates more points made in respiration.

8.4.2 Analysis of the relevant items on the questionnaire *'What do You Know About Energy and Your Body? Questionnaire 1'*

The author commenced leave just after the students had completed the interventionist strategy. The relieving teacher volunteered to re-photocopy and administer the diagnostic instrument but unfortunately during the copying process a number of items were not copied accurately and these instruments were administered without any person realising there was a problem. Some of the items were from an old version of the instrument and consequently the data collected did not resurvey all the conceptions of the students' who participated in the interventionist strategy. Nevertheless the data collected did assess many of the student conceptions and as such was still a valid diagnostic instrument for the designated task. The following analysis of the responses to the diagnostic instrument *'What do You Know about Energy and Your Body? Questionnaire 1'* therefore will of necessity be less conclusive but some information can be gleaned from the data.

A number of misconceptions were identified in both the pre- and post-test responses to the diagnostic instrument (see Section 5.3). These included, that there are a number of energy types needed by the body and that these energy types were obtained through the consumption of a variety of foods. Following on from these energy types was the notion that some foods are useful and others are useless, the energy in food is available slowly or fast, energy is released during digestion and the human gets energy from air or oxygen and sleep (see Sections 5.3.2.2 and 5.3.2.5). These misconceptions would indicate the diagnostic instrument does indeed identify a number of student-held conceptions and so this administration of the instrument has served as evidence that it is a useful device in aiding the identification of student held conceptions – both acceptable and unacceptable.

A total of 15 student responses were used in this analysis, though eight of these subjects did not respond to a complete set of items. The other 14 students in the class only completed either the pre- or post-strategy tests. Nevertheless, some information can be gained from this data as a number of students showed changes in their conceptual framework. A large number of students retained their lack of knowledge about the various aspects of energy and your body despite the interventionist strategy. A small number of students retained misconceptions while one student changed from an acceptable conception to an unacceptable conception. For example, – *"all foods have the same energy"* became – *"different energy is found in different foods"* (Dean). Another student had no response to a misconception where in Item 5 (energy being found in packets) she said that the energy – *" energy had to be small for the body to absorb it"* (Krystal). This lack of progress would indicate that for many students the strategy had little effect on their conceptual framework. However, for some students there were positive conceptual shifts.

The degree of conceptual change with respect to digestion that was identified using the diagnostic instrument varied from nil, to small through to large. An example of a small conceptual shift was where a boy (Liam) wrote in the pre-test — *" ... if we were getting energy. From sugars we get energy"* and this conception changed in the post-test to — *" food contains sugars, carbohydrates and other nutrients we need to produce energy"*. In this case, it can be seen that there are two changes with both being small but significant. The first conceptual shift was from energy is obtained from sugars to there being a number of energy sources. A female student (Lia) showed a similar degree of cognitive change in her notions of both digestion and respiration when she said — *" food contains carbohydrate which when you eat gets used as energy"* to later — *"in the food there are molecules which contain a form of energy. When we eat this food the energy is released through many processes"*.

Despite the small sample size and the small number of conceptual changes observed it was confirmed that the role of digestion was poorly understood prior to the interventionist strategy and that there was little change to the majority of the students' conceptual frameworks as a result of the strategy. But some students did show conceptual change to more scientifically acceptable notions.

In the previous data analysis section where the open-ended item was analysed (Sections 8.4.1), there was some conceptual development in the interventionist strategy's sub-area of respiration. Respiration data collected from the diagnostic instrument identified a number of changes in students' cognitive frameworks related to respiration. A number of students together provided 15 different written responses which showed some form of acceptable conceptual development in at least one aspect of the process of respiration. These changes included using fats in respiration, the role of the mitochondria and the conversion of ADP to ATP. One student (Zoe) who showed an improvement in her conceptions started with the response in the pre-test of — *"respiration turns food into useable energy"* to the post-test response of — *" energy from food molecule used to transfer energy from breaking up bonds to gain phosphate ions to help join the phosphate* *to ADP to form ATP (universal energy molecule)"*. Even though there is an error in this post-test answer it still shows an increase (accretion) in the amount of detail within the knowledge base of respiration.

Natalie showed a major concept shift within the conceptual tree of process (Chi *et al*. 1994) from a procedure when she went from thinking of respiration as being synonymous with breathing — *"respiration is breathing"* to an event or a constraint based interaction (depending upon the degree of complexity being used in the explanation) when she wrote that — *"sugar is broken into pyruvic acid"* and in another response — *" fats enter mitochondria where there are chemical reactions and ATP is produced"* which are both pieces about the process of respiration. This is an important conceptual change to occur as it indicates a separation of the two important concepts of breathing and respiration (Mann, 1994). Another student who reflected the same change in conceptions was Natalie. She had a similar category change but her response to the post-test was less expansive.

Of the 15 responses that indicated a change in the concepts held by the students, four students had changes that enabled them to give two or more separate responses using different aspects of the respiration process. This could indicate a larger degree of change and understanding of the process of respiration than a student who made a single appropriate response and would be further evidence of the effectiveness of the strategy.

From this analysis of the small quantity of data from the diagnostic instrument it can be seen that there is support for the findings of the open-ended item previously analysed in Section 8.4.1 both in the area of digestion and respiration. Both the open ended essay and the two-tier multiple choice tests showed some students do benefit from the interventionist strategy; however, many students showed no change in their conceptual knowledge in either digestion or respiration.

8.5 SUMMARY OF CHAPTER

This chapter has discussed the requirements of a teaching and learning model upon which to base an interventionist strategy. Following this delineation process was the selection of a suitable model and its subsequent modification to better suit the described requirements of a strategy and the anticipated outcomes of the lessons. The purpose of this strategy was to facilitate the changing and development of students' concepts as they related to the processes involved in ingesting food, its digestion and absorption and the absorbed food's utilisation by a cell through the process of respiration to produce useable energy in the form of ATP.

The strategy's development and implementation with a group of 33 students was then discussed and the methods employed to assess the effectiveness of the strategy via the administration of two instruments developed to identify student conceptions on the digestion of food and its utilisation in respiration. These two instruments were administered before the strategy and immediately after the strategy and then the open-ended item was re-administered five months after the strategy had finished. The two instruments consisted of a single open-ended essay item and the two-tier instrument *'What do You Know about Energy and Your Body? Questionnaire 1'* the latter was discussed in Chapter 4.

Both these tests were analysed individually to identify changes in student-held conceptions and to elicit any changes which may have occurred as a result of the interventionist strategy. Further, the results of both instruments were re-analysed to test the effectiveness of the strategy in the two sub-sections of energy conversions, namely, digestion and respiration.

The results of these analyses showed the strategy did in fact have a positive effect on the modification and development of individual student's conceptions. Students commenced the lesson sequence with a reasonably well developed set of conceptions related to digestion, some of which were scientifically acceptable. For many students, these conceptions were successfully modified to better represent scientifically acceptable notions and new information was added to the knowledge base. For many students, these modifications and adjustments did persist over a period of at least five months although the total quantity of change declined over time. This was more evident in the material added to the knowledge already held than in the modified notions.

Students showed they had few to no notions about the sub-section of respiration prior to the strategy's implementation. But, the strategy did increase the quantity of knowledge held by the majority of students as well as modifying their misconceptions and that this knowledge was retained over the ensuing five months. The additional quantity of information about respiration was considerably less than that for digestion but this could have been due to there being less of a knowledge base upon which to build and develop further information as has been suggested by researchers such as Trumper (1993b) and Vosniadou (1994).

This Chapter goes towards addressing Objective 4 which had as its purpose the development and assessment of the effectiveness of an interventionist strategy dealing with some aspect(s) of student misconceptions identified as a result of the administration of diagnostic instruments and the analysis of the data collected from these instruments (Chapter 4).

CHAPTER 9

CONCLUSIONS

9.1 INTRODUCTION

A large number of studies into student alternative conceptions have occurred throughout the past 30 years with many of these studies investigating various aspects of energy. But, few energy-related studies are in the field of biology and even fewer involve the human body. This study focused on the conceptions that students possess with respect to energy and the human body.

A number of previously discovered alternative conceptions were identified through the use of two questionnaires as were a number of new ones; how these conceptions changed over time was also examined. From this knowledge of student conceptions, a diagnostic instrument was developed which could facilitate the identification of student conceptions and their underpinning reasons. Further, based on the data collected from the two questionnaires, two areas of particular weakness were identified, namely, digestion and respiration. An interventionist teaching and learning strategy was developed which could help students adjust scientifically unacceptable notions and increase the student's knowledge base in these two conceptually difficult areas.

This study had four objectives:

Objective 1

To develop a series of questionnaires to help identify both scientifically acceptable and unacceptable notions held by students (in Years 8 through to 12) with respect to energy and the human body and the underpinning reasons for these held notions.

Objective 2

To investigate how student held energy notions and their underpinning reasons as related to the human body change over time and in what manner they change.

Objective 3

To develop a series of two-tier true/false diagnostic items for use by teachers and students as an aid in helping identify student held notions and their underpinning reasons about energy and the human body.

Objective 4

To develop a strategy for use by teachers and students, in Year 8 to Year 12, which may help overcome identified problems and to test the effectiveness of these interventionist strategies in helping students adjust their energy notions.

A summary of the findings that emerged, the limitations of this study, implications for teachers and some possible directions for future studies are given in the following sections of this chapter. This summary is followed with a set of final remarks which conclude this thesis.

9.2 OVERVIEW OF STUDY

Chapter 1 of this thesis began with an introduction to the field of misconceptions research that began in earnest in the 1970s and has continued ever since. The discussion showed that much of the research has centred on areas of science related to the domain of physics with less work in chemistry and relatively little in the area of biology. Within the physics domain, there has been an emphasis on work covering energy. But energy is ubiquitous in all domains of science and so this study extended the study of energy conceptions into the domain of biology, but more specifically to examine energy and the human body. Hence, this study of student conceptions was an attempt to provide more information in an area of importance in science in general (energy) and was specifically directed to a sub-section of biology which has received little attention (human biology). As this was an area of research that to a large degree has been neglected, such a study can provide both new information and information across content domains.

Various techniques used by previous researchers to examine student conceptions were briefly examined to arrive at a possible method that could be used in this study to examine student conceptions. From this examination, a suitable method was decided on.

This method was a two-tier multiple choice diagnostic instrument as described by Mann (1994) and Mann and Treagust (2000).

Following a review of the literature in the field of misconceptions research, the area of conceptual change and growth was examined together with definitions of conceptual change and growth and some of the models of conceptual growth (Chapter 2). Closely associated with conceptual change and the development of conceptions was a discussion on the role of language and how language can influence conceptual development. In association with the role of language, a caution was issued about the care needed when interpreting student responses to ensure that each student's meaning was accurately portrayed rather than the implied meaning of the researcher.

Chapter 3 investigated the history and current position of education in Western Australia which involved two major shifts from current education practice. These shifts were a pedagogy based on constructivist methodology and with student academic attainment measured by their achievement of outcomes rather than the current objectives. Further, the need for material to identify student conceptions and how these conceptions changed over time was discussed. Also considered was the need for material to be available to teachers which would model learning and teaching strategies based upon constructivist pedagogy as required by the Curriculum Council of that state. This discussion showed where this study was placed in relation to education in Western Australia and the need for the information developed as a result of this study.

Chapter 4 examined a number of sampling instruments and methods employed to gather data on student conceptions, in particular misconceptions. Using these methods a set of 28 items was developed which was subsequently divided to form two instruments titled *'What do you Know About Energy and Your Body? Questionnaires 1 and 2'*, which were used to identify student conceptions. These two instruments were based on the format developed by Mann (1994) and Mann and Treagust (2000) which was in turn a modification of a diagnostic instrument developed by Treagust (1986)and used by other biology researchers such as Odom and Barrow (1995). From these two instruments a number of misconceptions were identified.

A sample of 616 students from two suburban government schools were administered the instruments, with one school contributing 456 students from Years 8 to 12 while the other school supplied 160 students from Years 8, 9 and 11.

The results obtained from the administration of the questionnaires developed in Chapter 4 were discussed in Chapters 5 and 6. Chapter 5 examined the conceptions held by the 616 students and also investigated which of these conceptions have been reported previously and which are newly identified. Chapter 6 investigated the changes to the student-held conceptions and the ontological changes undergone by the students. This analysis is a cross section study based on each year cohort's data as time did not permit a pure longitudinal study. The data gathered from each year cohort was combined and represented many of the conceptions of that year group and the combined data was used to compare each year cohort and so infer changes which occurred from one age cohort to another.

Based on the findings of Chapters 5 and 6, a diagnostic instrument *'Energy and the Human Body'* was developed. This instrument comprised a set of 20 items and was based on a modified two-tier test as developed by Mann (1994) and Mann and Treagust (2000). The development of this instrument and the data generated from the administration of the trial items for this instrument were discussed in Chapter 7. The analysis of the data from this instrument's administration combined with the data discussed in Chapter 5 and 6 formed the basis for the identification of two areas upon which an interventionist strategy was developed. This teaching and learning intervention strategy was an endeavour to help students facilitate the adjustment of both their scientifically unacceptable notions and to increase the quantity of new, scientifically acceptable knowledge. This strategy was discussed on Chapter 8.

9.3 MAJOR FINDINGS OF THE STUDY INTO STUDENT-HELD CONCEPTIONS.

In this section, the findings relating to each of the objectives of this study, as outlined in Section 1.5 and Section 9.1, are summarised using the following subsections:

9.3.1 Identification of student held conceptions.

. 9.3.2 How student held conceptions change with time.

9.3.3 Development of a two-tier diagnostic instrument.

9.3.4 Development of an interventionist strategy and assessment of its effectiveness.

9.3.5 Relationship of the major sections of this study to science education in Western Australia

A more detailed description of these findings is to be found in Chapters 5, 6, 7 and 8.

9.3.1 Identification of Student-held Conceptions.

The data from the two questionnaires titled *'What do You Know About Energy and Your Body?'* were used to identify student-held conceptions as they related to energy and the human body. Each of the 28 items was based on a modified two-tier item, to which the stem of the item required a commitment of true or false and then a reason for this true/false commitment was made. It is from these reasons that the student-held conceptions were identified. To ensure accuracy in the translation of some of the terminology used by the students in their preferred reasons, a number of interviews were conducted to probe for student meaning of such words and phrases as burning, junk food and recharge.

