Brainstorming to concept maps: Developing ontological categories for energy

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A paper presented at the Australian Association for Research in Education (AARE) 2001 International Education Research Conference, Fremantle Australia

2nd- 6th December 2001.

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Abstract

Energy is an abstract concept that is poorly understood at the middle school level. Traditionally the use of imposed definitions and terminology, which have little relevance for students, has given the topic of energy a reputation for being boring and dry.

Students' preconceived understanding of the energy concept, derived from their own experiences was the starting point of this study. Students were required to analyse their own ideas on energy, brainstorm a variety of fields relating to the topic of energy and construct concept maps and Venn diagrams to represent their understanding. The schools' policy of integrating laptop computers in middle school provided additional tools to achieve the objectives of the science unit on energy. Guided development of students' schema from very specific examples to general categories helped to develop new ontological schema in the students' mental organisation of their knowledge and ideas relating to energy.

This constructivist approach formed the groundwork to the students learning processes which were dependent on the social interaction of students, students listening to each other, working as a team, the visual record, the linking of concepts and ideas, and the integration of new ideas with their existing ideas.

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Introduction

The concept of energy, which is common to all fields of science from living things to chemical reactions and physical events, has generated a wide range of acceptable definitions as well as many erroneous definitions. The position taken in the paper is that a constructivist approach to teaching energy, such as that recommended by Duit and Haeussler , can achieve a more meaningful learning and teaching experience. Subsequently, this paper describes the implementation of a constructivist teaching approach to the unit *Energy and Change* in which two desired outcomes were presented simultaneously: the development of students' information processing skills in gaining an understanding of what learning is about and an understanding of the energy concept. The research monitored the development of the students' understanding of the concept of energy along with the development of their analytical, presentation, communication and research skills in the processing of information.

The analysis of the learning process included identifying and evaluating the social/affective, ontological and epistemological aspects that contribute to meaningful learning. The study examined the conceptual change in students' understanding of the abstract concept of energy. The influence of the particular pedagogical strategy of making use of brainstorming and Venn diagrams in teaching energy is assessed . The correspondence of the ontological perspective of learning about energy with the pedagogical strategies of brainstorming and Venn diagrams are considered. This teaching strategy has a process and a subject matter component which both contribute to building the knowledge network .

This study aims to consider how the teacher helps the students to understand what learning is about in conjunction with developing a scientific understanding of the energy concept.

Background

<u>Energy</u>

Common alternative conceptions for the concept of energy include: energy is something existing in an object that is used up or consumed (; energy is seen to disappear; energy is perceived as an ingredient or a product; energy is motion; energy is associated with human activity with an anthropomorphic context; energy is seen as a fluid; energy is seen as a type of fuel; and energy flows into and out of machines . The above research has shown that students' understanding of energy from everyday experiences is quite different to the scientific understanding that students are expected to achieve after instruction. Duit and Haeussler reported that students seldom used the energy language when they are asked to explain processes, and that students did not use the energy knowledge they learned in science instruction in real life situations. Many of the recommendations for learning and teaching energy by Duit and Haeussler were adopted in this study including 'a focus on energy-related phenomena and uses of the word energy in situations with which students are familiar' (p. 198).

<u>Learning – the building up of knowledge</u>

Learning is about the building up of an individual's knowledge that includes ideas, facts, laws and rules – which are learnt, applied and integrated into existing knowledge. Knowledge is built up in a constructivist manner, sometimes quickly, at other times painstakingly slowly . Individuals have varying potential to store, apply and use knowledge. The level of understanding of knowledge that people achieve can vary; for example, a rote-learning synopsis describes an individual who knows a rule and is able to use it; on the other hand, an individual who knows how to do this, but also knows why he or she is doing it displays a meaningful learning synopsis .

To analyse the ways that students learn, it is necessary to have a framework of understanding of the learning process. Rote-learning reflects an instrumental level of understanding which Skemp (1976) described as being easier and quicker to grasp, providing immediate rewards and success with a proposed knowledge schema represented by discrete units. Meaningful learning reflects a relational level of understanding that is adaptable to new tasks and is 'organic in quality' (Skemp, 1976; p. 24) and is represented by a linked and interconnected schema of knowledge (Barak, Sheva, Gorodetsky & Gurion 1999). Skemp (1976) emphasised the significance and the subtlety of the differences between the two types of learning, in that the students may know the same facts of the subject but their ways of knowing are different. This epistemological perspective draws attention to the importance of foundation learning being presented in situ as part of a conceptual structure or schema. With this in mind, the way learners construct their knowledge is relevant and the strategies provided to accomplish this are significant. A comparable and complementary analytical framework for learning is that of conceptual change where meaningful learning infers revisions, assimilation and accommodation of new ideas within the students' knowledge framework or schema corresponding to the construction and modification of a knowledge framework (Harrison & Treagust, 2001).

In analysing meaningful learning that is conceptual change, Tyson, Venville, Harrison, and Treagust have described three main aspects or lenses that can be used for interpreting conceptual change – the epistemological, ontological, and social/affective aspects.

<u>Epistemological aspects</u> are concerned with the process of knowing about one's knowing or knowledge. According to Schommer , many factors influence a students' epistemology including age, cognitive ability, educational atmosphere and opportunity. She suggests learning is influenced by students' epistemological beliefs and that there is a need to raise the consciousness of students' personal epistemological beliefs (Treagust, Duit & Fraser, 1996). Research has shown that the development of students' epistemologies is closely related to the teaching strategies that they encounter. In particular this refers to the teacher's pedagogical content knowledge that has been specifically crafted by the teacher to suit the schooling and personal needs of his or her students . Attuning the instruction to the students' zone of proximal development is a strategy recommended by Vygotsky (1978).

<u>Ontological aspects</u> refer to the nature or status of things in the world – the way students link their ideas and knowledge . Chi (1992) describes the more common form of conceptual change as changes occurring within ontological categories and the infrequent radical conceptual change being changes occurring across ontological categories.

<u>Social/affective aspects</u> refer to the socio-cultural aspect of learning that includes the students' motivational beliefs, the learning environment, the role of learners in the classroom and discursive interactions (Mortimer, 1998; Pintrich, Marx & Boyle, 1993).

Novak (1980) used concept maps and V-diagrams to present the expressed knowledge network of students' understandings. These material representations of the mental state of the mind can be considered to be real and accurate (Monk, 1995). Novak claimed the 'learning to learn' program demonstrated meaningful learning and developed students' epistemologies by showing how scientific knowledge was constructed. The assumption is that meaningful learning results in new and interconnected ideas and knowledge inferring integration and then possible application of this knowledge. Students are often assessed on their ability to apply ideas or integrate knowledge, yet often this is not taught directly.

