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The development, implementation and evaluation of a Constructivist learning approach based on personal construct psychology

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THE DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF A CONSTRUCTIVIST LEARNING APPROACH BASED ON PERSONAL CONSTRUCT PSYCHOLOGY

by

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USE OF THESIS

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Abstract

This study involved the development, implementation and evaluation of a constructivist learning model based on Kelly's (1955) Personal Construct Psychology (PCP).

The thesis begins with a rationale for the use of PCP and then the instructional approach is derived from this theoretical basis. Following the derivation, examples of learning materials used in the implementation are presented. The second half of the thesis deals with data gathered before, during and after the implementation which occurred in two Year 9 science classes. The classes were part of a city high school in Western Australia.

Evaluation of the approach was conducted using a variety of methods. Students' science knowledge was assessed using a science test. Other techniques such as repertory grid methodology, interviews-about-events, questions-about-events, a questionnaire about beliefs to do with energy, and phenomenological classroom observations were also used to determine the effect of the implementation upon the students and teachers involved. Data gathered, often qualitative in nature, provided a rich description of the effect of the implementation. Results from the two classes undergoing the implementation were compared to one other class that was taught the same content in the traditional manner.

Results showed that students from the constructivist classroom learnt the school science as well as students taught with traditional methods. The results also showed that the constructivist approach resulted in the translation of formal school science into personal knowledge of students, with this knowledge being mostly scientifically correct. Additionally, these students became cognitively more complex individuals. Differences in the manner in which the two teachers implemented the constructivist learning approach had a significant effect on student learning outcomes.

The thesis concludes with many implications to arise from the study and some suggestions of future research directions.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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CHAPTER ONE

Introduction to the Study

Introduction

This research investigation implements and evaluates a constructivist learning approach based on a particular psychological theory. The thesis begins with a rationale for considering the psychological theory as a basis for the constructivist learning approach. In following chapters, the theoretical basis for the approach, which is grounded in Personal Construct Psychology (Kelly, 1955), is described and the learning approach is developed. This is followed by details and results of the implementation which was conducted in two Year 9 science classes. Results gathered during the implementation in these two classes are compared to a similar Year 9 class which was taught the same content with traditional methods at the same time. The results gathered are used to provide insights into the effects of constructivist learning approaches in general and to provide insights into this approach in particular. Following the discussion of the student results, further data gathered from interviews with the teachers and classroom observations, are presented and discussed. This thesis concludes with discussion of implications arising from the study and some suggestions for further research.

In the remainder of this chapter, the background and rationale for the study are explained.

Background and Rationale

Most science teaching methods currently used in Western Australian secondary science classrooms could be classified as cultural transmission approaches and objectivist in nature. These methods generally place the student in the position of being the passive receiver of knowledge with little emphasis on students' conceptions and the active participation of students in the acquisition of scientific knowledge. Scientific knowledge, in this approach, is seen as existing outside of the learner and the learner has to acquire this independently existing, objective knowledge. American science teachers, acting from this perspective, teach basic facts from textbooks (Stake & Easley, 1978) with occasional emphasis on individualised work from text books and whole class discussion (Mitman, Mergendoller, Packer & Marchman, 1984). There is no reason to believe that Western Australian science teachers act substantially differently from their American counterparts.

Some results of these cultural transmission approaches are that school science learning does not appear to last a long time, students lack the ability to problem solve using their science knowledge and students cannot apply their school science in a variety of different domains (White, 1988). According to studies from the wide field of misconceptions research (Anderson & Smith, 1984; Rice & Feher, 1987; Stead & Osborne, 1980;) students' own ideas about phenomena that they encounter in classrooms are rarely addressed, students do not use science concepts systematically, students' alternative frameworks undergo little change and meaningful change in students' beliefs about science phenomena does not occur. A final result of traditional instruction is that "students do not come away from instruction with a rich and full understanding of science concepts" (Shymansky & Kyle, 1992, p. 763).

A constructivist approach to science education provides an alternative approach. A constructivist approach would accord with a relativistic view of the nature of scientific knowledge in which the construction of formal knowledge in science is seen as a progression from the personal constructions of individual scientists, seeking to make sense of their experiences, towards a consensus of constructions by the community of scientists. Ideas held by the scientific community are not unchanging and the transformation of the consensus viewpoint is ongoing as evidenced by current debate about the Greenhouse Effect. Popper (1963), Kuhn (1970), Lakatos and Mosgrave (1970), and Feyerabend (1975) all argue for this more relativistic view of the nature of science knowledge.