From the analysis of this collected data, a number of commonly held misconceptions were identified which related to energy and the human body (Chapter 5). Some of these misconceptions had been reported previously and included the particulate nature of energy, energy being useful or not, energy obtained from air or sleep, energy not being conserved and fat not a source of energy for the human body.

Further, a number of misconceptions which were previously unreported were identified. These were:

- carbohydrates are different to sugars,
- fats lock away energy (for a variable degree of time ranging from when needed to never useable),

- fats are easy to use,
- fats are difficult to use,
- excess energy is excreted,
- the eye and the ear do not convert energy,
- sweat cools the body down because wind or air contacts the sweat,
- objects do not need energy to maintain movement only to become mobile.

Many misconceptions that related to energy in general were also identified when a student was using conceptions of energy which involved the human body. Such misconceptions related to:

- the particulate nature of energy,
- the eye does not convert energy but merely passes the received image on to the brain,
- the ear does not convert energy but passes the sound straight to the brain where it was translated,
- moving objects do not require energy once they were moving, it is only required for them to become mobile and only animate objects can have energy.

From these findings, a series of 29 two-tier items were developed, trialed and subsequently refined to form the 20 items which formed the diagnostic instrument titled *'Energy and the Human Body'*.

9.3.2 How student-held conceptions change with time

Chapter 6 discussed the manner in which student conceptions changed over time through a cross section analysis of the data collected from the administration of the two questionnaires developed to identify student-held conceptions. The use of the cross sectional data as representative of the notions held by that year cohort was based on the assumption that most students in that age cohort have been exposed to a range of formal and informal learning situations and as such were assumed to be representative of the notions held by that age group.

The responses to the two questionnaires showed that the reasons given by the Year 8 students were general in their nature and that this generality of answers decreased with increasing student age from Years 8 – 12 as more detail was included in the reasoning used in the students' responses.

More specific conceptual changes were identified with respect to energy and the human body and these were discussed in Chapters 5 and 6. These concepts centred around:

- the abstract nature of energy, energy conversions in general,
- the roles of the eye and ear in energy conversions,
- the cause of sweat being an effective cooling agent,
- the role of digestion and respiration in the cells for obtaining the energy required.

These changes to student-held conceptions were examined not only to identify the changes which occurred but whether these changes were evolutionary or revolutionary in nature and also the ontological changes which may have occurred from one year cohort to another cohort.

Further, Chapter 6 reported on possible conceptual pathways that students may follow as they develop acceptable concepts and some ontological changes were identified. This information showed that there were a number of ontological changes that were associated with the conceptual changes and a number of pathways were identified based on students' responses. These ontological changes centred on:

- the nature of energy,
- energy conversions,
- transfer of energy and body temperature regulation through heat gains and losses.

The degree of change of various concepts studied in this thesis varied from evolutionary in nature when the change was observed over a short period such as one or two years; to revolutionary over longer periods where a small number of conceptual changes appeared to undergo major category shifts. Some evolutionary changes included:

- the meaning of useful energy,
- an accretion of knowledge on respiration,
- energy conversions became more widely accepted and/or used, obtaining energy from air/oxygen,
- sleep or activity declined with student age,
- an improvement from thinking air or wind contacting sweat made the body cool to an appreciation of the role of evaporation in cooling the body.

In parallel to these evolutionary changes were a number of revolutionary changes which, in this cross section study, appeared to take place over a number years, that is, by comparing Year 8 and Year 11 or 12 students. Some of these revolutionary changes included:

- exchanging the particulate nature of energy into a more scientifically acceptable form (still general and only to something which was non-particulate),
- the role of the eye and ear changing from transferring the received energy to the brain to this energy being converted by the organ into a nerve conducted message which was then transmitted to the brain,
- the process of digestion not releasing energy from the food but only breaking up the larger food particles to facilitate absorption and use for energy elsewhere in the body.

9.3.3 Development of a Two-Tier Diagnostic Instrument

From the findings resulting from an analysis of the data collected from the administration of the two questionnaires '*Energy and Your Body'*, a series of 29 two-tier diagnostic items was developed and trailed. From an analysis of the information collected from the administration of the trial items, several items were discarded or reworded. The end result of this testing was a set of 20 items which by their nature could be used either individually or in any combination as required by the teacher. The resulting instrument is titled '*Energy and the Human Body*' and comprises 17 items which form the main instrument and three other items that can be used if desired. The development and subsequent trialing of the instrument was discussed in Chapter 7.The data collected during the development of these items indicated the unreviewed items did assess what they purported to.

9.3.4 Development of and Interventionist Strategy and an Assessment of its Effectiveness

The misconceptions identified in the first part of this thesis (Chapters 5 and 6) revealed a number of areas of concern about the role that digestion plays in the body's gaining of an energy source for use by the cells was related to students' notions of what occurs in the process of respiration and the particulate nature of energy. The second concern was that of the conversion (in the cell) of the absorbed food through the process of respiration. Since both of these areas form part of the curriculum for Year 9 students at the author's school, it was decided to develop a teaching and learning strategy which centred on these two areas. The lesson sequence was designed such that the progress of the food from ingestion to its conversion into useable energy (ATP) could be made explicit. The strategy was to be a guided-discovery lesson sequence based on a modified model of a curriculum proposed by Driver and Scott (1996).

The teaching and learning strategy was administered to a class of academically able Year 9 students who were also required to respond to two assessment instruments or open-ended items and a questionnaire which were administered immediately before and after the strategy's implementation. The open-ended instrument was re-administered five months after the strategy had been completed. The main objective of these instruments was to aid in assessing the effectiveness of the interventionist strategy.

Analysis of the results of the two pre and post-tests and the post-post-test showed that the strategy did prove to be effective in both the short term (immediately after completion of the lesson sequence) and over the longer term of five months. The long-term assessment showed that, although all students had forgotten some of the material they had learnt during the strategy's implementation, there was still a significant amount of knowledge retained.

9.3.5 Relationship of this Study to Science Education in Western Australia

Education in Western Australia has recently undergone a major pedagogical change from the traditionally teacher-centred objective-based curriculum to a constructivist and outcomes-based curriculum. This change has of necessity required a major pedagogical shift for the majority of teachers who teach at all student levels. One of the requirements of any constructivist classroom is that students commence lessons from their current position of knowledge. At the same time, teachers need to be able to identify misconceptions held by the students and also ensure that these students are aware of those areas of knowledge where their ideas may be different to scientific knowledge. Consequently, effective student learning is when students are able to identify their own knowledge position and conceptions so that they are consciously aware of their knowledge status. This consciousness will then enable students to commence the pursuit of further knowledge from a position of awareness of their knowledge framework.

The identification of student conceptions, both acceptable and unacceptable, enables teachers to create more effective lesson plans. It also enables teachers to be cognisant of students' misconceptions that may develop, and also at what stages of knowledge development conceptual problems may arise.

From the identification of concepts held by students in a variety of year-cohorts, a series of conceptual development pathways were proposed. Based on these pathways, a teacher could develop a lesson sequence to reduce the chances of students developing misconceptions as a result of the lessons. Further to this lesson aid, both teachers and students could identify where a student is located on a pathway and so be aware of potential problem areas which could arise and so avoid these in the student's quest to develop acceptable conceptions.

The identification of student misconceptions in this study and the approximate student age at which they develop will be of use to teachers by acting as a guide for what to expect from the students during their lessons. Teachers could then develop a lesson sequence and plan lessons to reduce these potential problems. Further, since not all students will have had the same exposures to public conceptions and the environment, they will not be at the same stage of conceptual development. The diagnostic instrument can be an easy to administer and time-efficient tool for teachers (and students) to use in the identification of existing conceptual understanding and also help locate an individual on a development pathway.

Another benefit of this study is that it can raise the awareness of teachers that energy can be relevant to the students themselves via the use of examples related to the students' body and not be inappropriate to a student's daily life experiences or to examples from the subject area of physics to which the biology lessons do not relate. First hand examples and experiences are of great benefit in facilitating learning and this study has shown that the student's own body can be a valuable tool in their study of energy.

9.4 LIMITATIONS OF THE STUDY

9.4.1 Cultural Differences

Although some of the findings of this study have been previously reported on and a number of new findings reported, caution must be taken when extrapolating these findings to other education systems due to the differences in language and culture. Both of these factors have a major influence on the manner in which concepts develop. This caution may apply to countries where English is not the first language and may even apply to countries which use English as their language because there are different meanings of a number of words and phrases in different countries. Similarly, caution must be taken for other cultural reasons and the manner in which a country's culture affects the way people view, interpret, understand and explain their surroundings.

9.4.2 Sample Representation.

The sample of students and the schools selected for this study was restricted and as such may not be representative of even the whole state of Western Australia in that there are a range of different curricula, content and methods of teaching for different age groups, especially when non-government schools are taken into account. This may mean that attempting to interpret the findings of this study to a particular age group could be tenuous as they may be at a different stage of concept formation due to their different exposure to the relevant concepts in the curricula.

The student population used as subjects for this study did not include many students who were identified as being academically very able or less able. Even so, the interpretation of the raw data was not based on student age but rather on the full population of students who responded to the questionnaires and were interviewed and so the proposed conceptual pathways should be applicable to a number of age groups of students. However, since some of the results that emerged from this study replicated those of previous studies conducted in a range of countries and age groups, the generalizability of the findings are enhanced.

9.4.3 Ontological Development Differences

Several ontological changes were discussed based on a number of potential concept-formation pathways which were derived from the collective data of a large number of students with a number of different age cohorts used to infer changes with student age. As such, individual students may follow any of a number of the proposed pathways in the formation of their concepts. Hence there is a difficulty predicting which of the pathways a particular individual would follow in developing an acceptable concept. Nevertheless, these findings could still be used as a guide for teachers and other researchers as to potential conceptual pathways that may be followed and help guide work based on this information, especially if the students' conceptual status is ascertained at the beginning of the topic to be studied.

9.4.4 Limited Diagnostic Instrument Testing

The diagnostic instrument appears to assess what is was designed to do but it has not been tested using a large population of students over a range of ages and a number of education systems. The population used to develop and assess the suitability of the instrument came from the same school from which the majority of students used for the collection of the data. So there may be special problems inherent in using the same school as there could be local influencing factors in the curriculum or its delivery. Even so, the instrument should be applicable to a range of situations since it is based on data which have been replicated in previous studies.

9.4.5 Interventionist Strategy

The interventionist strategy was developed to suit one specific curriculum and for a particular year group of students and as such may not be applicable to other classes. But, even with this warning, the teaching and learning strategy should be able to be readily modified to suit the required situation. A further problem with the use of this instrument is the time it takes for students to adequately complete it. This time requirement is difficult to reduce while still enabling the students to have sufficient time to become fully immersed with the material. Despite the time requirement, the interventionist learning strategy did prove to be an effective set of strategies covering both digestion and respiration either together or separately.

9.5 IMPLICATIONS FOR SCIENCE EDUCATORS

Based on the findings of this study the following implications emerged that can be used by teachers to improve their delivery of science education:

9.5.1 Raising Teacher Awareness

A general development from this study has been to raise the awareness in teachers of the notion that energy is not limited to the domain of physics but is readily applicable to many other domains of science, including the study of the student's own body and its everyday functioning.

9.5.2 Identified Misconception Pathways

A number of student-held misconceptions involving energy were identified. These notions are related to not only physics but were transferable to energy and the human body. In conjunction with these previously known misconceptions, a number of new ones were also identified and from these misconceptions, a series of possible conceptual development pathways were proposed. By the use of these conceptions and pathways, teachers can develop lesson sequences which commence at points where each student's knowledge is currently located. Not only can the lesson start at an appropriate point but also it can direct student learning along acceptable conceptual pathways rather than simply aim to eliminate the development of misconceptions and attempt to correct scientifically unacceptable conceptions or aim to achieve an acceptable conception without knowing alternative directions that can eventuate.

Through the use of these conceptual pathways, teachers can be more mindful of possible problems that may arise and enable strategies to be quickly developed should a problem be identified. Lessons can be planned to reduce the chances of incorrect pathways developing as they can be anticipated.

9.5.3 Use of Diagnostic Instrument

Teachers need easy to use means of identifying student-held conceptions since knowing these can enable better planning of lesson sequences. The diagnostic instrument, *'Energy and the Human Body'*, facilitates the convenient identification of students' concepts. Through the use of this instrument not only are conceptions identified, but once these are known students' understanding can be identified and located on the conceptual pathways developed in this study.

Following the identification of student-conceptions, a teaching and learning strategy was developed which traces the path of food from its ingestion, through the processes of digestion and absorption and then the process of respiration. The lesson sequence presented here can be used in whole or as two separate lesson sets of digestion and respiration and is suitable for a range of age groups from Year 9 through to Year 12.

This interventionist strategy helps model a constructivist method of teaching and as such may be of use to teachers in the state of Western Australia, where this method is the implied teaching methodology (Curriculum Framework, 1998, p. 13). This strategy involves students being actively engaged with a series of activities which model the various processes that are involved when food is used to produce useable energy by a human body. Teachers in Western Australia have not been provided with the necessary in-servicing of the pedagogy of constructivism and are consequently often unaware of what is involved in this pedagogy. This teaching and learning strategy may help teachers develop some notion of what is involved in one aspect of this pedagogy by providing a model set of lessons.

9.6 FUTURE RESEARCH SUGGESTIONS

While this study fits into a large corpus of work on students' conceptions, it shows that more research is still needed to identify students' conceptions in a wide range of science domains. More importantly is the need to examine the manner in which misconceptions are transferred across a range of science domains. This study identified a number of misconceptions that are carried across domains.

While there is a large corpus of misconception work, a number of issues are raised as a result of this study. In particular, more work is needed to look at misconceptions as they relate to the human body. The examples presented in this research show physics and its applications are not restricted to the domain of physics alone but are applicable across domains. The human body forms an ideal example for teachers to use in a class situation since the human body comes with intrinsic interest to the students and comes with each student to every lesson.