The focus of the study is on the students' perspective and their understanding of the process of learning and the scientific content of the topic energy. The aims of this study are: 1) To document how the teacher helped the students to understand what learning is about, and 2) To illustrate how this teaching approach helped students develop a scientific understanding of the energy concept.

Methodology

The study with one teacher and two general science classes, involved 48, 12-13 year old female students in Grade 8 attending a private college in Perth, Western Australia. Each class was observed for approximately 4 hours per week for a period of six weeks when the first author acted as a participant observer in all lessons (Merriam, 1988). The school policy required teachers to integrate computer use into their subject matter in a meaningful way (Kessell, 2001). As the students had a personal laptop computer from Grade 5 onwards, they were familiar and confident with their use.

A pre- and post- test on energy content of a generic nature, without consultation of the specific content being taught in these classrooms, required students to provide written answers to situations - most presented graphically – that examined their conceptual understanding of the energy concept. Twenty students were interviewed about their understanding of energy at the conclusion of the unit of work. Processing of the data included transcribing, coding and analysis of observations and test items, transcribing, coding and analysis of interviews and the scrutiny of assignments. Corroborating evidence from various data sources, both qualitative and quantitative, were used to make any assertions and conclusions. This form of "methodological triangulation" (Cohen & Manion, 1994, p. 236) was used to improve the validity and quality of data (Anderson, 1997). Discussion with peers helped to substantiate the conclusions being drawn in the discussion. The SPSS statistical package was used with statistical analyses.

The unit Energy and Change (Dawson & Hawkins, 2000) was innovative and interesting and is instrumental to the results of this study. The teaching unit comprised:

1. Introductory lessons on brainstorming and constructing Venn diagrams in both group and class forums;
2. Group activity - *Me and my laptop- two heads are better than one*;
3. Booklet: *Introduction to Energy*

The desired outcomes from this teaching unit were a better understanding of the nature of energy and energy transformations and an improved ability to solve problems by processing information. This contrasts with more traditional formats, which are more content and fact-oriented, often attempting to cover a more extensive range of energy concepts. This program intentionally targeted a reduced number of energy concepts, with the desired outcome of achieving meaningful learning.

The teacher introduced students to brainstorming activities and Venn diagrams assuming no previous skill at these tasks. Initially students' brainstormed topics on everyday topics chosen by students from which they constructed Venn diagrams. This activity was repeated on several familiar topics and after doing some initial research on the brain and the laptop, brainstormed these topics as well.

Then the students were introduced to the group activity titled *"Me and my laptop- two heads are better than one"* comparing the brain with a laptop computer. This assignment was relevant to the students who used laptop computers everyday and required them to compare and contrast two information-processing systems. The activity *Me and my laptop- two heads are better than one* focussed on improving students' ability to research, prioritise, categorise, evaluate and present information. Students worked in self-selected groups of four over 10, 50-minute lessons. A section of the written instructions of the assignment follows:

The purpose of this task is to:

- *Allow you to use your researching skills to investigate the workings of the two most important 'computers' in your life*
- *Produce a piece of work that may be viewed by new middle school students so that they understand how their laptops work*
- *Produce a piece of work that shows your learning about this topic*

The assignment was divided into seven parts: Part A Initial thoughts; Part B Finding out a little bit….; Part C Brainstorming; Part D Venn diagram; Part E Research Plan; Part F Presentation; Part G Reflection. Students were given an assessment rubric to show how their work would be evaluated.

Following this activity, the teacher directed instruction using the booklet *Introduction to Energy*. The booklet concentrated on identifying different types of energy, the transformation of energy, energy conservation, the degradation of energy and the classification of different types of energy. Similar to the previous exercise, students began by brainstorming the topic of energy and then worked through the booklet that contained activities and experiments on energy. Students' ideas and definitions of energy were discussed in groups and formalised through class discussion. During these activities students began to categorise sources of energy, converters of energy and receivers of energy.

Results

How the teacher helped the students to understand what learning is about

To examine the first aim of the study it is necessary to look at the effects of the pedagogical strategies used by the teacher. While, the influence of the specific teaching strategies cannot be ascertained categorically because there was no control group for comparison, the results are useful in monitoring students' perspectives of learning which is influenced by the pedagogical strategies used by the teacher that included brainstorming, Venn diagrams, discussion and group work and student evaluation.

Brainstorming

The teacher went to great lengths to teach the skills required for brainstorming to work. Although many students had had brainstorming experiences, the teacher still described what it was, why they were doing it, the role of the recorder, and the role of every group member. The teacher discussed the term 'idea' and how brainstorming generated a range of ideas and how one idea can help produce another and so on, and, that ideas can be categorised within the brainstorm. The 'group'-generated brainstorm was achieved through students listening to each other, thinking about the issue and recording all ideas no matter how unusual or off-beat they may seem. The teacher emphasised that criticism can dampen peoples' enthusiasm and the recorder has an important role to record all the ideas, fairly. The main rule for brainstorming stressed by the teacher was not to exclude any ideas. The teacher intentionally began the brainstorming exercise by using a topic that a student suggested, and with which all students were familiar. The class worked in small groups of four students, each group developing a brainstorm of ideas on large sheets of paper. Then the ideas were shared with the class on the whiteboard. The students were highly motivated because it was a topic chosen by one of them and was about them. The teacher's description of the brainstorming task as producing an *explosive* diagram was an excellent descriptor that communicated to the students the purpose of the brainstorming activity.

Students completed several brainstorms on different topics so that they became comfortable with the strategy and successful at tackling new ideas. The students went to great lengths to beautify their product with colour coding and decoration, even for a 20-minute task (see Figure 1). Throughout the task, the students were encouraged to use their experiences and ideas in building new knowledge onto what they already knew. This method demonstrated that it was the process of the task and not the end result which was the focus and that the most fundamental competences that are often assumed understood, may need to be taught.

Brainstorming could appear to some to be a superficial task, however the teacher developed the skills that the students needed to perform this task completely and successfully. The time given for thinking, consideration of others, repetition to master the skills, listening to others and presentation are important components. The students responded positively to these tasks producing quite extensive brainstorms. With a constructivist basis, the brainstorming activities allowed students to use their own ideas and knowledge to construct a representation of their understanding or thinking on a particular topic.

Insert Figure 1

Venn Diagrams

This diagrammatic tool which can help categorise and identify patterns in information, has an advantage over similar methods including Compare and Contrast, Like/Unlike and Similarities and Differences, because of it's visual impact. Students used colour, and decorations to highlight the differences and similarities. The Venn diagrams were constructed from the diverse range of ideas developed during the brainstorming activities (see Figure 2). Once again the teacher initially used the new approach on everyday, familiar items by comparing and contrasting bicycles and roller blades, then bicycles and the school bus.