Similarly Driver (1983), Gunstone (1988) and Osborne and Freyberg (1985), for example, all argue for this relativistic view of science to be expressed in constructivist approaches to learning. Lorsbach and Tobin (1992) maintain that teachers operating with constructivism as a referent "can become more sensitive to children's prior knowledge and the processes by which they make sense of phenomena". O'Loughlin (1992) supports this:

> Science teachers, therefore, face the simultaneous challenges of validating their students' personal ways of knowing, ... equipping them with an understanding of the fundamentally socioculturally constituted ways of knowing that underlie science so that the process of doing science is demystified and they do not feel compelled to defer to the intrinsically authoritative power of the received view. (p. 816)

Shapiro (1988) calls for studies which focus on the learner's active involvement with the curriculum and which shed light upon the processes of learning, processes that are likely to occur in a constructivist setting.

Constructivist epistemological considerations have been translated into a science education context in varying ways by researchers such as Driver and Bell (1985), Osborne and Wittrock (1983) and Cosgrove and Osborne (1985). Conceptual change research, exemplified by Posner, Strike, Hewson and Gertzog (1982), could also be classified as constructivist in origin. It is generally accepted by these researchers that there are sound educational reasons for adopting constructivist learning approaches but what constitutes a constructivist approach ?

What is Constructivism ?

There has a been a large increase in the number of science educators referring to constructivism when discussing research in the last ten years. This statement is supported through an examination of the ERIC data base which shows 19 references to constructivism in the period 1966 to 1981 and 321 references in the period 1983 to 1992. Most of the former references explicitly refer to constructivism within a Piagetian context and these writings comprise a first main group. Latter articles are not necessarily based upon Piagetian constructivism but all of these latter articles would accept that people construct their own interpretations of external events.

The latter articles mentioned above can be grouped into another two main divisions depending upon the philosophical basis of their constructivism. One group would comprise radical constructivists of which von Glaserfeld (1989) would be a leading proponent. Radical constructivists propose that constructivism can concern itself only with knowledge of an experiential kind. A fundamental belief is that it is logically impossible to know anything, that could be reasonably demonstrated about one's own world, beyond our own experiential interface. Because individual constructions can never be checked against an independent existing reality, the only validation of a person's knowledge is the extent to which the knowledge fits the person's experience. Our knowledge, when viewed this way, can only be derived from our human ways of perceiving and conceiving. This view of constructivism presents enormous challenges to be overcome before such a position could be adopted as the basis for practical approaches that could be used in a science classroom.

The third main category of research would comprise writers who regard constructivism as referring to the construction of an objective reality, existing outside of learners but accessible to them. This appears to be the position adopted by practical constructivist approaches to learning cited above. The learner is regarded as interacting with this objective reality and constructing their own version of it and this knowledge is regarded as accessible through cognitive processes which generally do not necessarily involve affective components of a person's thinking.

Most of the recent writings categorised into the three groups above do not have an explicitly declared theoretical basis of the constructivism referred to in their writings. Consequently, it is unclear in most writings whether the constructivism discussed is Piagetian, radical or refers to the construction of an objective reality.

This lack of an explicitly stated epistemological base leads to use of the term constructivism in an almost solipsistic fashion where it can mean whatever the author defines it to mean, within the bounds of the general proposition that constructivist learning is an active, social process with prior knowledge being an important factor. This lack of clear links to an epistemological base and lack of common meaning of the term result in different views of constructivism. Some examples of these different views are:

"learning as a social process of making sense of experience in terms of extant knowledge" (Tobin, 1993, p. 242) in reference to teacher learning.

"learning is seen as the modification of learner's existing ideas, that is, conceptual development" (Tasker, 1992, p. 30).

"Individual construction of knowledge and learning are at the heart of constructivist belief. Social interactions are important, too". (Tippins, Tobin & Hook, 1993, p. 51).