While there has been little work carried out on misconceptions as they relate to the human body, this study shows that work can be easily carried out over a variety of areas of science and can be related directly to biology or perhaps more importantly to the human body. More information on misconceptions can be used by not only teachers in classes but in a number of other fields to help overcome prejudices and falsehoods which abound in everyday life. As a consequence of this knowledge, it may be possible to overcome some of the myths and errors which are perpetuated via such sources as the media. Typical examples perpetrated by the media are food is burnt, energy is burnt, organs for donation are removed before the donor is dead, and many diets are not effective or even beneficial to the body.

There is a need to identify the potential pathways that learners may follow while developing conceptions. This approach has the advantage of helping teachers prepare material to reduce the incidence of misconceptions forming and can also could lead to more information on how learners actually develop their knowledge. Some pathways were suggested in this thesis but far more work needs to be carried out in this area or research. With this knowledge of the development of specific pathways of conceptual development, the manner in which conceptual growth and development occurs may become clearer to researchers.

Another area where future research work could be pursued is in the field of lesson presentations which can be utilised by teachers to overcome identified misconceptions.

Many researchers show various teaching strategies used in an attempt to remove or adjust student held misconceptions. Frequently these lessons involve small numbers of students with little work carried out to trial lesson sequences and their effectiveness in full size classrooms. It is this type of applicable information which teachers need rather than the identification of student conceptions or lesson applications in small group situations. Further, these good lesson plans should model good practice and as such could aid in the development of better lessons sequences which attempt to help students achieve acceptable science notions.

With the identification of misconceptions and the pathways that learners can follow in developing their knowledge, this information can be incorporated into pre-service and in-service courses. In this way, teachers' awareness of misconceptions can be raised and some methods by which these misconceptions can be reduced illustrated. This awareness can only be of benefit to both teachers and learners in the future, as it should provide a starting point for the improvement in future lesson preparation and development.

9.7 FINAL REMARKS

This work has identified new material which can be utilised by science educators both in the classroom and in teacher pre- and in-service courses. This new material includes a number of misconceptions; it has proposed a number of pathways that may be followed in the development of knowledge involving energy and the human body. From this misconception knowledge, an instrument was developed for use by teachers to aid in the identification of student-held conceptions. A lesson sequence which can be used by teachers to help students of various ages develop acceptable concepts about energy and the human body was also created, tested and found to be effective for a number of students.

These new pieces of information add to the overall picture of student conceptual development and with this knowledge, education practitioners are in a better position to make necessary changes and improvements in their classroom practices to better enhance student learning.

Moreover, there is scope for teachers to use the diagnostic instrument developed in this study to identify the position of their students in the development of their conceptions as they relate to energy and more particularly energy and the human body. This knowledge can further enhance the preparation of student learning experiences. Further, there is a lesson sequence provided which teachers can use as it is or modify it to suit their situation.

Finally, this thesis may encourage others to continue studies in the identification of student conceptions, both those that are acceptable and those that are unacceptable, and from these conceptions to develop pathways learners may follow while developing their conceptions.

The development of possible conceptual pathways that students may follow as they develop and adjust their concepts is a major outcome of this study. It is from this knowledge of conceptual pathways that the education of students of all ages can be better facilitated and that this knowledge can then be applied to the classroom situation and not just remain a corpus of knowledge found only in books and journals.

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APPENDIX 1

PROPOSITION STATEMENTS RELATED TO ENERGY AND THE HUMAN BODY

SOURCES OF ENERGY

1 Energy which impinges upon and is used by the body comes in a number of forms. Some of these forms are chemical energy, sound, light and heat (infra-red radiation).

2 Sound is a form of energy the human body utilises to aid in its monitoring of the external environment (via hearing).

3 Light is a form of energy the human body utilises to aid in its monitoring of the external environment (via seeing).

4 Food is the source of chemical energy for the body and this energy is found within the food's molecular bonds.

5 The chemical energy in food is the main source of the energy for all endothermic chemical reactions which occur in the body.

6 Different food groups are used as energy sources by the human body and have different energy values.

7 The major food groups used as chemical energy sources include some carbohydrates, lipids and protein.

8 Glucose is the major "everyday" source of chemical energy used by the cells of the human body (in the process of respiration).

9 Energy in food is chemical energy and varies only in quantity in a food group.

ENERGY INTAKE AND RECEPTION

10 A number of specialised organs and systems receive energy from the external environment.

11 Some of the regions of the body which receive energy from the environment are the gut, eyes, ears and skin. (The energy includes chemical energy, light, sound and heat respectively).

12 If the environmental temperature is greater than that of the body heat will enter the body through the processes of conduction, convection and radiation.

13 If the human body is in the Sun it will absorb heat energy from the Sun as infra-red radiation.

PROCESSING AND MOVEMENT OF ENERGY SOURCES

FOOD DIGESTION

14 Digestion enables the ready absorption of food for use by the body.

15 Digestion releases little energy the body can utilise for other processes.

ABSORPTION

16 Absorption is the process by which the digested food moves from the gut lumen into the cells lining the gut wall and eventually the body (ie the blood or lymph).

17 Once absorbed into the body the molecules of absorbed food are transported to the liver and thence to where they are needed by the body.

TRANSPORTATION OF ENERGY

18 Blood and lymph are the major means of transportation of materials within the body.

19 Chemical energy and heat are transported around the body in the blood and lymph.

20 Requirements for the mitochondria to convert energy into a useable form (ATP) come from the blood and lymph systems.

21 Sense organs convert different sensory inputs into 'electrical' energy in the form of action potentials.

22 Nervous system is the body system that can move energy through the body very quickly in the form of electrical impulse (action potential).

23 Some forms of chemical energy, as well as heat, freely move between the blood (and lymph) and the interior of the body's cells.

ENERGY REACTIONS

24 Metabolism is the sum of all chemical reactions that occur in the human body and results in the release of heat as a by-product.

25 Catabolic reactions require energy to occur.

26 Anabolic reactions may release energy as heat or if respiratory will also yield utilisable energy in the form of ATP.

27 Energy can be transformed from one form into another.

28 A number of regions of the body convert energy into energy the body can use or interpret (eg, eye, ear, skin, mitochondria).

RESPIRATION

29 Respiration is a complicated chemical process that occurs in all the cells of a living organism.

30 Respiration occurs all through an individual's life.

31 Respiration occurs within the mitochondria (within the cells).

32 Energy in the form of chemical energy found in various sources (ie carbohydrates, lipids and proteins) is transferred to ATP (or creatine phosphate) during respiration.

33 Respiration (specifically of glucose and lipids) is the chemical process which results in the transformation of chemical energy from absorbed food into chemical energy in the form of ATP.

34 It is ATP that the body can use as its energy source for nearly all of its endothermic (and exothermic) reactions.

35 Respiration uses oxygen (which is absorbed into the body via the lungs) and carbohydrates and lipids (from food).

36 The end products of Respiration are the wastes of carbon dioxide, water and heat and utilisable energy in the form of ATP.

37 Breakdown of amino acids also releases energy that is used in the formation of ATP.

38 Excess amino acids can be deaminated and then converted into glucose and lipids (gluconeogenesis) and (lipogenesis) for use or storage.

39 Respiration can be summarised by the general equation

40 Glucose/lipids/protein + oxygen ---→ ATP + carbon dioxide + water + heat

41 ATP is an "energy storage" molecule.

42 ATP is the 'universal energy molecule' meaning it can be used (when required) by all cellular reactions.

43 ADP + P -----→ ATP

44 Creatine phosphate is stored in all cells.

45 Creatine phosphate is a 'quick-release' store of energy for the re-formation of ATP from ADP (via the creatine phosphate cycle).

ROLE OF ATP

46 Energy stored in the body in the form of chemical energy is found in a number of molecules of which ATP and creatine phosphate are the most important.

47 ATP stores immediately available energy (chemical energy).

48 ATP is the molecule often referred to as the "universal energy molecule" which the body can use as the energy source for all endothermic chemical reactions.

49 ATP releases energy when a phosphate bond is broken to form ADP and a phosphate ion.

50 ATP can also be replenished from creatine phosphate when ATP levels are low.

SLEEP

51 Many of the body's general activities decrease (but do not stop) when the body is asleep and so this leads to a decrease in the demand for energy.

52 During sleep, respiration still occurs and so energy levels within the cells are restored to the maximum level suitable for that cell.

53 During sleep the body still converts energy, so the body can function

SIGHT

54 The eye is the organ that receives electromagnetic radiation (or energy) and transforms it into electrical energy (electrochemical) which the brain can interpret (for seeing).

55 The "electrical energy" the brain can interpret is in the form of action potentials which are electrochemical in nature.

56 The creation and maintenance of action potentials requires the expenditure of energy by the nerve cell.

HEARING

57 The ear is responsible for transforming air pressure changes (in the form of sound energy or waves) into electrochemical energy (action potential).
58 Electrochemical energy (action potential) is the form of energy the brain can interpret for us to hear a sound.
59 The brain uses the action potentials (electrical energy) from the ear to help monitor the external environment by interpreting them. (Hearing process)

SKIN

60 The skin receives or gives off energy, particularly heat, to the external environment.
61 Sweating is a method the body employs to help it loose heat through the process of evaporation.

"USES"

TERMINOLOGY

62 Metabolism is the sum total of all chemical reactions (anabolic and catabolic) in the body with each of these processes using energy.
63 Anabolic and catabolic chemical reactions involve energy release and/or use.
64 Many of the body's chemical reactions require the addition of energy before they will occur due to their high energy of activation.
65 Respiration is the process whereby the energy in the bonds within organic molecules is transferred to other molecules, in particular ATP and creatin phosphate.
66 When we cause an object to move we transfer some of our energy to the object.

GENERAL USES

67 Energy is utilised by the body in a number of ways to carry out various functions within the body and to cause the body to act on phenomena outside of the body

BODY TEMPERATURE REGULATION

68 In endothermic organisms a "constant" body temperature is important for the optimum functioning of that organism.

69 Release of heat from metabolic processes is vital for the body's functioning in endothermic organisms.

70 Heat is a waste or by product of all chemical reactions (metabolism) within the body.

71 Heat released from all the chemical processes is a waste. This waste is used by the body to help maintain a constant body temperature.

72 Blood helps transport and evenly distribute heat energy throughout the body (as does lymph).

73 The human body utilises the heat energy from its metabolic processes as an aid in the maintenance of a relatively constant body temperature.

74 Body temperature is regulated so as to remain as constant as possible (at around 37^{o}C) and so remain within tolerable limits for optimum operation of the body.

75 Excess heat in the body needs to be removed from the body.

76 Heat transfer between the body and the external environment occurs via the processes of radiation, convection and conduction.

77 If the air temperature is greater than the body temperature then the body will gain heat.

78 If the air temperature is less than the body temperature then the body will lose heat.

79 If the body temperature is elevated then one mechanism the body can utilise to reduce its heat content is through the production of sweat.

80 Sweat, when it evaporates, removes heat from the skin (latent heat of evaporation).

81 The removal of heat from the skin results in cooling of the blood within the skin (and hence the body).

82 Insulation occurs through deposition of fat in a layer beneath the skin (subcutaneous fat).

83 At a conscious level, the body utilises a number of behavioural mechanisms to reduce heat loss and heat gain.

STORAGE

84 Stored chemical energy varies in quantity and ways the “storage” chemicals are used by the body.

85 The chemicals in which energy is stored depends upon how quickly the chemical may be called upon as an energy source by a cell.

86 Energy may be stored in a variety of chemicals, some of which include glycogen, lipids, glucose, ATP and creatine phosphate.

87 Excess carbohydrates and lipids are stored within the body in the form of glycogen and fat. Glycogen within the cells and lipids within cells in small quantities and in adipose tissue (large quantities).

88 ATP stores energy as an immediate energy source within the cell.

89 Creatin phosphate is an energy source available for immediate use in the re-formation of ATP

90 Glucose is stored within the body in the form of glycogen (mainly within the muscles and liver cells).

91 Stored glycogen can be converted to glucose when glucose is at a low level within the cell (and body).

92 Stored lipid or fat can be used at a later time by the body when other energy sources are at a low level within the body.

ENERGY “LOSSES”

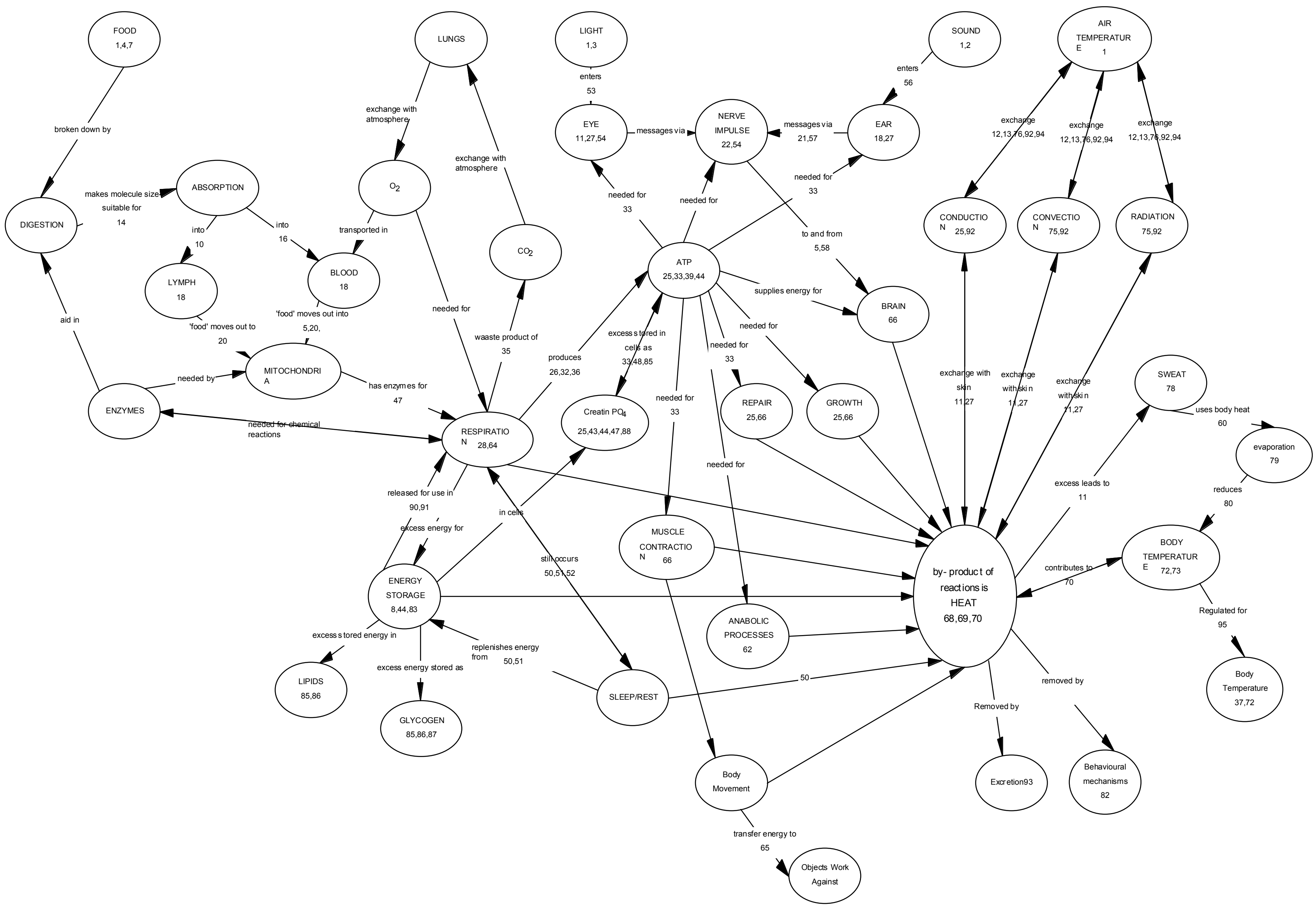
Energy cannot be created or destroyed (Second Law of Thermodynamics)

93 Heat transfer between the body and the environment takes place through the processes of convection, conduction, and radiation.