Insert Figure 2

Both brainstorming and Venn diagrams are visual aids to learning in that they were the students' creation and helped to represent the organisation of ideas on paper and in the students' minds.

Discussion and Group Work

There were discussions between students, among groups and among the class, as well as proof-reading other students' work, job-sharing, conforming and co-operating throughout all lessons. When students discussed issues they were forced to verbalise their ideas and open them up to criticism of the other members of the group. This process builds confidence in the students' own ability and helped them confirm the logic of their thinking. Often only when challenged or forced to express their understanding, did the learner really accept new ideas, as illustrated in the following examples:

> S1: *They both use chemical energy*
>
> S2:*What do you mean by chemical?*
>
> S1: *You are going to have to explain that.*

And the response when asked about the phrasing of a question, she replied

> S3: *I knew I wasn't right but I was going to ask the other members of the group"*

When reviewing activities, the teacher led class discussions by expanding on students' contributions, asking pertinent questions and waiting, leading, sometimes repeating, and procuring the desirable answers from the students. This process gave students thinking time and encouraged them to understand the reasoning in preference to telling them the reasons. The teacher gave extremely positive responses to all students' contributions, never rejecting a student's response, but sometimes encouraging each of them to think further with responses such as ' you're close', or ' yes, but try to think more about….'. Students enjoyed writing their answers on the board. These positive and active teaching strategies were used to improve students' confidence and understanding of the concepts being studied and are supportive of the constructivist ideology. Group products such as brainstorms or Venn diagrams were photocopied so all members of the group had a copy. Job-sharing occurred to help produce the final products.

Student Evaluation

Students were taught new research skills to improve their information processing ability. These skills included brainstorming, producing Venn-diagrams, identifying key words, being able to formulate focus questions, note-taking and skim reading. These skills encouraged students to display their thinking in written form so that it could be shared with others. To accomplish this, the students had to know the purpose, the method and the criteria of each skill by asking themselves, how do I use it? why do I use it?, when do I use it?. By understanding these criteria, the students built up their own framework of information processing tasks. It is common to speak of knowledge frameworks for scientific content however the knowledge framework is equally valid for skills.

In the self-evaluation checklist completed by the students, they had to rate their competence at a series of skills such as brainstorming, writing focus questions, using keywords and taking notes. This reflective process required students to recognise the particular skill and then self-evaluate their competence at performing that skill. In particular, the skill 'I wrote my assignment in my own words' is of interest because the pedagogical strategies used provided students with the necessary skills to be able to do this. This is a key factor in learning, in that students must be given ways to assimilate the ideas and concepts for meaningful learning to occur.

How this teaching approach helps students develop a scientific understanding of the energy concept.

In response to the second aim of the study, three aspects of the students' understanding of energy are considered in relation to preconceptions of energy, conceptions of energy and the categorisation of energy concepts.

Students' preconceptions of energy

The pre-test results revealed that all students had a conceptual understanding of energy that was associated with their life experiences, confirm the result reported by Duit and Haussler (1994). The reasons given to support their answers in the tests were coded and the results indicated that most students associated energy with activity (67.3%), heat (64.7%), effort (73.5%), and sugar in food (77.5%). Nearly all students agreed with statements about energy such as: 'energy comes from natural sources' (92%), 'energy is something which makes things happen' (92%), 'energy can be shown in many different forms' (92%), 'energy can be changed from one form into another form e.g. electricity to light' (86%), 'energy is used to heat, cool, and light our homes' (98%) and 'energy can be wasted' (89.8%). However, more than half of the sample could not distinguish temperature and heat (51%), and the effect of volume on these quantities. Effort and energy was confused by 81.6% of the students sampled. According to , many students see energy as a 'thing' that is used up or consumed. This notion is consistent with the test results with 65.3% of students disagreeing or choosing 'don't know' to the statement 'energy is never destroyed'. Similarly, there was a strong 'don't know' response to the statements: 'energy can be dispersed into the surroundings and appear lost' (43%), energy is stored in the atomic structure of materials' (49%) and 'energy is lost by machines which are not 100% efficient' (49%) (see Table 1). Students only managed to list an average of 2.7 types of energy and 2.9 sources of energy in the pre-test. A lack of detailed knowledge was indicated by poor responses to questions such as: 'What energy form is the original source of all energy?' with only 30.6% providing a correct answer and 'What type of energy is absorbed during photosynthesis?' with only 46.9% giving a correct answer. Overall, students' understanding of energy was as expected, reflecting their personal experiences and being shallow in terms of scientific detail.

Table 1

Students' perceptions of the energy concept pre and post instruction (n=49)

Q8 Energy:	Pre-test %			Post-test %		
	Disagree	Don't Know	Agree	Disagree	Don't Know	Agree
a. Comes from natural sources	2	6	92	2	0	98
· Can be visible and invisible	14	8	78	50	0	50
· Is something which makes things happen	2	6	92	2	0	98
· Can be shown in many different forms	8	8	92	2	0	98
· Can be changed from one form eg electricity into another form eg light.	0	14	86	2	0	98
· Is never destroyed	29	37	35	33	13	54
· Can be dispersed into the surroundings and appear lost	6	43	51	7	17	76
· Is stored in the atomic structure of materials	8	49	43	9	26	65

· Is lost by machines which are not 100% efficient	20	49	31	21	33	46
· Is used to heat, cool, and light our homes	0	2	98	2	0	98
· Can be wasted	4	6	90	8	9	83

The students' conception of energy

The *Energy and Change* unit introduced students to a number of new terms such as energy, source, converter, receiver, inputs and outputs, kinetic and potential and required them to use these terms appropriately. After completing an introductory brainstorm on energy and performing a number of activities about energy the students working in groups of four were required to write their own definition of energy. The results are recorded in Table 2.

Table 2

Definitions of energy provided by groups of students in the classroom

Class	Definition
1	Energy comes in many form and from many different sources and can be transformed or changed to achieve results such as light heat sound or movement
1	Energy s an invisible transformation from one object to another. It is produced in many forms.
1	Energy is a natural source that gives an object movement, sound heat and light.
1	Energy is a natural source which makes things happen
1	Energy is the idea that gives things the ability to act
1	Energy is a source which makes things move work or create something else. To be seen it has to be transformed.
1	Energy is something that cannot be seen which causes change or things to happen, ie, sound, heat, movement, light….
2	Energy transfers heat, light and movement
2	Energy is invisible and is found in many places

2	Energy is an invisible source that produces heat, light, sound and movement
2	Energy is any source that produces heat, light, movement and sound
2	Energy is any form of a reaction produced by two or more substances
2	Energy is a current that produces heat, light and sound.