A constructivist curriculum is "the understandings which students construct during science lessons" (Bell 1991, p. 37)

This lack of clear definition of the term constructivism is also apparent when the term is applied retrospectively, especially to conceptual change studies. This retrospective application of the term has grown to encompass an expanding base of research involving "importance of teacher conceptions of...roles of teachers and learners in shaping the nature of the science classroom" (Gunstone, 1991, p. 32). Research examined in this article is given the term preconstructivism, with no definition of this term or indication of when preconstructivism became constructivism or when we may expect a post constructivist era.

A lack of clear definition has also led to the term "referent" being used in some writings, such as in "Referents for making sense of science teaching" (Tobin, 1993), perhaps as one way of avoiding the problem of linking constructivism to a clear epistemological base. Unfortunately, the use of referent does not solve the problem of exactly what is meant by constructivism, as the idea to which "referent" refers is not clearly defined and referring to constructivism assumes that we all have a similar constructed meaning for constructivism which clearly is not the case.

As there are no clear links to a well defined theory base, the ability of studies framed in a constructivist setting to contribute to theory development is diminished. This has been recognised by Treagust (1991, p. 67), who maintains that "there is a need to develop a theoretical position to subsume this data" in reference to the growing amount of qualitative data gathered from science classrooms which is deemed constructivist in origin. Further, he suggests that theory development is not far advanced in terms of being able to explain learning science as personal construction.

In summary of the above, the term constructivism appears to be fashionable, used loosely with no clear definition of the term and used without clear links to an epistemological base. The general conclusion that can be reached is that the field of constructivism, as applied to science teaching, is under theorised. Consequently the explanatory power of any existing theory is diminished and there is no systematic way of choosing future research directions nor of evaluating current curricula which purport to be constructivist in nature.

The Piagetian Base for Constructivism

Piaget's theories are the basis for many constructivist approaches though this is not always acknowledged. This base, if it is the implied base for a constructivist approach, is open to criticism.

A student's constructions, from a Piagetian perspective, arise through assimilation and accommodation. This view of construction emphasises the personal nature of construction and denies the social construction of knowledge (as opposed to social interaction) and any consideration of the subjectivity involved in the process of construction. This lack of recognition of social construction has little value in providing "the foundation for a radically reformed science education" (O'Loughlin, 1992, p. 799).

Additionally, it seems that the Piagetian view of constructivism seeks to distance the learner from concrete reality and from their own personal experiences. At the highest stage of reasoning, according to Piaget, cognitive development is content free, logical, ahistorical, value free and abstract. This picture is a sociocultural free and decontextualised picture of cognitive development. Such a decontextualised notion of the active learner implicit in Piaget's work is not likely to empower, as the abstract "formal cognitive skills may increase a child's ability to adapt to present society rather than criticise it or change it" (Buck-Morss, 1975, p41).

Cavallini (1991) provides similar criticisms. Piaget, according to Cavallini (1991), underestimates the importance of social and personal culture for building up cognitive structure. Another criticism from Cavallini (1991) is that Piaget identifies thinking with formal reasoning which tends to over simplify the process of thinking. There are many other processes involved with thinking, apart from logic. For example the familiarity of the situation, the links between the person's knowledge and reasoning method, the methods of analysis, procedures, categories, rules and language all influence the thinking process and would seem to be recognised by those claiming a broader constructivism referent in their writings than the constructivism model of Piaget.

Piaget's theory also supports the individual nature of intelligence, the separation of thinking from contexts and situations, the separation of ways of reasoning from the person's knowledge and the strict relationship between mental development and age. Most recent studies challenge these assumptions. Some other additional criticisms of a Piagetian approach are listed below.

1. The implementation of Piaget's theories has resulted in a focus on stage theory. Many science educators perceive his theory of stages to be a series of limitations.

2. Piaget's theories compartmentalise knowledge artificially into affective, cognitive and psychomotor domains.

3. Piaget's (and Bruner's) theories generally have been about the structure of cognitive processes with less regard for affective components such as the student - teacher relationship and classroom climate.

4. Piaget's theories were never intended to be used in a classroom where learners have to attend to a predetermined curriculum at a set place and set time.

Groen (1978) reinforces the first point above, with the assertion that the construct of stages of development have been taken out of context and has lead to practices which are inconsistent with Piaget's theory as a whole.