94 Excretory processes result in the removal of heat from the body.

95 If the external environment’s temperature is lower than that of the body heat will be lost to the environment.

96 As the skin cools, the blood flowing through the upper layers will in turn be cooled (and ultimately the whole body cooled)


FOOD 1,4,7
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makes molecule size suitable for 14
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into 10
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LYMPH 18
BLOOD 18
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exchange with skin 11,27
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Body Temperature 37,72
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removed by
Excretion93
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APPENDIX 8

APPENDIX 3

Series of four collages used as discussion points during the interviews discussed in Chapter 4.

Electronic copy not available.

APPENDIX 4

QUESTIONNAIRE 1

STUDENT CODE ---- ----- ----- ------

ENERGY AND YOUR BODY
QUESTIONNAIRE 1

WE ARE ONLY DEALING WITH ENERGY AND YOUR BODY AND WHAT YOU THINK ABOUT THESE TWO THINGS.

PART 1

List 5 things which involve energy, movement and your body.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________

List 4 things which involve your body and energy, but do not involve exercise or any movement of your body by muscles.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________

Please do not add or change anything in this section now that you have completed it.
This is important.

PART 2

Read each statement.
Circle the Agree or Disagree to show how you feel about the statement.
Please explain as fully as you can your reasons for Agreeing or Disagreeing with the statement.

1 The energy in the food we eat is found in tiny bundles or packets found in between the food particles.

AGREE / DISAGREE

REASON ____

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2 All foods contain the same amount of energy.

AGREE / DISAGREE

REASON ____

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3 Energy in the food we eat may be useful or not useful to us.

AGREE / DISAGREE

REASON ____

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4 The different types of energy we need are found in different foods.

AGREE / DISAGREE

REASON ______________________________

5 We must eat a variety of foods to get all the energy we need.

AGREE / DISAGREE

REASON ______________________________

6 We get energy from the air we breath.

AGREE / DISAGREE

REASON ______________________________

7 In the process of respiration, energy in sugars is converted into energy that the cell can use to do things.

AGREE / DISAGREE

REASON ______________________________

8 Some parts of our body which receive energy are our eyes, our ears, our nose, our skin and our lungs.

AGREE / DISAGREE

REASON ____

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9 When we eat too much food, our body only takes in the energy it needs, the rest passes out of our body.

AGREE / DISAGREE

REASON ____

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10 When you hear a friend talking, the sound energy comes from that friend's mouth into your ear and then into your brain where it is used to hear.

AGREE / DISAGREE

REASON ____

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11 When we ride a bicycle, some of our energy is transferred to the bike.

AGREE / DISAGREE

REASON ____

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12 We have a body temperature of nearly 38^{o} C which is often greater than the surrounding air temperature. This body temperature is a result of all the chemical reactions which occur in our body.

AGREE / DISAGREE

REASON ____

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13 When we sweat, the heat in our body is changed into sweat. As sweat leaves the body it takes the heat with it.

AGREE / DISAGREE

REASON ____

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THANK YOU FOR YOUR WORK ON THIS.

Please be sure you have your code on the top of the first page. This is important for later on.

APPENDIX 5

QUESTIONNAIRE 2

STUDENT CODE ---- ----- ----- ------

ENERGY AND YOUR BODY

QUESTIONNAIRE 2

WE ARE ONLY DEALING WITH ENERGY AND YOUR BODY AND WHAT YOU THINK ABOUT THESE TWO THINGS.
PART 1

List 5 things which involve energy, movement and your body.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________

List 4 things which involve your body and energy, but do not involve exercise or any movement of your body by muscles.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________

Please do not add or change anything in this section now that you have completed it. This is important.

PART 2

Read each statement.

Circle the Agree or Disagree to show how you feel about the statement.

Please explain as fully as you can your reasons for Agreeing or Disagreeing with the statement.

1 When we digest food, we release the tiny bundles of energy found between the food particles so they can move into our blood to be carried to the cells for use.

AGREE / DISAGREE

REASON ____

2 We get energy from the food we eat.

AGREE / DISAGREE

REASON ____

3 We get energy from when we sleep.

AGREE / DISAGREE

REASON ____

4 We only absorb the useful energy from the food we eat.

AGREE / DISAGREE

REASON ____

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5 There is a difference between the energy in different foods. The energy in some f oods is easy to use, in other foods it is difficult to use, and in other foods it cannot be used at all.

AGREE / DISAGREE

REASON ____

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6 The energy that we get in food is made into useable energy in the cells by a process called respiration.

AGREE / DISAGREE

REASON ____

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7 In the process of respiration, energy in fats is converted into energy that the cell can use to do things.

AGREE / DISAGREE

REASON ____

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8 The energy in food is passed into the cells of the body. The cells change this energy (from the food) into movement energy, heat, sweat and the rest is destroyed.

AGREE / DISAGREE

REASON ____

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9 When we put on weight (get fat) we are changing excess useful energy into energy in the form of fat so we can use it later if we need energy.

AGREE / DISAGREE

REASON ____

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10 When we ride a bicycle, some of our energy is transferred to the bike.

AGREE / DISAGREE

REASON ____

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11 The energy we use in an activity like playing a game comes from the oxygen we breathe in.

AGREE / DISAGREE

REASON ____

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12 There are a number of parts of our body which receive energy from our surroundings.

AGREE / DISAGREE

REASON ____

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13 When we see something like a tree, some of the light energy from the tree is transferred via the eye to our brain and so we see that tree.

AGREE / DISAGREE

REASON ____

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14 We have a body temperature of nearly 38^{o} C which is often greater than the surrounding air temperature. This body temperature is a result of all the chemical reactions which occur in our body.

AGREE / DISAGREE

REASON ____

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15 When sweat evaporates into the air it cools us down by the process of evaporation.

AGREE / DISAGREE

REASON ____

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THANK YOU FOR YOUR WORK ON THIS.

Please be sure you have your code on the top of the first page. This is important for later on.

APPENDIX 6

Research Project:

Students' use of formal and informal knowledge about energy to understand energy systems of the human body.

PARTICIPANT INFORMATION SHEET

Michael Mann is conducting this research project as part of his Doctor of Philosophy program. This research is designed to identify children's understandings of the way in which energy is used in the human body, where these ideas have come from and how they progress over time. This information will be very useful to Michael and other teachers implementing the new program under the Curriculum Framework. The study also has the potential to be of benefit to your child.

To find this information Mr Mann intends to administer questionnaires in 2000 to a number of students. In addition, a few students will be asked to participate in a follow-up interview.

If you are asked to put an identifying code on the questionnaire, it is for the purpose of correlating the questionnaires and selecting interviewees for the follow-up interviews. At no time will your identity be revealed to anyone but Mr Mann.

You have the right to refuse to be part of this study in part or whole. This can be done by filing out the form attached to the Participant Consent form and returning it to Michael Mann. Should you wish to withdraw during the program this may be done in writing or verbally to Michael at any time.

Prof. D. TREAGUST

August 2000

APPENDIX 7

Research Project:
Students' use of formal and informal knowledge about energy to understand energy systems of the human body.

PARTICIPANT CONSENT SHEET (PADBURY)

Dear parent/guardian

Thank you for reading the Participation Information Sheet.

By not returning this form or contacting Michael Mann (tel. 93073199), your tacit agreement to your child's participation in the research project will be assumed on the following understandings:

- Your child will be asked to complete a questionnaire(s) and may be asked to be interviewed.
- Your child's name will not be used in any written reports.
- The data collected will be secured electronically or locked in a secure filing cabinet for a period of no more than 5 years, after which it will be destroyed.
- Your child may choose to withdraw from the study at any time by simply
- indicating , in writing or verbally, a desire to no longer participate.

If you DO NOT wish your child to participate in this research, please complete and return this form to Michael Mann (via the school Science Department) as soon as possible.

Thank you for your co-operation.
Michael Mann

AUGUST, 2000

I do not wish my child to participate in the research being carried out by Michael Mann.

____________________ CHILD'S NAME ________________________

DATE (Please Print)

Research Project:
Students' use of formal and informal knowledge about energy to understand energy systems of the human body.

PARTICIPANT CONSENT FORM (BELRIDGE)

Dear parent/guardian

Thank you for reading the Participation Information Sheet.

By returning this form or contacting Michael Mann (tel. 93073199), your agreement to your child's participation in the research project will be assumed on the following understandings:

- Your child will be asked to complete a questionnaire(s) and may be asked to be interviewed.
- Your child's name will not be used in any written reports.
- The data collected will be secured electronically or locked in a secure filing cabinet for a period of no more than 5 years, after which it will be destroyed.
- Your child may choose to withdraw from the study at any time by simply indicating , in writing or verbally, a desire to no longer participate.

If you do not object to your child participating in this research, please complete and return this form to Michael Mann (via your child's Science Teacher) as soon as possible.

Thank you for your co-operation.

Michael Mann

AUGUST, 2000

I do not object to my child participating in the research being carried out by Michael Mann.

____________________ CHILD'S NAME______________________________

DATE (Please Print)

____

Parent/Guardian signature

APPENDIX 8

The material in this table is the author's interpretation of how *Curriculum Frameworks* information relates to energy and the human body and is by no means a complete set of pointers for any Level of the Strand (of Energy and Change). The strand has a broad coverage of the topic of energy and associated changes that involve the human body.

SUB STRAND OUTCOME	Energy is required for different purposes in life 1	Energy is transferred and that people use different types of energy for different purposes 2	Patterns of energy use and some types of energy transfer 3
Energy is vital for existence & quality of life & society	• Awareness of energy use for number different things in everyday life (eg throw walk). • Use energy when being active (any activity as example). • Way use energy in everyday life eg activity like running, walking to school. • Light, sound, heat help us everyday.	• Ways others use energy (eg teacher, friend). • Physical activity makes a person hot and tired. • Need energy to do things eg. Playing sport uses energy. • Different energy types used for different activities eg. sound to hear, light to see. • Energy moves from one thing to another eg, light from object to eye, sound from object to ear.	• How energy replaced when take in food • (food to replace Chemical energy.). • Lack energy when stored supply low therefore no more for conversion or need extra conversions to be useful. • More food if exercise than if lazy. • Amount of energy required/used varies with activity level, age of person. • Changes in energy requirements with a number different factors & predict when use more energy.
Energy can be transferred between objects and systems	• Recognise source of energy for the body is food. • Food is a source of energy for us.	• Some forms of energy transfer involve • energy transfer from muscle to whole body. • Chemical energy in food to muscle movement. • Diff types of energy used - chemistry, heat, kinetic energy, mechanical (in muscle). • Energy in food to muscle energy & heat.	• Energy transfer from chemical in muscle to movement (muscle move.) when contracts. • Energy transferred from muscle (pull) on bones & so body moves or transferred to other things • Energy transferred from food (source) to body (receiver) where becomes useful. • Energy sources & energy receivers ie parts of body receivers of energy from outside sources eg. Food source body receiver, object source ear or eye receiver, sun heat source skin receiver.

Processes of energy transfer can be controlled enabling changes to be more efficient	• Respond to need for intake energy to exercise or continue of energy. • Need to take in food to replenish energy "used" during exercise. • Need to take in energy before exercise so will be able to exercise longer. • Food source of energy. • Eat more/less food depends upon our needs.	• Diff types of food give different energy amounts. • Identify types of energy involved, chemical, heat, kinetic, mechanical of muscles. • Different foods different energy yields eg lipids more energy than carbohydrates than protein.	• Body stores energy (glycogen, glucose, creatine phosphate, ATP) & muscle/cell receiver when use it to do activity or to live. • Body stores energy & cells receive when use energy. • Fats energy store (number of other molecules store energy also).