The results highlight the difficulty of defining energy and the variety of acceptable definitions. The definitions generated by the students revealed the significant impact of their recent science class experiences performing experiments displaying light, heat, sound and movement energy. Within the students' definitions were the important issues about energy: energy is an idea; energy can't always be seen; energy can be changed from one form into another. The distinction between the invisible concept of energy and the visible manifestation of energy in different forms such as light, heat, sound is conceptually challenging (Duit and Haeussler 1994; Chi, 1992)

Aspects of energy such as heat, temperature and work, which were shown to be poorly understood by students in the pre-test, were not covered in this introductory teaching unit on energy; consequently, the post test results for questions regarding these aspects are largely unchanged. In the post-test, all 11 items investigating the students' understanding of the energy concept showed a marked decrease in the number of 'Don't Know' responses in comparison with the pre-test results, with six items reducing to zero (see Table 1). During the interview, after the completion of the teaching unit, students' responses to the question 'What is energy?" included:

It is something that makes things happen!

If something is moving it involves energy. It means you can't do anything without energy otherwise it would be like a photograph or you would just be like a statue

Invisible

Something you can use

It is an idea

Something that makes thing work

Creates movement, sun light

Something that makes things work

Its invisible and its something that makes thing works

It is an invisible substance that creates heat, light

These responses made after the completion of the teaching unit are very similar to the responses made during the class (see Table 2), suggesting that the students had assimilated their new conception of energy. The interviews delved deeper into the students' understanding about the nature of energy:

R Can energy be destroyed?

S1 No

S1 No it goes into one form or another

S2 It goes into the atmosphere

R Can energy get lost?

S1 It can only get lost in space but in air then it goes straight back

S2 It can get so you can't use it

> *S3 Energy can't really be destroyed completely, it can't actually get lost but we can' t see it – or know where it is.*

The responses indicate that as a result of the teaching unit, these students had developed their initial conceptual understanding of energy. The ways this development occurred is described in the next section.

<u>Categorisation of types of energy</u>

Initially the students' ideas of energy were undifferentiated and sometimes scientifically incorrect with items of matter being classified as energy types (see Table 3). In the pre-test, inanimate objects were called a type of energy and students referred to steam energy, water energy, machinery energy, sport energy and tree energy. The teacher addressed this problem by identifying different types of energy, their origin and the nature of the energy.

Table 3 Development of students' concept of types of energy following the teaching unit on Energy and Change

Program	Activity	Examples
Pre-test Introductory lessons on brainstorming and constructing Venn diagrams Group activity - *Me and my laptop- two heads are better than one*;	Pre-test Examples and activities practising these processes Research, planning, processing information, communicating and presenting.	Steam energy, water energy, sport energy No specific relevance to the energy concept Recognising and understanding the energy changes occurring in the nervous system and computers*.

Booklet: *Introduction to Energy*	Performed experiments – observing visible types of energy	light, heat, sound and movement energies
	Instruction in new terms for energy types– kinetic and potential	kinetic and potential used alongside visible energy types
	Re-categorisation of existing categories such as heat, light and sound into either kinetic or potential through deeper analysis of the origin of the energy.	All energies expressed as KE or PE e.g. battery – stored electrical energy = PE; Food – stored chemical energy = PE; PE can be used to produce KE when using a bike;

* A very high (VH) achievement outcome on the rubric for the activity *Me and my laptop- two heads are better than one*

After doing experiments, identifying different types of energy, students developed criteria for their classification of common types of energies of which they had experience. Following instruction in scientific terminology, students began to use the terms potential and kinetic appropriately and eventually, the instruction extended the classification of all energy to these two categories. Students displayed their ability to classify a range of everyday examples in terms of kinetic and potential energies, in the post-test and in the interviews. The change from undifferentiated ideas on energy to a structured framework with a foundation of particular criteria reflects the changes in the students' ontological understanding of energy.

The number of correct responses to questions about the type and source of energy increased significantly from the pre-test to the post-test, with the mean number of correct answers increasing from 2.7 to 5.8 for Question 9 on types of energy ($p<0.001$) and from 2.92 to 4.5 for Question 10 on sources of energy ($p<0.001$). The pre-test answers for questions 9 were simple e.g. solar energy, electricity, light energy, but the post test answers were more diverse and more specific, e.g., mechanical energy, potential energy, kinetic energy, atomic energy, radiant energy, chemical energy. Similarly with question 10; the answers in the pre-test were simple, e.g., sunlight, water energy, coal energy, and in the post-test they were more specific, e.g., batteries, food, sun, chemicals. In the pre-test, many students gave the same answers for questions 9 and 10 because they were unable to distinguish the source from the type of energy. In the post-test, the students managed this distinction much more successfully, probably due to the classification scheme they had learnt.

We contend that the process learning activities had enabled students to sort and categorise new information so that it could be integrated into their personal knowledge network. This process is occurring here with an initial categorisation of types of energy into familiar categories such as heat, sound, movement etc, then an extension to include the new categories of kinetic energy and potential energy; finally, the re-categorisation of existing categories such as heat, light and sound was either kinetic or potential through deeper analysis of the origin of the energy. The application of the new categorisation scheme to familiar examples helped the students to accept it as a valid organisational scheme. The teacher provided leadership to assist the students to understand this new classification scheme and for them to learn the meaning and appropriate use of the scientific language.

The understanding of the phenomena of energy is built up with layers of understanding similar to that suggested by Renstrom, Andersson, and Marton in reference to students' understanding of matter. In this teaching/learning situation the layers refer to identifying the source, type and changes to energy. Both desired outcomes outlined in the introduction of this paper are attended to here: the learning and processing of new information using new classification schemes

The concept of energy converters was used to identify the types of energy and introduce students to the conservation of energy through accounting of energy changes. The pre-test saw no use at all of the terms kinetic, potential, transforms, converts or flows, whereas in the post-test these terms were noted many times, e.g. 'kinetic energy being transformed into potential energy by the muscles in his legs'; 'the heat energy is transformed into movement'; 'The man is on a hill so he has gained potential energy'; Students used flow charts to represent the transformation of energy form one type into another e.g. Heat--à water---> steam ---à movement --àelectricity. All students interviewed used the terms kinetic and potential. Evidence of accurate use of the terminology was recorded many times in the interviews, e.g.,

> *Petrol has potential to make things go*
>
> *The wax contains potential chemical energy.*
>
> *Hang-glider has got potential – no he's got kinetic – or moving energy and he has potential because he is so high*

Because of the difference in the pre- and post-test results, it is suggested that the changes in the students' answers can be attributed to the learning experiences as a result of this instruction that was described in the previous section. Further evidence of the effect of the instruction on students' understanding is demonstrated where in the pre-test, students referred to 'using up' energy - 8.2% in Q2ii, and 24.5% in Q1ii, whereas in the post test no students used this terminology in Q2ii and only 6.4% used the term in Q1ii. The more accurate descriptions and extensive use of scientifically correct terminology were observed in both the written and verbal assessments.