It can be stated that a Piagetian framework as a basis for a constructivist approach to teaching and learning has inadequacies. Further it seem that if constructivist research is framed according to Piagetian principles, then results would be expected to be used to modify and extend this theory. However it appears that little attempt is made to relate findings made from constructivist studies to Piagetian constructivism. From this it may be concluded that Piaget's theories are not the basis for current constructivist research or are an inadequate base with little explanatory power for the data gathered from recent research. A new constructivist base is needed.

Why Use Personal Construct Psychology ?

Personal Construct Psychology (PCP) is an explicitly stated, constructivist theory which consequently has the potential to be brought to bear on the field of student constructions. It is a well articulated theory founded on a fundamental postulate and 11 corollaries providing a clear theoretical framework upon which research can be based. It is an accessible theory.

Kelly's epistemology and theory of personal constructs would, according to Watts, Gilbert and Pope (1982) allow the distinction between personal meaning and the formal knowledge of science to be bridged:

> Rather than treating all concepts as if they are the distinct clear cut entities of physics, we propose to view the process through which scientists structure their domains as being similar to the way that people deliberately construct their own world views (p. 4).

Recent work in cognitive psychology (Head, 1986) has renewed interest in the work of Kelly (1955). Kelly's theory emphasises each individual's unique construction of the world but, in contrast to Piaget, provides a theory which emphasises the social nature of such constructions. The Alternatives for Science Education (Association for Science Education, 1979) document suggested that alternative models in psychology, such as that of Kelly (1955) should be considered for their implications for science education. Up to this time, no learning approach, based on Kelly's (1955) work, has been developed for use in science classrooms despite its potential to contribute to constructivist learning theory. Some other reasons for considering Kelly's (1955) theory include:

1. The student is responsible for his/her own learning and this is a fundamental part of his theory. Kelly viewed learning as an essential part of life and unseparated from life because a person was engaged

ceaselessly in exploration and enquiry. He regarded the basic task of students to enquire, undertake new ventures, and commit themselves to those undertakings.

2. An important emphasis in PCP is on communication and the sharing of meaning. If shared meaning is recognised as important in science learning, then this constructivist theory can suggest methods which may effectively lead to common understandings in a classroom of students.

3. This psychology integrates affective factors with cognitive factors. More studies of affective factors in action are needed according to Fensham (1988) as it is probably a major force for improving science education. Attention is also drawn to affective factors by Novak (1981), White and Tischer (1986) and West and Pines (1983). Affective factors are regarded as indistinguishable from cognitive factors.

4. Many of the corollaries are directly applicable to current science education research and can provide explanatory power to these mostly constructivist studies. The fragmentation corollary states that "A person may successively employ a variety of construct subsystems which are inferentially incompatible with each other". When viewed in the light of this corollary, misconceptions, alternative frameworks and the like are seen as a natural and normal part of every student's psychological construction.

5. PCP can answer fundamental constructivist questions such as how is knowledge constructed, how do we form constructions and how are constructions organised. In this theory, meaning is explicitly defined. Such explicit definition does not exist in other constructivist theories and meaning is not defined in most writings dealing with constructivism.

A final reason for considering PCP as a basis for a constructivist approach to science learning is that "there is little research to guide teachers in the selection of practices that are conducive to students constructing knowledge" (Lorsbach & Tobin, 1992). Personal Construct Psychology is a well developed constructivist theory which has the potential to further theorise the field of science learning.

Purpose of the Study

Broadly stated the purpose of this study is to develop, implement and evaluate a learning approach derived by the author from Personal Construct Psychology (Kelly, 1955). An emphasis in the study is the acquisition of qualitative data about learning outcomes and a comparison of students' learning in classes undergoing the constructivist approach with students' learning in a traditional science classroom.

For the purposes of this study, some terms require operational definition. The term "school science" is the science that consists of facts, laws and principles written in science text books and which, when taught from an objectivist perspective, is most likely to be rote learned. Two examples, relevant to this study, are "Energy cannot be created or destroyed" and "Energy is the capacity to do work". School science is the science that students separate from "their real world explanations" (Lorsbach & Tobin, 1992) which can be regarded as the students' personal knowledge.

Similarly, students' own understandings, their personal knowledge, can be defined operationally as understandings that fit with the students' own perceptions of phenomena and are expressed in their own language as opposed to rote learned language. Most often these understandings have expressible links to other personal understandings of the student. Students' own understandings are characterised often by idiosyncratic interpretations of external events. To assess each student's personal understandings, new techniques were developed for this study and these are explained in relevant chapters.