SUB STRAND OUTCOME	**Energy interacts with different substances & this can affect use & transfer 4**	**Models & concepts to explain energy transfer in an interaction 5**	**Principals & concepts used to explain transfer of energy that occur in energy system 6**
Energy is vital for existence & quality of life & society	• Different sources of energy available or needed by body. • Food as energy supply & different foods have different amounts of energy & useful energy available. • Use energy to make things move or change.	• Explain respiration in terms of energy flows (Chemical->chemical-> ATP-> movement). • Metabolism releases energy eg. Respiration. Anabolism needs energy. • Store energy in fats and use when needed.	• Explain how parts of body work as levers to enable movement. • Describe how energy concepts can be used to calculate work done. • Tendons store energy when move.
Energy can be transferred between objects and systems	• Diets as impediment to energy flow into body (low fat, carbohydrate.) & different energy use & cost of • different diets. • Insulation - slow heat transfer eg fats, cloths. • Deafness and blindness as energy impediments	• Energy obtained from respiration of food not all used - some as heat, rest, movement. • Efficiency of energy system ie useful & waste energy (not lost) when exercise or use energy. • Release heat when exercise where heat is the end or by-product.	• Relationship between energy content of food & how much energy body can use/do ie do sports, diets. • Energy intake before, during after exercise. • Energy intake before during, after exercise.
Processes of energy transfer can be controlled enabling changes to be more efficient	• Gain/loose heat over skin through conduction, convection, radiation. • Role of sweat and evaporation as cooling mechanism. • Body reacts to energy arriving at body eg. Light and retina, sound and ear, heat and sunburn.	• Analyse energy transfers (changes) that occur in body when food (source) is used to produce movement. • Energy transfers- glycogenesis, glycolysis, gluconeogenesis as different energy stores for use. • Muscle contraction and the role of energy (detail of processes).	• Examine factors which effect the level of energy consumed by different people due to age, sex, job, pregnancy etc. • Energy conservation through the use of aids & effective use of energy ie use of machines to aid in work.

SUB STRAND OUTCOME	Role of science in developing systems of energy transfer 7	Assess the role of science in helping us explain energy systems, production and use. 8
Energy is vital for existence & quality of life & society	• Societal demands fro energy (in food) and how meet these demands. • How science has affected energy production (food) to meet demands of society. • Energy in diets & societal pressures on diet and exercise. • Inventions & how these affect energy use by humans.	• Analyse different ways food production & refinement involve energy use & loss & efficiency
Energy can be transferred between objects and systems	• Science Theories to analyse different systems of energy transfer (eg comparison of glucose & lipid metabolism for energy - number of steps & energy lost during process • usefulness of each gram for gram.	• Explain how the energy needs of different societies are met (eg. Food, heating, etc.).
Processes of energy transfer can be controlled enabling changes to be more efficient	• Operation of eye or ear via theories to explain their functioning, eg, photochemical reaction of eye, role and functioning of cochlea.	• Describe how scientists determine which foods are less environmentally damaging to produce. • Explain how science may determine how contribute to decrease reliance on highly processed foods (in terms of energy wastage/usage). • Global effects of energy use by humans. • Energy use to produce food.

APPENDIX 9

SPECIFICATION GRID OF PROPOSITIONS AND ITEM NUMBERS

Major Energy Area	Proposition Statement Number	Item Number
Sources of Energy	1	T1.4, T2.7, T1.10, T1.15, T2.13
	2	T1.4, T2.6, T2.8, T2.70
	3	T1.4, T1.15, T2.13
	4	T1.1, T2.7, T1.6, T2.9, T2.14
	5	
	6	T2.7
	7	
	8	
Energy intake and Recep-tion	9	T1.4, T2.6, T2.8, T2.70, T1.10, T1.15, T2.13
	10	T1.1, T1.4, T2.6, T2.70, T1.10, T1.15, T2.13
	11	T1.12
	12	
Process-ing & Move-ment of Energy Sources food	13	T1.2, T1.5, T2.9, T2.14
	14	T1.2, T1.5, T2.9, T1.14, T2.14
absorption	15	T1.3, T1.5, T1.14, T2.14
	16	T1.3, T2.8, T1.14, T2.14

Major Energy Area	Proposition Statement Number	Item Number
Energy Conver-sions	23	
	24	
	25	
respiration	26	T1.1, T1.5, T1.6, T2.12
	27	T2.12
	28	T2.12
	29	T1.2, T2.2, T1.5, T1.6, T2.9, T2.10, T1.7, T1.14
	30	T2.2, T1.5, T1.6, T1.7, T2.12, T2.14
	31	
	32	T2.9, T1.7
	33	T2.12
	34	T2.2, T2.9
	35	T2.9, T2.13, T2.14
	36	T2.2, T1.6, T2.9, T1.7, T2.12
	37	
	38	

Major Energy Area	**Proposition Statement Number**	**Item Number**		**Major Energy Area**	**Proposition Statement Number**	**Item Number**
Transportation of energy	17	T2.1			39	
	18	T2.1			40	
	19	T2.1			41	
	20	T1.4, T2.6, T2.70, T1.15, T2.13			42	
	21	T1.4, T2.6, T2.70			43	
	22				44	T1.11
	45	T1.11			68	T2.11, T1.13
	46	T1.15			69	
sleep	47	T2.8, T1.11			70	T2.8
	48	T2.8, T1.11			71	
sight	49	T1.4, T2.6, T2.8, T1.10, T1.15, T2.13			72	T2.11, T1.13
	50	T1.4, T2.6, T1.15, T2.13			73	T2.11, T1.13
	51	T1.4, T2.6, T1.15, T2.13			74	T1.13
hearing	52	T2.6, T2.8, T2.70, T1.9, T1.10			75	
	53	T1.9		storage	76	T2.4
	54	T2.6, T2.70, T1.9			77	
skin	55	T2.6, T2.70			78	T2.4, T1.3, T1.7, T1.14, T2.14
	56	T2.8, T1.10			79	T2.4, T1.3, T1.7, T1.14, T2.14
"Uses" terminology	57				80	
	58				81	
	59	T2.3			82	T1.3, T2.14

Major Energy Area	Proposition Statement Number	Item Number
Body Temperatu re Regulat ion	60	
	61	T1.12
	62	T2.3, T2.10, T2.11, T1.12
	63	T2.3, T2.10, T2.11, T1.12
	64	T2.3, T2.10, T2.11, T1.12
	65	
	66	T2.3, T1.12
	67	T1.12

Major Energy Area	Proposition Statement Number	Item Number
	83	T1.3, T2.14
	84	T2.4, T1.7, T2.14
Energy "Losses"	85	T2.14
	86	
	87	T2.11, T1.13
	88	T1.3, (T1.14)
	89	
	90	T2.11, T1.13
	91	
	92	T2.5, T1.8

Note: Items marked with an asterisk were considered to be beyond the scope of courses held for Years 8 – 12 which involve energy except those of biology and human biology.

Sections under the heading of Major Energy Areas are sub-divided into main areas involving energy and sub-sections of these areas.

APPENDIX 10

TWO TIER DIAGNOSTIC INSTRUMENT (WHITE)

ENERGY AND YOUR OWN BODY

INSTRUCTIONS
Your task is to say whether or not the statement is true or false. Which ever your choice is, please CIRCLE the true or the false.

When you have done this, you should chose one of the reasons that best matches your reason for saying true or false and CIRCLE the letter for this reason. If none of the reasons offered is suitable then use the lined space to put your own reason in. Remember it is important to select a reason. If you do not agree with the reasons given, please supply your own reason in the space provided.

This test only deals with energy and the human body and what is involved in this. Do not consider other processes when answering these questions.

THIS TEST DOES NOT COUNT TOWARDS YOUR ASSESSMENT

1 Blood transports molecules of food around the body so the cells can take these molecules in and use them as a source of energy.

TRUE/FALSE

A we absorb the energy produced by the digestion of food and the blood carries this energy around our body to where it is needed
B blood circulating gives us energy
C blood is unable to support or carry excess energy
D blood carries oxygen around the body not the energy
E blood carries the sugars around the body for the cells to absorb which they can then use to make energy

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2 Respiration can use food molecules such as glucose (and other sugars), fats and proteins to produce useable energy (ATP).

TRUE/FALSE

A respiration is breathing
B fats are unable to be used for energy but sugars are
C energy is released by digestion not respiration
D we get our energy when we are active (like exercising) not from food
E respiration burns energy not create it
F respiration is the process of making all food components into useable energy

G ____

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3 The heat released from the chemical reactions in our body is a waste product that we can use to help regulate our body temperature.

TRUE/FALSE

A chemical reactions contribute to the heat production
B our body temperature is from the heat we produce when we exercise only
C the chemical reactions produce heat as a waste product and we convert this heat into temperature
D heat is from the flowing of blood through our veins and arteries not the chemical reactions
E energy is "burned" to give heat for the body
F the body makes its own heat, it is not from chemical reactions

G ____

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4 Energy may be stored in the body for later use. Fat (lipids) is one such chemical which is used for energy storage.

TRUE/FALSE

A we store fat but we cannot use this fat for energy at some later time
B energy is changed into fat to be stored
C excess energy is not changed into fat
D we store the excess energy in the bonds of the fat
E respiration does not convert fat into energy
F there is no left over energy as we use all we take in

G ______________________________

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5 When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE

A the bike is not living and so cannot use or have energy
B we use energy up not transfer it to the bike
C bike makes its own energy
D use energy to move the pedals but no energy is transferred to the bike
E our leg movement energy is transferred to the bike and then becomes movement energy of the bike
F we push on the pedals which makes the bike move but there is no energy transferred to the bike

G ______________________________

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6 When we hear a sound, the sound comes from the object into our ears where it is converted into electrical energy which the brain can interpret.

TRUE/FALSE

A convert sound energy into electric current and the brain interprets these electrical signals

B sound passes to brain where the sound waves (energy) are interpreted

C vibrations move the eardrum and then the vibrations pass into the brain

D sound waves pass through the ear to the brain

E ____

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7 Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE

A all food has the same energy but in different amounts

B different food groups have different amounts of energy with the same type of energy in foods

C each food has a number of different types of energy in it and each of these are in different amounts

D we carry out different types of activities and so these activities need different types of energy to occur

E ____

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8 We get energy the body can use from a number of sources. Some of these sources are food, sleep, air, light, sound and heat

TRUE/FALSE

A we only get useable energy from our food
B we get useable energy from food, air and sleep not the others that are listed
C these are only some of the ways our body can get useable energy into it
D we only get useable energy when we are exercising or being active
E we do not get useable energy from our surroundings
F we only get useable energy from respiration

G ______________________________

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9 Respiration is the process in which the energy in food is converted into useable energy.

TRUE/FALSE

A respiration is breathing and has little to do with energy
B respiration is the taking in of energy from food during its passage through the gut
C respiration is the filtering out of bad energy and storing and using good energy
D digestion is how we get energy not respiration
E respiration is where the energy in food molecules is converted into useable energy
F ______________________________

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10 Heat is released as a by-product of all chemical reactions that occur in the body.

TRUE/FALSE

A we only get hot when we do exercise or we are active not at other times
B we only get hot when we sweat
C we get heat from our surroundings because that is hot
D heat is a type of energy and when we are active we use up this energy so no energy is left
E get the heat from jumpers and clothes
F heat is from the friction of the blood flowing around the body
G ______________________________

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11 Excess heat in the body needs to be removed, this occurs in a number of ways one of which is by the evaporation of sweat.

TRUE/FALSE

A heat particles are removed when we sweat
B heat is removed from the skin by convection currents and radiation not evaporation
C it is the air moving over our skin that makes us cool
D heat is evaporated away from the skin
E the process of sweating cools us down not evaporation

F ______________________________

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12 Respiration occurs within the cells and results in the production of useable energy.

TRUE/FALSE

A cells change food into energy
B respiration is breathing and supplies oxygen not energy
C it is digestion that produces the energy the body needs from the food we eat
D respiration is where “food” molecules are broken down to release energy
E respiration is taking the energy from the digested food

F ____

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13 When we see an object, light comes from the object into our eyes where it is converted into electrical energy which the brain can use.

TRUE/FALSE

A light energy transfers the image to brain
B the eye captures the image and then the brain receives that image
C eyes can't receive energy from the surroundings
D energy goes into the eye, to the retina and then to the brain via the optic nerve
E the eye focuses on the tree and its image is passed to the brain

F ____

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14 Any excess energy in the food we eat is destroyed.

TRUE/FALSE

A we don’t absorb the excess energy but excrete it
B energy is taken into the body and stored in fat for use later
C unused energy is absorbed and then it is destroyed if there is too much of it
D we cannot destroy the energy we absorb so we store it in the body as fat so it is out of the way
E there is no excess energy as we use it all up

F ____

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APPENDIX 11

TWO TIER DIAGNOSTIC INSTRUMENT (BLUE)

ENERGY AND YOUR OWN BODY

INSTRUCTIONS
Your task is to say whether or not the statement is true or false. Which ever your choice is, please CIRCLE the true or the false.

When you have done this, you should chose one of the reasons that best matches your reason for saying true or false and CIRCLE the letter for this reason. If none of the reasons offered is suitable then use the lined space to put your own reason in. Remember it is important to select a reason. If you do not agree with the reasons given, please supply your own reason in the space provided.

This test only deals with energy and the human body and what is involved in this. Do not consider other processes when answering these questions.

THIS TEST DOES NOT COUNT TOWARDS YOUR ASSESSMENT

1 Food is a source of chemical energy for the body and this energy is found inside the food molecules.

TRUE/FALSE

A energy is found as little bundles between the food particles
B energy is found as little bundles inside the food particles
C energy is in the chemical bonds of the food molecules
D energy is both in between the food molecules and inside the food molecules
E energy is transformed from the food molecules

F ____

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2 Digestion does not release energy the body can utilise.

TRUE/FALSE

A energy is released from food during digestion
B digestion converts food molecules into energy
C digestion filters the energy out of the food
D energy is produced elsewhere in the body
E energy in food is converted in the body cells but not by digestion
F digestion uses energy not produces it.

G ______________________________

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3 When we eat too much food the body only takes in the energy it needs and excretes the rest.

TRUE/FALSE

A we absorb all the energy and the excess energy is excreted
B unused energy is destroyed
C not all the excess energy is destroyed some is stored as fat or excreted
D unused energy is stored as fat and used later if it is needed
E unused energy turned to fat which cannot be used later
F unused energy is turned into fat and used later
G ______________________________

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4 Sense organs such as the eye and the ear convert the different types of energy into electrical energy (action potential) the brain can use.

TRUE/FALSE

A the sound or light these organs receive goes straight from the ear or eye to the brain which then decodes the message
B light and sound are not energy so there are no conversions needed
C the eye or ear helps transfer the light or sound energy to the brain where it is translated
D the light or sound energy transfers the image or sound to the brain
E seeing and hearing has nothing to do with energy transfer

F ____

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5 Digested food is absorbed into the body and this digested food can then be used by the body in a number of different processes, one of which is respiration which produces useable energy.