Discussion

As a result of using many of the teaching strategies reported by Duit and Haeussler (1994 students did learn basic aspects of the energy concept, they did use the energy language they learnt in school when explaining processes and they did learn and use the energy knowledge they learned in real life situations.

The positive results would suggest that students developed a sound knowledge network for energy inferring a meaningful learning of new knowledge. From their ability to use new terminology accurately and appropriately in interviews and in the post-test we can infer that students have constructed or extended their knowledge network. This can be described as conceptual change within their ontological category of energy.

By using the multidimensional framework to examine those aspects that have influenced these changes, it is apparent that the teaching style of the teacher and the teaching strategies used were instrumental in effecting the conceptual change. Each aspect of the analytical framework will be considered:

Epistemological aspects

We have only indirect evidence of the students' epistemology. However, the improvement in the students' understanding and application of new knowledge suggests that the strategies employed here provided students with knowledge of how ideas are built up. The teaching of skills in the processing of information directly showed students how to learn and how to think - thus developing process skills; and the students' personal experiences with energy were used to build and extend their personal understanding of the concept. Students were given learning opportunities appropriate` to their zone of proximal development (Vygotsky, 1978). The numerous strategies, appropriate to the students' level combined to achieve the end result. Fundamental to this is the dissection, analysis and teaching of the many processes and skills that were undertaken within the teaching unit. Brain-storming and Venn diagrams provided diagrammatic representations of students' ideas and thinking – helping students to generalise and cluster ideas; provide structure to thinking; help identify anomalies; predict future needs; and communicate ideas between class members. Mortimer (2000) reflects that students have to make sense of the data and relate it to their existing ideas and ways of thinking. He comments: "This sense-making step can involve significant conceptual and ontological challenges for the learner" (Mortimer 2000, p.129), inferring that learners must reorganise and reconstruct the talk and the activities of the social plane. The visualisation of ideas, the repetition of tasks, the reflective strategies and the use of multiple representations of the concept of energy influenced the students' epistemology. The strategies used here support Novak's idea of 'learning how to learn' which was developed using the strategies of concept-mapping and Gowin's epistemological V (1980, p.61).

Ontological aspects

The ontological development can be considered in terms of the two desired outcomes of the teaching unit: the processing of information and the scientific content of energy. There was a significant development of students' ontological framework of energy, energy types and the transformation of energy throughout this teaching unit. From an undifferentiated accumulation of ideas, students developed an extended ontological framework based on particular criteria to identify energy, types of energy and energy transformations. The successful implementation of this framework was seen in the students' categorisation of all energy situations as kinetic or potential energies. The students assimilated the new terms, and used them appropriately, suggesting that they had extended their ontological framework/knowledge network into a more scientifically acceptable form. Chi (1992) suggests that 'physical science concepts belong to a distinct ontological category' (p. 179) which are not an extension of the students' existing frameworks. This is difficult to ascertain; however, the use of this ontological framework with everyday events as recorded in the interviews would suggest that in this case – it is an extension of the students' existing framework.

During the interviews, many students clarified the questions - asking for specification of the source, e.g., with a picture of an archer, students specified the energy of the arrow, the string of the bow and the archer - at particular times – demonstrating that they understood the energy was being transferred between bodies and changing form. The specificity of the time and place indicates that students had particular criteria to meet so that they could categorise their responses according to their newly developed ontological framework.

Students had memorised some definitions but they applied them so they had meaning, e.g., potential energy was referred to as 'energy of position above the ground' and this was applied to numerous situations eg hang-glider, monkey in a tree, etc. This also forms criteria that have to be met before classification can be made.

The contrasting components of this teaching unit - the information processing and the topic of energy, may seem unrelated, but this is far from the case. They complement each other and their knowledge frameworks work together. Content is often considered the focus of the learning, especially by students, yet the thinking and learning *skills* developed from information processing are equally or even more important. This teaching unit is consistent with Chi's (1992) idealized ontology of knowledge that distinguishes matter, events and abstractions, in that the energy content corresponds to the matter component and the processing skills to the events component of knowledge. These ontological categories are not commonly differentiated in the teaching and learning process. This teaching unit has learning directed to the development of skills, which are often hidden within the content of the syllabus, as well as learning directed to the development of the energy concept. Since the thinking and learning skills are transferable across all content areas, they are most valuable and deserve to be taught specifically and focussed on.

The pedagogical strategies adopted in this teaching unit relate directly to the development of the students' ontological frameworks. Teachers or researchers cannot 'see' an individual's ontological framework, but we can see the results of using it. The pedagogical strategies used in this research have provided some insight into the students' ontological frameworks through their use. The visual display of ideas, sorting, prioritising and categorisation of new information and the relationships between the concepts of energy, energy types and energy transformations were reflections of ontological frameworks that we want the students to develop. The strategies can direct the learning to a meaningful result.

Social /Affective aspects

For meaningful learning to occur it is suggested that students must actively build their own personal knowledge networks. Discussion, collaborative and cooperative tasks are significant strategies that provide for ideas to be socially mediated. The laptop/brain activity was highly motivating to the students and enabled them to practise skills on everyday tangible items with which they were familiar, before applying those skills to the abstract concept of energy. This is evident from the student comment: "We know everything about what we have experienced with laptops in education – so we just write down our experiences".