TRUE/FALSE

A digestion produces the energy we need from our food and we absorb this energy
B we only use food for energy nothing else
C food is "burnt" with air to produce the energy our body uses
D respiration is breathing and does not involve energy
E respiration is breathing and this does not produce energy but uses it
F food is changed into movement energy in the muscles

G ____

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6 Respiration is the set of chemical reactions which result in the changing of energy in the absorbed food into chemical energy the cells can use.

TRUE/FALSE

A respiration is breathing and supplies oxygen not energy
B digestion produces the energy the body needs from the food we eat
C respiration uses energy it does not produce it
D respiration is when fats are converted into energy
E body turns food into energy
F respiration is the process for converting energy in food into useable energy

G ____

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7 Fats (lipids) are used by the body as an energy store and they can be used later when the body is running low on energy.

TRUE/FALSE

A we store fat but we cannot use this fat for energy at some later time
B energy is changed into fat to be stored and used later
C excess energy is not changed into fat but is either destroyed or excreted
D we store the excess energy in the bonds of the fat for use later
E fat people are less energetic therefore they do not use it later
F there is no excess energy as we only absorb what we need
G ____

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8 When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE

A bicycles can't use human energy
B a bicycle is not living therefore it does not get or need energy
C we use energy up not transfer it
D the bicycle creates its own energy
E the bicycle does not consume energy
F our energy makes the pedals etc move so the bicycle moves
G ____

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9 The ear converts sound energy into electrical energy (action potentials) the brain can use.

TRUE/FALSE

A sound energy is transferred straight to the brain which uses this to “hear”
B the sound energy transfers the noise to the brain.
C eyes don’t receive energy from our surroundings
D seeing has nothing to do with energy transfer because sound is not energy
E ears don’t receive energy from our surroundings
F hearing has nothing to do with energy transfer
G ____

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10 A number of regions of the body receive energy from the environment. Some of these regions are the eyes, ears, skin, lungs and gut.

TRUE/FALSE

A we only take in energy in our food
B we get energy from food, air and sleep not the others
C these are only some of the ways our body can get energy into it, there are more
D we only get energy when we are exercising or being active
E we do not get energy from our surroundings
F we only get energy from respiration

G ____

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11 During sleep our body produces more energy than it uses up and so our energy levels are restored back to normal.

TRUE/FALSE

A we do not get any energy when we are asleep
B we do not use as much energy as we produce when we are sleeping
C we do not digest food when we are asleep so we get no more energy
D we use energy when we are asleep so we do not restore our energy levels
E we are not active and so do not get or use any energy that we can store

F ____

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12 We have an average body temperature of about 37°C which is often higher than our surroundings.

TRUE/FALSE

A we get heat energy from the chemical reactions in our body and this gives us our body temperature
B the blood flowing (friction) and heart beating give us our body temperature
C viruses raise our body temperature
D energy is burned to give heat and hence our body temperature
E we get our heat from the clothes we wear; for example, jumpers
F we are not hotter than our surroundings
G ____

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13 The evaporation of sweat cools the body down.

TRUE/FALSE

A the air or wind coming in contact with the water in sweat cools us down
B sweating does not cool us down (it just disappears into the air)
C sweat cools us down by taking the heat with it as it leaves the skin surface
D heat energy is taken from the body so the water can evaporate
E heat particles are removed along with the water when we sweat
F air passing over our skin cools us down not evaporation
G ____

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14 When we eat too much food the body only takes in the food energy it needs and excretes the rest.

TRUE/FALSE

A unused energy is absorbed and is turned into fat and can be used later
B food that is not needed goes straight through the gut and is excreted
C some energy is stored, we use some and the rest goes out of the body
D excess energy is stored as fat which is a reserve supply of energy
E unused energy is passed out as waste
F energy does not pass out of body but is stored & turns to fat
G ____________________

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15 The eye converts light energy into electrical energy (action potentials) the brain can use to help us see.

TRUE/FALSE

A light energy is transferred straight to the brain which uses this energy to "see"
B light burns an image on the retina which then transfers this image to the brain
C light is reflected onto the retina and transmitted to the brain for use
D the reflected light from the object is converted by the eye into electrical energy which is transmitted to the brain.
E eyes don't receive energy from our surroundings
F seeing has nothing to do with energy transfer

G ____________________

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APPENDIX 12

PERCENTAGE SCORES FOR TRIAL DIAGNOSTIC INSTRUMENTS

PERCENTAGE BLUE INSTRUMENT

		TRUE	FALSE	X	A	B	C	D	E	F	G	Total
Quest 1	8	95.8	4.2		4.1	25	20.8	37.5	41.7			24
	9	84.1	15.9		6.8	15.9	22.7	11.3	40.9	4.5		44
T C	10	91.6	6.2	2.1	4.1	25	33.3	27	45.8			48
Quest 2	8	33.3	66.6		29.1	41.6	16.6	8.3	4.2	12.5	4.2	24
	9	30.2	69.7		18.6	9.3	23.2	16.2	18.6	18.6	2.3	43
T E	10	35.4	60.4	4.1	31.2	12.5	20.8	4.1	16.6	16.6		48
Quest 3	8	70.8	29		33.3	12.5	41.6	37.5	4.1	16.6		24
	9	50	50		15.9	2.2	34	29.5	9	15.9		44
F D	10	58.3	37.5	4.1	12.5		33.3	35.4	8.3	8.3		48
Quest 4	8	60.8	34.7	4.3	65.2	17.3	39.1	26	8.6			23
	9	72.7	27.2		38.6	6.8	20.4	18.1	15.9			44
T F	10	66.6	31.2	2	33.3	6.2	27	37.5	4.1	2		48
Quest 5	8	65.2	34.7		47.8	17.3	13	17.3	39.1	26		23
	9	52.2	47.7		36.3	4.5	2.2	13.6	34	13.6		44
T C	10	55.3	40.4	4.2	36.1	21.2	4.2	12.7	27.6	8.5		47
Quest 6	8	36.3	59	4.5	50	9	36.3	18.1	18.1	9		22
	9	63.6	36.3		43.1	6.8	13.6	11.3	11.3	9.1		44
T F	10	58.3	38.5	2	35.4	8.3	22.9	8.3	33.3	8.3		48
Quest 7	8	86.3	13.6		22.7	45.4	4.5	27.2	18.1	13.6		22
	9	50	50		30.9	11.9	23.8	19	4.7	11.9		42
T D	10	65.9	29.7	4.2	31.9	29.7	10.6	21.2	14.8	2.1		47
Quest 8	8	40.9	59.1		27.2	27.2	22.7	36.3	13.6	45.4		22
	9	56.8	43.1		22.7	4.5	13.6	18.2	22.7	29.5		44
T F	10	43.7	54.1	2	20.8	10.4	8.3	12.5	12.5	43.7	2	48
Quest 9	8	72.7	27.2		68.1	40.9	4.5	4.5	13.6	4.5		22
	9	61.3	38.6		43.1	11.3	15.9	2.2	4.4	18.1		44
NOT USE	10	68.7	29.1	2	43.7	29.1	6.2	8.3	6.2	6.2		48
Quest 10	8	52.3	47.6		23.8	33.3	38.1	14.2	19	14.2		21
	9	48.7	51.2		24.3	14.6	26.8	29.2	4.9			41
T G	10	52	45.8	2.1	16.6	33.3	29.1	8.3	18.7	8.3		48

Quest 11	8	85.7	14.2		28.5	57.1	14.2	28.5	9.5			21
	9	79	21		21	25.5	9.3	18.6	9.3	9.3		43
T B	10	70.8	25	4.1	22.9	35.4	10.4	22.9	12.5	8.3		48
Quest 12	8	60.8	39.1		47.8	43.4	30.4	26.1	30.4			23
	9	56.4	43.5		25.6	20.5	23.1	25.6	10.3	2.5	2.5	39
T A	10	63.8	34.0	2.1	31.9	23.4	10.6	25.5	12.7	8.5		47
Quest 13	8	86.9	13.1		65.2	13	34.7	26		8.6		23
	9	70	30		20	7.5	30	12.5	25	10	2.5	40
T D	10	62.5	35.4	2.1	31.2	20.8	25	8.3	18.7	14.5	2.1	48
Quest 14	8	54.5	40.9	4.5	59.1	18.1	45.4	22.7	18.1	13.6		22
	9	57.8	36.8	5.2	18.4	7.8	13.1	26.3	10.5	21		38
F A	10	58.3	39.6	2.1	31.2	12.5	22.9	29.1	8.3	16.6		48
Quest 15	8	86.3	13.6		63.6	27.2	27.2	18.1	18.1	13.6		22
	9	58.9	41.1		20.5	2.5	15.3	23	20.5	23		39
T D	10	63.8	31.9	4.2	29.7	25.5	14.8	29.7	14.8	4.2		47

PERCENTAGE WHITE INSTRUMENT

		TRUE	FALSE	X	A	B	C	D	E	F	G	Total
Quest 1	8	60.8	39.1		34.7	13	8.6	43.4	43.4			23
	9	75.7	21.2	3	54.5	6	3	15.1	18.1			33
T E	10	74.2	20	5.7	37.1	8.5	2.8	20	48.5			35
Quest 2	8	12.5	87.5		62.5	16.6	41.6	8.3	20.8	4.1	4.1	24
	9	60.6	39.3		18.1	6	9.1	9.1	9.1	30.3	6	33
T G	10	35.2	58.8	5.8	26.7	5.8	17.6	11.7	8.8	2.9		34
Quest 3	8	70.8	29.1		54.1	8.3	20.8	4.1	41.6	12.5		24
	9	51.5	45.4	3	24.2	3	12.1	27.2	24.2	15.1		33
T G	10	60.6	33.3	6	9.1	3	24.2	24.2	27.2	12.1		34
Quest 4	8	83.3	16.6		25	50	12.5	33.3	8.3			24
	9	74.1	25.8		16.1	25.8	12.9	12.9	9.6	12.9		31
T D	10	76.4	17.6	2.9	20.5	20.5	2.9	50	2.9		2.9	34
Quest 5	8	47.6	56.5		43.4	39.1	26	47.8	17.3	13		23
	9	63.6	33.3	3	18.1	9.1		30	24.2	3		33
T E	10	58.8	35.2	5.8	5.8		2.9	20.5	50	14.7		34
Quest 6	8	66.6	29.1	4.1	45.3	29.2	41.7	25	16.7			24
	9	62.5	37.5		37.5	18.7	18.7	6.2	9.3			32
T A	10	79.4	14.7	5.8	35.2	26.4	26.4	11.7	2.9			34
Quest 7	8	62.5	37.5		33.3	20.8	58.3	12.5				24
	9	75	25		12.5	18.7	37.5	25	3.1			32
F A/B	10	73.5	20.5	5.8	8.8	20.5	47	17.6	5.8			34
Quest 8	8	66.6	29.1	4.1	16.6	33.3	45.8	12.5	12.5			24
	9	68.7	28.1	3.1	6.2	28.1	9.3	9.3	21.8	9.3	3.1	32
F G	10	39.3	51.5	9	12.1	30.3	33.3	15.1		6		33
Quest 9	8	12.5	83.3	4.2	70.8	8.3	8.3	20.8				24
	9	43.8	53.1	3.1	31.3	15.6	12.5	9.4	21.9	3.1		32
T E	10	45.5	45.5	9.1	39.4	18.2	18.2	6.1	12.1	3		33
Quest 10	8	56.5	34.8	8.7	30.4	13	30.4	21.7	17.4	26.1		23
	9	56.7	40.	3.3	20	20	16.7	23.3		6.7		30
T G	10	67.6	26.5	5.9	14.7		14.7	20.6	20.6	29.4	2.9	34

Quest 11	8	58.3	37.5	4.1	20.8	8.3	29.1		45.8			24
	9	54.8	41.9	3.2	25.8	9.6	29	9.6	16.1			31
T F	10	61.7	32.3	5.8	35.2	17.6	23.5		32.3	8.8		34
Quest 12	8	20.8	73.9	4.3	21.7	56.5	26.1	8.7	8.7			23
	9	50	46.6	3.3	16.6	36.6	13.3	10	16.6			30
T A	10	35.2	58.8	5.8	11.7	41.1	11.7	5.8	23.5			34
Quest 13	8	77.2	22.7		40.9	27.2	4.5	40.9	22.7			22
	9	62	34.4	3.4	27.5	20.6	20.6	13.7	10.3	3.4		29
T D	10	50	44.1	5.8	35.2	5.8	26.4	29.4	11.7			34
Quest 14	8	13.6	86.3		31.8	13.6	22.7	18.1	22.7			22
	9	23.3	73.3	3.3	26.6	33.3	3.3	10	13.3			30
F B	10	30.3	63.6	6	30.3	42.4	6	9.1	12.1	3		33

NOTE: under each question number is a pair of letters beginning with T or F. These are the correct responses for that question

PAPPENDIX 13

PERCENTAGE SCORES FOR DIAGNOSTIC TRIAL INSTRUMENTS

PERCETNAGE SCORES BLUE INSTRUMENT

		TRUE	FALSE	X	A	B	C	D	E	F	G	Total
Quest 1	8	95.8	4.2		4.1	25	20.8	37.5	41.7			24
	9	84.1	15.9		6.8	15.9	22.7	11.3	40.9	4.5		44
T C	10	91.6	6.2	2.1	4.1	25	33.3	27	45.8			48
Quest 2	8	33.3	66.6		29.1	41.6	16.6	8.3	4.2	12.5	4.2	24
	9	30.2	69.7		18.6	9.3	23.2	16.2	18.6	18.6	2.3	43
T E	10	35.4	60.4	4.1	31.2	12.5	20.8	4.1	16.6	16.6		48
Quest 3	8	70.8	29		33.3	12.5	41.6	37.5	4.1	16.6		24
	9	50	50		15.9	2.2	34	29.5	9	15.9		44
F D	10	58.3	37.5	4.1	12.5		33.3	35.4	8.3	8.3		48
Quest 4	8	60.8	34.7	4.3	65.2	17.3	39.1	26	8.6			23
	9	72.7	27.2		38.6	6.8	20.4	18.1	15.9			44
T F	10	66.6	31.2	2	33.3	6.2	27	37.5	4.1	2		48
Quest 5	8	65.2	34.7		47.8	17.3	13	17.3	39.1	26		23
	9	52.2	47.7		36.3	4.5	2.2	13.6	34	13.6		44
T C	10	55.3	40.4	4.2	36.1	21.2	4.2	12.7	27.6	8.5		47
Quest 6	8	36.3	59	4.5	50	9	36.3	18.1	18.1	9		22
	9	63.6	36.3		43.1	6.8	13.6	11.3	11.3	9.1		44
T F	10	58.3	38.5	2	35.4	8.3	22.9	8.3	33.3	8.3		48
Quest 7	8	86.3	13.6		22.7	45.4	4.5	27.2	18.1	13.6		22
	9	50	50		30.9	11.9	23.8	19	4.7	11.9		42
T D	10	65.9	29.7	4.2	31.9	29.7	10.6	21.2	14.8	2.1		47
Quest 8	8	40.9	59.1		27.2	27.2	22.7	36.3	13.6	45.4		22
	9	56.8	43.1		22.7	4.5	13.6	18.2	22.7	29.5		44
T F	10	43.7	54.1	2	20.8	10.4	8.3	12.5	12.5	43.7	2	48
Quest 9	8	72.7	27.2		68.1	40.9	4.5	4.5	13.6	4.5		22
	9	61.3	38.6		43.1	11.3	15.9	2.2	4.4	18.1		44
NOT USE	10	68.7	29.1	2	43.7	29.1	6.2	8.3	6.2	6.2		48
Quest 10	8	52.3	47.6		23.8	33.3	38.1	14.2	19	14.2		21
	9	48.7	51.2		24.3	14.6	26.8	29.2	4.9			41
T G	10	52	45.8	2.1	16.6	33.3	29.1	8.3	18.7	8.3		48

Quest 11	8	85.7	14.2		28.5	57.1	14.2	28.5	9.5			21
	9	79	21		21	25.5	9.3	18.6	9.3	9.3		43
T B	10	70.8	25	4.1	22.9	35.4	10.4	22.9	12.5	8.3		48
Quest 12	8	60.8	39.1		47.8	43.4	30.4	26.1	30.4			23
	9	56.4	43.5		25.6	20.5	23.1	25.6	10.3	2.5	2.5	39
T A	10	63.8	34.0	2.1	31.9	23.4	10.6	25.5	12.7	8.5		47
Quest 13	8	86.9	13.1		65.2	13	34.7	26		8.6		23
	9	70	30		20	7.5	30	12.5	25	10	2.5	40
T D	10	62.5	35.4	2.1	31.2	20.8	25	8.3	18.7	14.5	2.1	48
Quest 14	8	54.5	40.9	4.5	59.1	18.1	45.4	22.7	18.1	13.6		22
	9	57.8	36.8	5.2	18.4	7.8	13.1	26.3	10.5	21		38
F A	10	58.3	39.6	2.1	31.2	12.5	22.9	29.1	8.3	16.6		48
Quest 15	8	86.3	13.6		63.6	27.2	27.2	18.1	18.1	13.6		22
	9	58.9	41.1		20.5	2.5	15.3	23	20.5	23		39
T D	10	63.8	31.9	4.2	29.7	25.5	14.8	29.7	14.8	4.2		47

PERCETNAGE SCORES WHITE INSTRUMENT

		TRUE	FALSE	X	A	B	C	D	E	F	G	Total
Quest 1	8	60.8	39.1		34.7	13	8.6	43.4	43.4			23
	9	75.7	21.2	3	54.5	6	3	15.1	18.1			33
T E	10	74.2	20	5.7	37.1	8.5	2.8	20	48.5			35
Quest 2	8	12.5	87.5		62.5	16.6	41.6	8.3	20.8	4.1	4.1	24
	9	60.6	39.3		18.1	6	9.1	9.1	9.1	30.3	6	33
T G	10	35.2	58.8	5.8	26.7	5.8	17.6	11.7	8.8	2.9		34
Quest 3	8	70.8	29.1		54.1	8.3	20.8	4.1	41.6	12.5		24
	9	51.5	45.4	3	24.2	3	12.1	27.2	24.2	15.1		33
T G	10	60.6	33.3	6	9.1	3	24.2	24.2	27.2	12.1		34
Quest 4	8	83.3	16.6		25	50	12.5	33.3	8.3			24
	9	74.1	25.8		16.1	25.8	12.9	12.9	9.6	12.9		31
T D	10	76.4	17.6	2.9	20.5	20.5	2.9	50	2.9		2.9	34
Quest 5	8	47.6	56.5		43.4	39.1	26	47.8	17.3	13		23
	9	63.6	33.3	3	18.1	9.1		30	24.2	3		33
T E	10	58.8	35.2	5.8	5.8		2.9	20.5	50	14.7		34
Quest 6	8	66.6	29.1	4.1	45.3	29.2	41.7	25	16.7			24
	9	62.5	37.5		37.5	18.7	18.7	6.2	9.3			32
T A	10	79.4	14.7	5.8	35.2	26.4	26.4	11.7	2.9			34
Quest 7	8	62.5	37.5		33.3	20.8	58.3	12.5				24
	9	75	25		12.5	18.7	37.5	25	3.1			32
F A/B	10	73.5	20.5	5.8	8.8	20.5	47	17.6	5.8			34
Quest 8	8	66.6	29.1	4.1	16.6	33.3	45.8	12.5	12.5			24
	9	68.7	28.1	3.1	6.2	28.1	9.3	9.3	21.8	9.3	3.1	32
F G	10	39.3	51.5	9	12.1	30.3	33.3	15.1		6		33
Quest 9	8	12.5	83.3	4.2	70.8	8.3	8.3	20.8				24
	9	43.8	53.1	3.1	31.3	15.6	12.5	9.4	21.9	3.1		32
T E	10	45.5	45.5	9.1	39.4	18.2	18.2	6.1	12.1	3		33
Quest 10	8	56.5	34.8	8.7	30.4	13	30.4	21.7	17.4	26.1		23
	9	56.7	40.	3.3	20	20	16.7	23.3		6.7		30
T G	10	67.6	26.5	5.9	14.7		14.7	20.6	20.6	29.4	2.9	34

Quest 11	8	58.3	37.5	4.1	20.8	8.3	29.1		45.8				24
	9	54.8	41.9	3.2	25.8	9.6	29	9.6	16.1				31
T F	10	61.7	32.3	5.8	35.2	17.6	23.5		32.3	8.8			34
Quest 12	8	20.8	73.9	4.3	21.7	56.5	26.1	8.7	8.7				23
	9	50	46.6	3.3	16.6	36.6	13.3	10	16.6				30
T A	10	35.2	58.8	5.8	11.7	41.1	11.7	5.8	23.5				34
Quest 13	8	77.2	22.7		40.9	27.2	4.5	40.9	22.7				22
	9	62	34.4	3.4	27.5	20.6	20.6	13.7	10.3	3.4			29
T D	10	50	44.1	5.8	35.2	5.8	26.4	29.4	11.7				34
Quest 14	8	13.6	86.3		31.8	13.6	22.7	18.1	22.7				22
	9	23.3	73.3	3.3	26.6	33.3	3.3	10	13.3				30
F B	10	30.3	63.6	6	30.3	42.4	6	9.1	12.1	3			33

NOTE: under each question number is a pair of letters beginning with T or F. These are the correct responses for that question

APPENDIX 14

FINAL TWO TIER DIAGNOSTIC INSTRUMENT

ENERGY AND THE HUMAN BODY

INSTRUCTIONS
Your task is to say whether or not the statement at the beginning of each item is true or false. Which ever your choice is, please CIRCLE the true or the false.

When you have done this, you should chose one of the reasons that best matches your reason for saying true or false and CIRCLE the letter for this reason. If none of the reasons offered is suitable then use the lined space to write your own reason.
Remember it is important to give a reason. If your reason does not agree with any of the reasons given, please supply your own reason in the space provided.

This test only deals with energy and the human body and what is involved in this. Do not consider other processes when answering these questions.

THIS TEST DOES NOT COUNT TOWARDS YOUR ASSESSMENT

1 Food is a source of chemical energy for the body and this energy is found inside the food molecules.

TRUE/FALSE

A energy is found as little bundles between the food particles
B energy is found as little bundles inside the food particles
C energy is in the chemical bonds of the food molecules
D energy is both in between the food molecules and inside the food molecules
E energy is transformed from the food molecules

F ____

2 Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE

A each food has the same type of energy and the same amounts of this energy
B different food groups have different amounts of energy with the same type of energy in foods
C each food has a number of different types of energy in it and each of these is in different amounts
D we carry out different types of activities and so these activities need different types of energy to occur

E ____

3 We get energy the body can use from a number of sources. Some of these sources are food, sleep, air, light, sound and heat

TRUE/FALSE

A we only get useable energy from our food
B we get useable energy from food, air and sleep not the others that are listed
C these are only some of the ways our body can get useable energy into it
D we only get useable energy when we are exercising or being active
E we do not get useable energy from our surroundings
F we only get useable energy from respiration
G ____

4 When we eat too much food the body only takes in the energy it needs and excretes the rest.

TRUE/FALSE

A we absorb all the energy and the excess energy is excreted
B unused energy is destroyed
C not all the excess energy is destroyed some is stored as fat or excreted
D unused energy is stored as fat and used later if it is needed
E unused energy turned to fat which cannot be used later
F unused energy is turned into fat and used later
G ____

5 Energy may be stored in the body for later use. Fat (lipids) is one such chemical which is used for energy storage.

TRUE/FALSE

A we store fat but we cannot use this fat for energy at some later time
B energy is changed into fat to be stored
C excess energy is not changed into fat
D we store the excess energy in the bonds of the fat
E there is no excess energy as we only absorb what we need
F there is no left over energy as we use all we take in
G ____

6 Digestion does not release energy the body can utilise.

TRUE/FALSE

A energy is released from food during digestion
B digestion converts food molecules into energy
C digestion filters the energy out of the food
D energy is produced elsewhere in the body
E energy in food is converted in the body cells but not by digestion
F digestion uses energy not produces it.
G ____

7 Blood transports molecules of food around the body so the cells can take these molecules in and use them as a source of energy.

TRUE/FALSE

A we absorb the energy produced by the digestion of food and the blood carries this energy around our body to where it is needed
B blood circulating gives us energy
C blood is unable to support or carry excess energy
D blood carries oxygen around the body not the energy
E blood carries the sugars around the body for the cells to absorb which they can then use to make energy
F____

8 Heat is released as a by-product of all chemical reactions that occur in the body.

TRUE/FALSE

A we only get hot when we do exercise or we are active not at other times
B we only get hot when we sweat
C we get heat from our surroundings because that is hot
D heat is a type of energy and when we are active we use up this energy so no energy is left
E get the heat from jumpers and clothes
F heat is from the friction of the blood flowing around the body
G ____

9 Respiration can use food molecules such as glucose (and other sugars), fats and proteins to produce useable energy (ATP).

TRUE/FALSE

A respiration is breathing
B fats are unable to be used for energy but sugars are
C energy is released by digestion not respiration
D we get our energy when we are active (like exercising) not from food
E respiration burns energy not create it
F respiration is the process of making all food components into useable energy
G ____

10 Sense organs such as the eye and the ear convert the different types of energy into electrical energy (action potential) the brain can use.

TRUE/FALSE

A the sound or light these organs receive goes straight from the ear or eye to the brain which then decodes the message
B light and sound are not energy so there are no conversions needed
C the eye or ear helps transfer the light or sound energy to the brain where it is translated
D the light or sound energy transfers the image or sound to the brain
E seeing and hearing has nothing to do with energy transfer
F____

11 During sleep our body produces more energy than it uses up and so our energy levels are restored back to normal.

TRUE/FALSE

A we do not get any energy when we are asleep
B we do not use as much energy as we produce when we are sleeping
C we do not digest food when we are asleep so we get no more energy
D we use energy when we are asleep so we do not restore our energy levels
E we are not active and so do not get or use any energy that we can store

F ____

12 Fats (lipids) are used by the body as an energy store and they can be used later when the body is running low on energy.

TRUE/FALSE

A we store fat but we cannot use this fat for energy at some later time
B energy is changed into fat to be stored and used later
C excess energy is not changed into fat but is either destroyed or excreted
D we store the excess energy in the bonds of the fat for use later
E fat people are less energetic therefore they do not use it later
F there is no excess energy as we only absorb what we need
G ____

13 We have an average body temperature of about 37^{o}C which is often higher than our surroundings.

TRUE/FALSE

A we get heat energy from the chemical reactions in our body and this gives us our body temperature
B the blood flowing (friction) and heart beating give us our body temperature
C viruses raise our body temperature
D energy is burned to give heat and hence our body temperature
E we get our heat from the clothes we wear; for example, jumpers
F we are not hotter than our surroundings
G ____

14 Excess heat in the body needs to be removed, this occurs in a number of ways one of which is by the evaporation of sweat.

TRUE/FALSE

A heat particles are removed when we sweat
B heat is removed from the skin by convection currents and radiation not evaporation
C it is the air moving over our skin that makes us cool
D heat is evaporated away from the skin
E the process of sweating cools us down not evaporation
F ____

15 Any excess energy in the food we eat is destroyed.

TRUE/FALSE

A we don't absorb the excess energy but excrete it
B energy is taken into the body and stored in fat for use later
C unused energy is absorbed and then it is destroyed if there is too much of it
D we cannot destroy the energy we absorb so we store it in the body as fat so it is out of the way
E there is no excess energy as we use it all up
F ____

16 When we eat too much food the body only takes in the food energy it needs and excretes the rest.

TRUE/FALSE

A unused energy is absorbed and is turned into fat and can be used later
B food that is not needed goes straight through the gut and is excreted
C some energy is stored, we use some and the rest goes out of the body
D excess energy is stored as fat which is a reserve supply of energy
E unused energy is passed out as waste
F energy does not pass out of body but is stored & turns to fat
G ____

17 When we ride a bicycle, some of our energy is transferred to the bicycle.

TRUE/FALSE

A the bike is not living and so cannot use or have energy
B we use energy up not transfer it to the bike
C bike makes its own energy
D use energy to move the pedals but no energy is transferred to the bike
E our leg movement energy is transferred to the bike and becomes the movement energy of the bike
F we push on the pedals which makes the bike move but there is no energy transferred to the bike
G bicycles can't use human energy
H we use energy up not transfer it
G ____

SUPPLEMENTAL ITEMS

1s When we hear a sound, the sound comes from the object into our ears where it is converted into electrical energy which the brain can interpret.