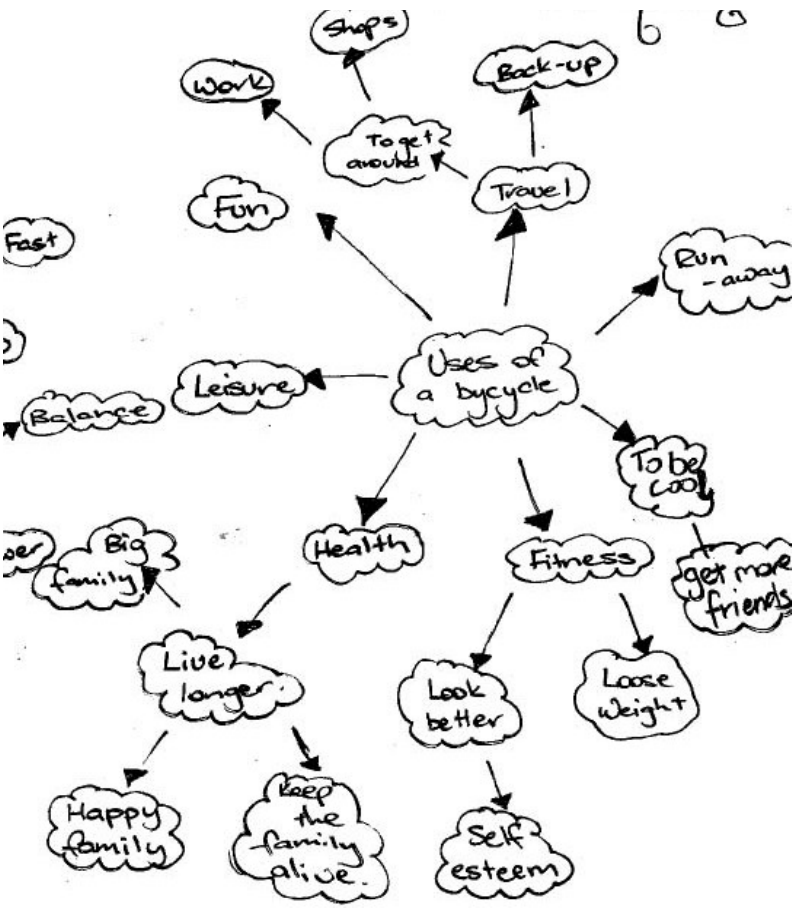
Conclusion

Energy is indeed an abstract concept to grasp; yet it is applicable to a diverse field and is relevant to every person's life. *Energy and Change* is one of the four strands of the Western Australian Science Curriculum. It is a valuable area to teach and the analysis of strategies to improve the teaching of energy is worthwhile. At this introductory level, the teaching unit has concentrated on all students mastering a few basic ideas about energy as well as mastering basic information processing skills.

The combination of the classroom environment, the teaching strategies, the individual learner differences, the teacher's style, the available resources and other unknown factors all contribute to the learning process. Despite this myriad of factors, it is still worthwhile identifying useful pedagogical practises that have been proven to enhance learning. The focus on thinking and learning skills in information processing alongside energy concepts has proved beneficial. The analysis of pedagogical strategies directed at developing the students' ontological frameworks of energy and information processing has helped to provide meaningful learning and highlights the importance of understanding how students learn. Learning results in students extending and re-organising their knowledge network. This description of students' mental organisation of ideas cannot be viewed directly and its structure is determined from looking at the results of its use (Harrison & Treagust, 2000).

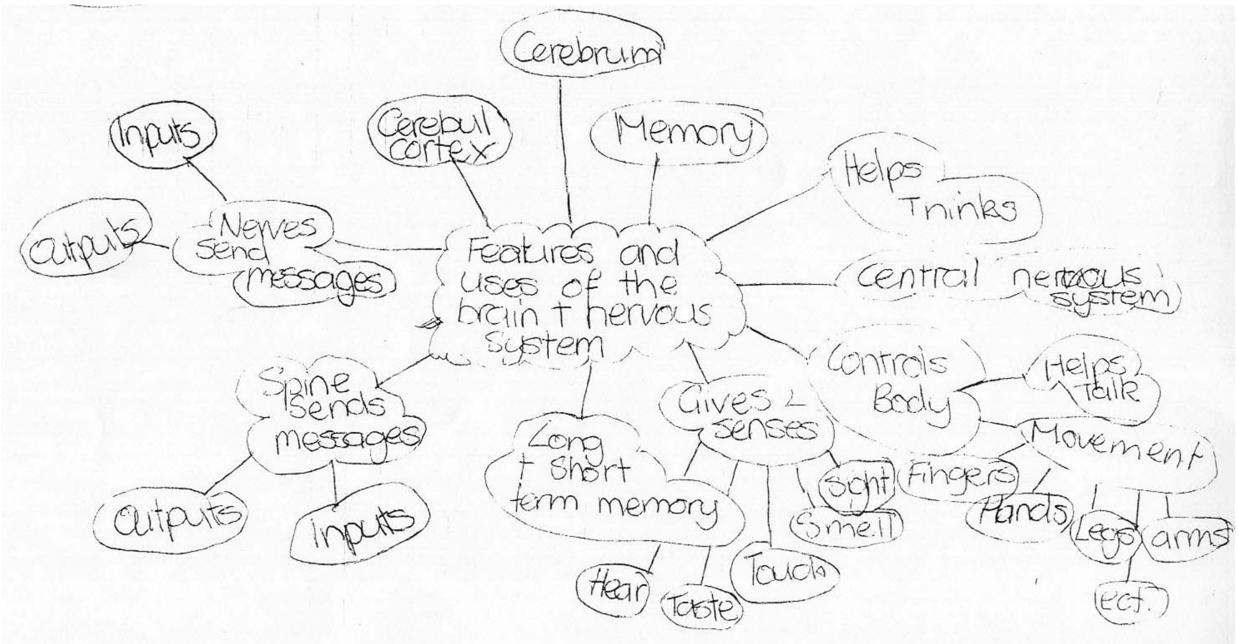
The identification of the most basic and necessary skills, the building up of skill-level and the mastery of these basic skills and has shown the importance of clear instruction which does not assume any prior knowledge and uses the students' current knowledge and understanding as the starting point. By recognising the importance of providing students with a means of organising their knowledge, it is proposed that more meaningful learning will occur. These learning mechanisms are not commonly exposed or obviously linked to the teaching strategies. Consequently, teachers and students may both benefit from a deeper understanding of the role and reason for use of the particular pedagogical strategies being used. Although learning is an innate behaviour, it is necessary to provide students with strategies to learn how to learn which extend their epistemological perspective. This relates to the ways of knowing to which Skemp (1976) referred when differentiating meaningful and relational understanding from rote and instrumental understanding.

There are many different ways students construct knowledge. These pedagogical approaches have been shown to correspond with the development of the ontological frameworks that students are constructing in the development of their knowledge frameworks. For meaningful learning, the students' knowledge framework must be interconnected and ideas and knowledge linked as demonstrated in this study.