TRUE/FALSE

A convert sound energy into electric current and the brain interprets these electrical signals
B sound passes to brain where the sound waves (energy) are interpreted
C vibrations move the eardrum and then the vibrations pass into the brain
D sound waves pass through the ear to the brain
E ______________________________

2s When we see an object, light comes from the object into our eyes where it is converted into electrical energy which the brain can use.

TRUE/FALSE

A light energy transfers the image to brain
B the eye captures the image and then the brain receives that image
C eyes can't receive energy from the surroundings
D energy goes into the eye, to the retina and then to the brain via the optic nerve
E the eye focuses on the tree and its image is passed to the brain
F ______________________________

3s The evaporation of sweat cools the body down.

TRUE/FALSE

A the air or wind coming in contact with the water in sweat cools us down
B sweating does not cool us down (it just disappears into the air)
C sweat cools us down by taking the heat with it as it leaves the skin surface
D heat energy is taken from the body so the water can evaporate
E heat particles are removed along with the water when we sweat
F air passing over our skin cools us down not evaporation
G ______________________________

APPENDIX 15
GETTING ENERGY

Pre-test questionnaire and essay

Describe in detail how a cell obtains energy so it can carry out its function(s). For example, explain how a muscle cell get the energy needed so it can contract and so help us move. In this description start with getting energy into the body.

Write out the meaning (in your own words) of any new word or term that you come across during this section of work. To do this set up a vocabulary or terminology page if you haven/t already got one. This will help you understand and remember what you are doing.

You will have made an outline of the human body and placed various organs of the body on it. Now we are going to look at the digestive system n more detail as a start to looking at the movement of energy into, through and out of the human body.

Collect a diagram of the digestive system and label the following part: mouth, oesophagus, stomach, duodenum, small intestine, large intestine, rectum, anus. [Also label the liver, pancreas teeth appendix.]

Class discussion on the function of each section of the digestive tract (not actual processes in detail but what occurs).

Library Research/Teacher Input
Draw a diagram of each of the following molecules. You will need to either go to the library or your teacher will put them on the overhead projector.

- *Glucose, or fructose or maltose*
- *Any two amino acids and a diagrammatic representation of a protein*
- *Fat or oil (just show the glycerol and fatty acids, there is no need to show all of the atoms present unless you wish to)*
- *Water*
- *Minerals such as calcium, sodium, potassium, chloride and hydrogen carbonate (or bicarbonate) ions.*

What are the two main things or components in each of the molecules you have drawn? Could there be any other things in these molecules? If so what are they?

Now label each of these diagrams so you point out which parts of each molecule are the atoms, the bonds and empty space. Colour may be helpful in distinguishing each of the parts and where they are.

Collect a molecule construction kit for your group. As a group, make up molecules of glucose, an amino acid and a lipid (only one molecule of each per group is needed). Use your drawings as models to help you build these molecules. The models will give you an idea of what the molecules look like in 3D.

Now go back to the questions above and change any answers you think may need changing.

These molecules you have drawn and made are all found in food.

Why do we eat food? Make a list of all your reasons for eating food. Make a list of things the body can use food for.

FOOD DESCRIPTION

Briefly describe how you get energy from the food you eat. Start from when you take a bite of the food.

Discussion of food groups and why each is important to a human.

What food groups and/or molecules from each food group would you expect to find in a bite of buttered bread?

Now look at the molecules you have drawn above. Answer the following questions by imagining you could look at your bite of buttered bread and you can see the molecules.

What things such as the elements, bonds and other things are found in the buttered bread? Where do you think the energy is in this bite of food is? (This bite of food has quite a lot of energy in it)

Now you will carry out a modelling exercise of the processes food goes through from being eaten until the energy in it is ready for use by the body's cells and any unused or left over material is excreted. Remember food may be used for a number of things by the body only one of which is as an energy source.

FOOD "PROCESSING"

Read your responses to the work on "Food Intake". Add or adjust any answers that you think may need changing in some way. Use different coloured ink for this (just so you can follow the changes you may make).

Now discuss these answers from "Food Intake" with your partners. In different coloured ink adjust any of your answers you now disagree with.

When you and your partners are satisfied with your answers (remember you may agree to disagree) continue on with this work. Don't forget to check and adjust your vocabulary or terminology list as well.

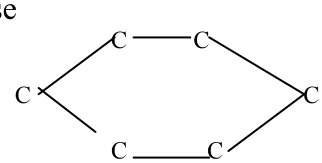
Food Digestion

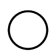
Collect a container from the tray your teacher has.

The contents of the container represent a bite of the buttered bread (you described above) and you have chewed up before swallowing.

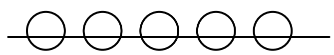
The following shapes found in the container, are used to represent some of the molecules and ions that are present in your bite of food (but they are not to scale).

glucose

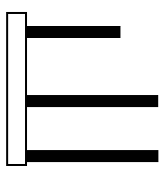


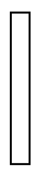
Amino acid 

Chain of amino acids

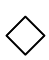


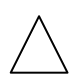
Lipid



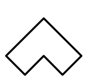
with  glycerol

 Fatty acids

Minerals 

Vitamins 

Water



Your task now will be to carry out the process of ingestion, digestion, absorption and then the transportation of the "food" to the cells of the body.

What size do the molecules of food have to be before they can be absorbed into the body?

Now break up the bite of food (food bolus) into its compounds. As you separate each molecule from the food bolus break it into the smallest pieces you can by pulling them apart. For example, break a protein into its amino acids, lipids into glycerol and fatty acids and starch if present into glucose molecules. (There are other molecules in the bread and butter but we are not going to deal with these again.)

What part of digestion do you represent in this model of digestion?

This breaking up of larger molecules into smaller ones is similar to the action of chewing and the action of the digestive enzymes that break up the food in the stomach and small intestine.

When digesting has been completed the food is ready for absorption into the body.

You can only absorb smallish molecules. In this case these molecules are glucose, amino acids, glycerol, fatty acids, minerals and water. Some of these molecules may appear large in our modelling process but in real life they are small enough to pass across the cell wall and gut wall. Vitamins are actively picked up by the cells lining the gut wall and then transferred to the blood capillaries near the gut cells. They are then distributed to the body cells where they may be needed.

Not all of the food you eat is absorbed because it cannot be fully digested. What is this undigested food called when you eat it? What happens to this undigested food?

In your body, (the real situation) describe what happens to the food bolus before it can be absorbed into the body?

Food Absorption

Collect a piece of chalk and some glue from your teacher.

Most of the absorptioon takes palce across the little ‘finger-like’ projections that cover the small intestine. These finger-like projections are called villi (singular is villus). They increase the surface area of the gut lining and so speed up the absorption of ether digested food.

On your desk draw the following diagram which is a labelled diagram of a villus. Make the drawing about 50 cm in length.

.

On this diagram you have drawn place the 'digested food' near the cells of the gut or villus wall.

All of the food except the lipid components is absorbed across the gut wall and into the blood capillaries found in each of the villus of the small intestine. The lipid components (of glycerol and fatty acids) are absorbed into the cells of the gut wall where lipids are re-formed. Reform the lipoids by gluing glycerol and fatty acids back together. These remade lipids pass directly into the lymph capillary of the villus. From the capillaries the absorbed food passes out of the villus to the body.

Carry out the process of absorption by sliding the 'food molecules' across into the capillaries and the on to the vein (which goes straight to the liver). Remember that only the lipids go into the lymph. They do not go into the blood capillaries.

By what process do the digested food particles move out of the gut into the capillaries of the villi? Describe in your own words what you have done (in this modelling process) to the 'food bolus' from taking a bit until it is available for the body to use. Describe what happens (in real life) to a bite of bread and butter until it arrives in the cells of the body for them to use. Now using textbooks and do the resources add more information to your description of digestion. When you are satisfied that you have a good accurate description of the digestion and absorption of the food write out a neat copy of this description (of digestion and absorption).

RESPIRATION

Since we have gone through the processes of digestion and absorption go back over all of your earlier work in answering the questions and change any answers you may feel need to be changed. Use another different coloured ink for this.

What do you think respiration means?

Respiration is also a term often used to describe the process of breathing and gas exchange. If you have given this as the meaning of respiration look for another meaning that involves energy and write that down in your notebook.

Energy that can be used by any cell of the body needs to be stored in a molecule that can move about and that can be used by any cellular process in the body that requires energy. This molecule is called ATP or the "universal energy molecule".

You will be breaking the paper molecules into smaller molecules of water and carbon dioxide and getting energy released (which you will use to form the universal molecule or ATP.

Respiration of Glucose

Collect model molecules of glucose and a lipid, some oxygen molecules, some phosphate ions and ADP molecules plus glue.

Brief discussion by teacher on the reactions that occur in respiration.

How did a glucose molecule get into a body cell from the food we have eaten? Briefly outline the steps involved. What things are present within this molecule of glucose? How do you think the cell gets the energy it needs from the absorbed food? Write out a word equation for respiration using glucose as the starting molecule. You may need to use a reference book to find this equation although you learnt about it in Year 8.

This word equation is a very simplified representation of what really happens during the process of respiration. You are now going to carry out a model of the process of respiration. (Remember the model is a rough copy of what actually occurs during the real process.) The real process involves lots of steps and is very complicate and is very difficult to model.

What are the reactants and the products of the equation of respiration you have written? What atoms in the reactant molecules do you think are combining with each other during the process of respiration to form the products? Where do you think the energy on the reactant side of the equation come?

Where do you think the energy is coming from that is produced by respiration?

Take you glucose molecule. You will need to twist and tear each bond joining two carbon atoms so that the bond is broken (try to keep the bond intact as you will use this bond to join the phosphate ion to ADP to form a new ATP molecule. This tearing will release the energy of the bond. (It takes energy to hold two atoms together and when the bond is broken that energy is releases). In the reactions for glucose respiration, the carbon atoms eventually join with oxygens to form carbon dioxide and the hydrogen joins with oxygen to form water. When you break a bond join the released carbon or hydrogen atom(s) to oxygen to form carbon dioxide or water. Do this joining by gluing carbon and oxygen or two hydrogen atoms to one oxygen atom to form the products of respiration (carbon dioxide O-C-O and water O-H-O).

At the same time as you break a carbon-carbon (C- C) bond, transfer that bond energy so you can use it to form ATP or "universal energy molecule" of ATP. Glue the phosphate to ADP (using the bond from the carbon-carbon bond) to make and ATP or universal energy molecule. In real life we do not get one ATP from each bond we break, but, a number of bonds will supply the energy required to form the ATP.

The process you have carried out is a respiration of a very complex process that results in the energy all cells of the body can use.

Continue to twist and break the bonds until you have broken up the glucose molecule and formed a number of carbon dioxides, waters and 'universal energy molecules'.

What happens to the carbon dioxide and water molecules made during the process of respiration?

Briefly describe what occurs to a molecule of glucose, as it is broken down to form carbon dioxide, water and the production of useable energy.

Go back to the beginning of this section on respiration and check your original answers and adjust them where necessary (use different coloured ink).

Respiration of Lipids

In modelling the respiration of lipids we will be following the same procedure which is very similar to that of glucose. In reality the respiration of lipids in a cell is a very different process. It still need bonds to be broken and carbon and hydrogen are joined to oxygen to form carbon dioxide and a water and the formation of the "universal energy molecule' ATP occurs.

With lipid respiration the fatty acid chains are removed from the glycerol first and then each carbon or hydrogen is removed and combines with oxygen to form carbon dioxide and water respectively and the energy released in breaking the bond is used to join phosphate to ADP to form ATP or "universal energy molecule".

Now collect a lipid molecule, oxygens, phosphates and ADPs.

Remove the fatty acids from the glycerol. Little energy is released in this bond breaking. To get energy, you will need to remove carbons and hydrogens by twisting and breaking bonds. Use the released energy from the carbon-carbon bonds to help ADP from ATP by joining a phosphate to the ADP. We do not get one ATP from each bond we break but a number of these bonds will supply the energy required to form the ATP.

> What happens to the carbon dioxides and water molecules formed from the process of lipid respiration?
>
> Briefly describe what occurs to a molecule of lipid as it is broken down to form carbon dioxide, water and the production of useable energy.

Summary
Go back over this work with your partners. Discuss what you have done and why.

As a group create a summary of what occurs to a glucose molecule in a piece of bread and butter you have just bitten of the slice of bread and butter from when it enters your mouth through to your removing the waste products form the cell.

Repeat this process for lipids.

> Where is the energy in the food you ate located?

This modelling process you have carried out should have helped you to see the processes involved in getting energy from food. If you are unsure about any part of this exercise discuss it with your teacher.

APPENDIX 16

The following table shows various data involving responses to a number of items from the two questionnaires titled *What do You Know About the Human Body*. The responses were held by only a small number of students within the total cohort and as such these results were not included within the text.

The numbers in the table are raw numbers to illustrate their small size while the numbers in brackets are the percentage of the total cohort of students who responded to the relevant item.

Notion	Year 8	Year 9	Year 10	Year 11	Year 12
Sense organs convert external energy into nervous impulse.	0 (0) n = 79	2 (2.9) n = 62	0 (0) n = 117	3 (7.1) n = 56	0 n = 43
Clothing contributes heat energy to the body	2 (6) n = 33	0 (2) n = 35	1 (0) n = 49	0 (0) n = 33	0 (0) n = 24
Friction of blood movement contributes heat energy to the body.	2 (6) n = 33	1 (1.4) n = 70	1 (0.9) n = 108	0 (0) n = 32	1 (2.2) n = 45

Note: n is total population of the year cohort who responded to the item(s) from which these notions were given as student reasons.