Happier
More friends
Better life
Social
Learn more
Excursions
Cuts down on polution
Transport to co-curricular act.
~~Eco~~ Uses of a School Bus.
Parent/Driver can do other things
Better earth
Transport
Loger lives for us
Enables more kids to get to school on time.
Owner earns money for fares.
Happier
Better education
Earns more
Better future

Figure 1



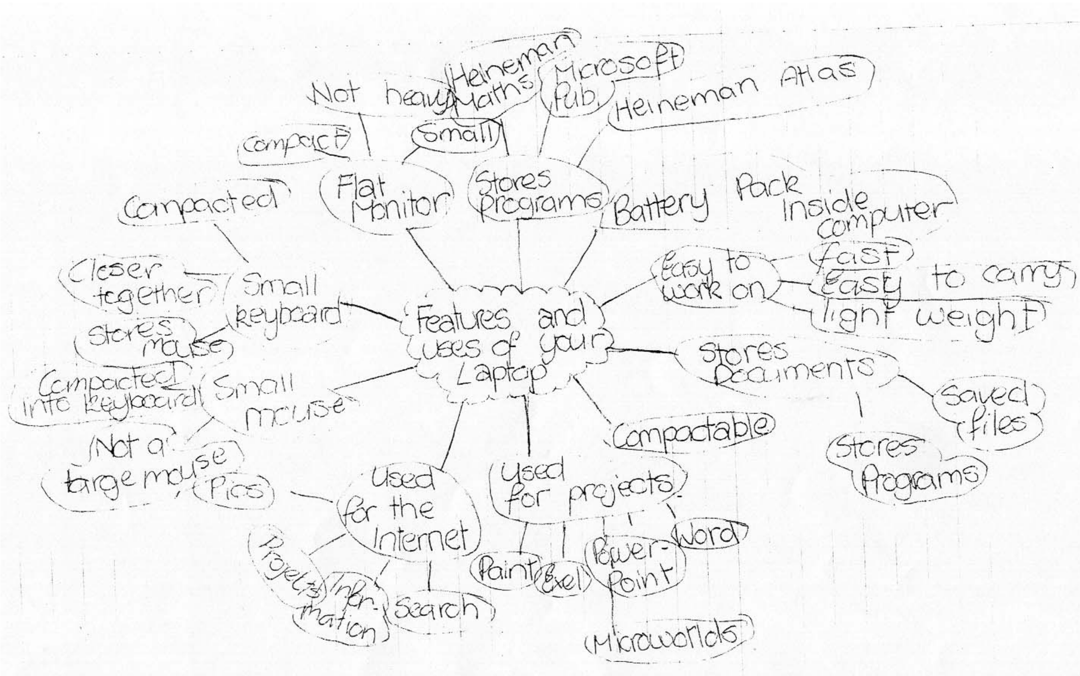
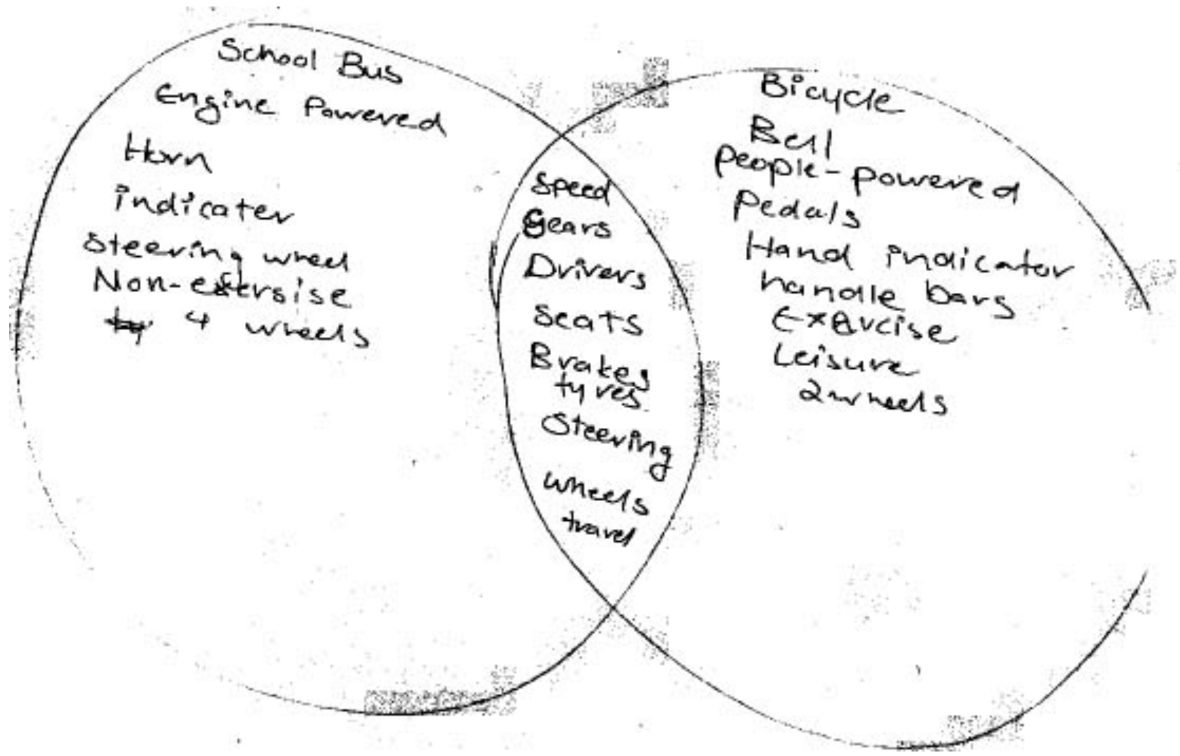


Figure 1 cont'd



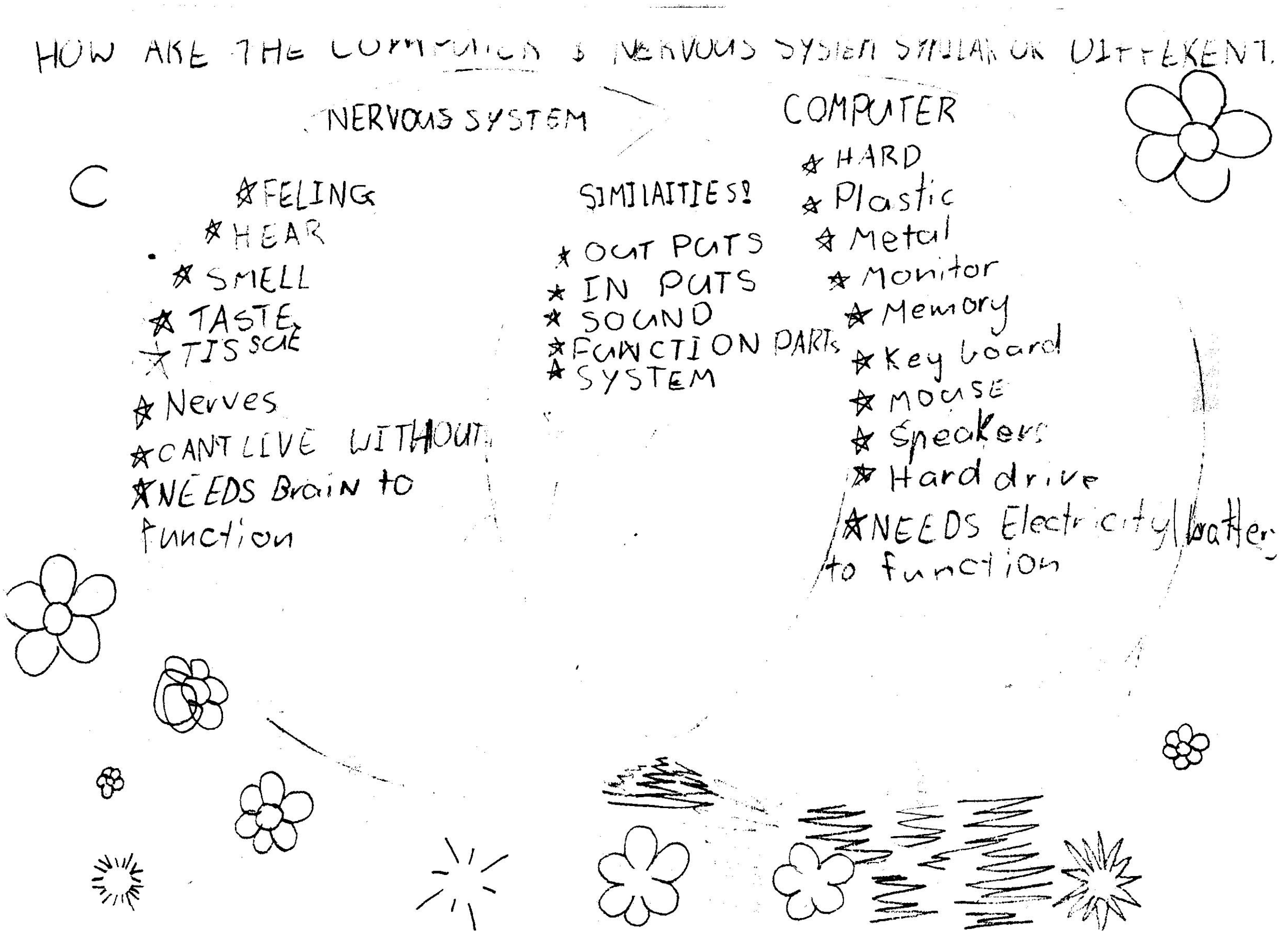


Figure 2 cont'd

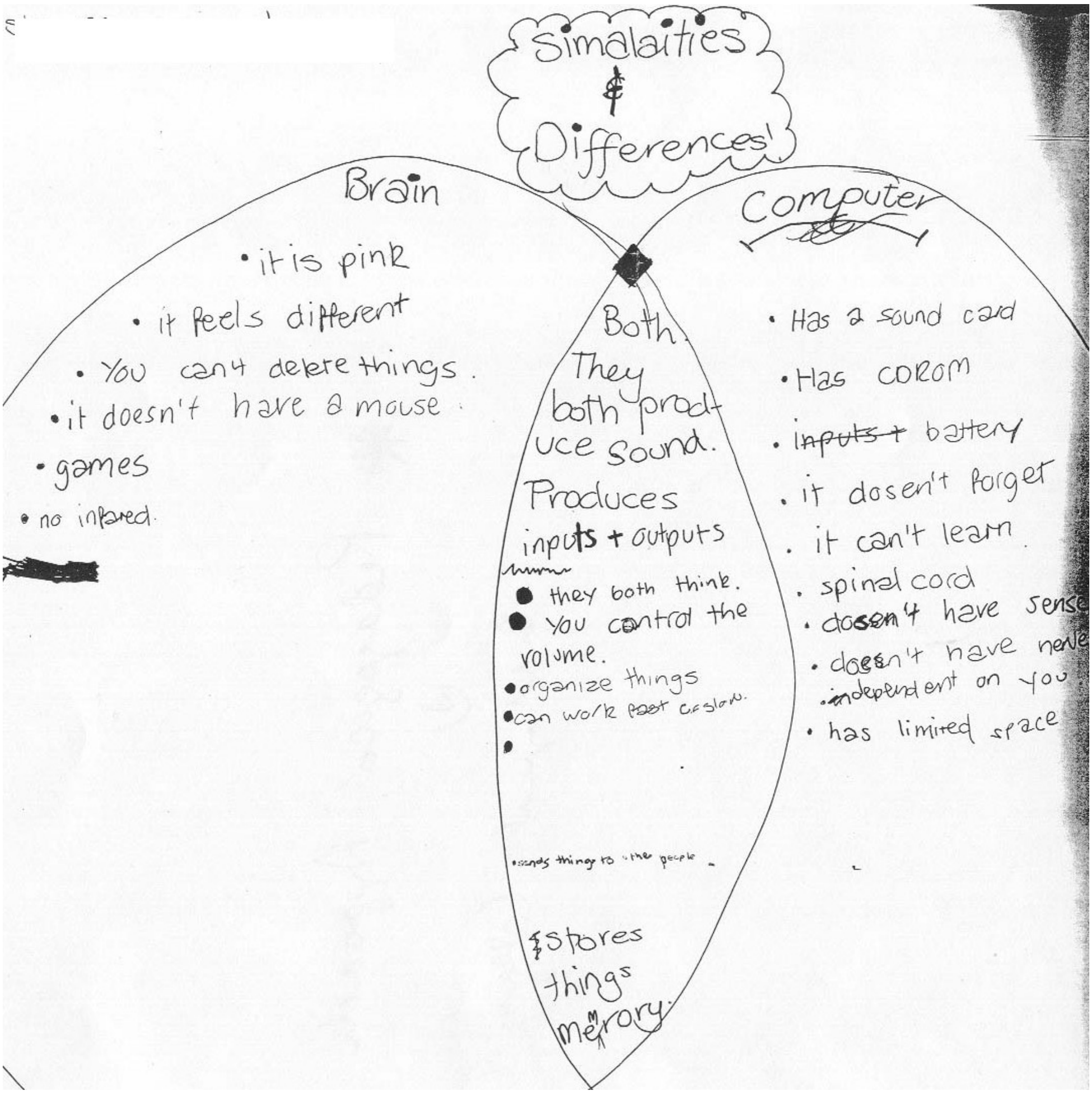


Figure 2 cont'd

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