If the implemented constructivist learning approach can be deemed successful then it can be expected that students will learn the school science as well as their counterparts undergoing traditional instruction, but students learning constructivistly will have increased personal knowledge about energy. An additional expectation would be that students' personal beliefs about energy in various situations would be changed, possibly to become more scientifically correct, because of the nature of the constructivist approach. The reason for this expectation is explained in a later chapter.

Students increased personal knowledge would be manifested in several ways. Firstly they would have a greater number of constructs to use in energy situations and secondly there would be evidence of the school science in these constructs demonstrating the successful construction of school science ideas. Thirdly, because of their increased personal knowledge, students would be able recognise more forms and uses of energy in a given number of situations.

It is now possible to state the following research questions:

1. Are there differences in how well students learn school science between students taught with traditional methods and students undergoing the constructivist approach ?

   This will be determined using a school science test and by assessing students' use of supplied constructs derived from stated school objectives.

2. Are there differences in students' personal knowledge concerning energy between students taught with traditional methods and students undergoing the constructivist approach ?

   This will be determined by assessing the number of constructs held by students, by assessing the degree to which school science has been translated into the students' personal knowledge, by assessing the students' ability to recognise forms and uses of various types of energy and by determining any differences in students' beliefs about situations to do with energy.

3. Does the manner of implementation of the constructivist approach, by each of the two teachers, influence the quality of learning outcomes in their respective classes ?

   This will be determined by gathering classroom observations and linking these observations to results related to questions one and two above.

CHAPTER TWO

Personal Construct Theory

Introduction

An overview of Personal Construct Psychology (PCP) is presented in this chapter. This overview is presented in sufficient detail to allow the reader to understand the derivation of the learning approach, which is explained in subsequent chapters. Learning, in terms of PCP, is described in this chapter for similar reasons. This overview is followed by discussion of the meaning of constructs, according to this particular psychology. Concluding the chapter is a description of repertory grids as these are an important data gathering tool in this study.

Overview of Theory

Personal Construct Psychology (PCP) has been applied in many areas since its original beginning in a clinical psychology context. Some examples are in business (Ginsberg, 1989), economics (Jankowicz, 1991), sociology (Smith, 1990) and the natural sciences (McEwan, Colwill & Thomson, 1988). There has been widespread use in education (Pope & Keene, 1981) but of relevance to this study is the application of PCP to science education. Gilbert and Pope (1986), Happs and Stead (1989), Shapiro (1988), Watts and Pope (1989) and have all made contributions in this field.

This constructivist theory has as its focus the contention that our psychological processes are guided by the way in which we anticipate future events. The theory is explicitly stated and is based upon one fundamental postulate and 11 corollaries which are listed below in their original form which uses non gender inclusive language.

The Fundamental Postulate: A person's processes are psychologically channelized by the ways in which he anticipates events.

The Construction Corollary: A person anticipates events by construing their replications.
The Individuality Corollary: Persons differ from each other in their construction of events.

The Organisation Corollary: Each person characteristically evolves, for his convenience in anticipating events, a construction system embracing ordinal relations between constructs.
The Dichotomy Corollary: A person's construction system is composed of a finite number of dichotomous constructs.
The Choice Corollary: A person chooses for himself that alternative in a dichotomized construct through which he anticipates the greater possibility for extension and definition of his system.
The Range Corollary: A construct is convenient for the anticipation of a finite range of events only.
The Experience Corollary: A person's construction system varies as he successively construes the replication of events.
The Modulation Corollary: The variation in a person's construction system is limited by the permeability of the constructs within whose range of convenience the variants lie.
The Fragmentation Corollary: A person may successively employ a variety of construct subsystems which are inferentially incompatible with each other.
The Commonality Corollary: To the extent that one person employs a construction of experience which is similar to that employed by another, his psychological process are similar to those of the other person.
The Sociality Corollary: To the extent that one person construes the construction processes of another, he may play a role in a social process involving the other.

The above postulate and corollaries make PCP one of the most explicitly stated theories in psychology and, according to Bruner (1956), it is the single greatest contribution of the past decade to the theory of personality functioning.

Kelly did not see a person's behaviour as driven by instincts or by schedules of reinforcement. He viewed people as being engaged in a process of observation, interpretation, prediction and control of their external environment. This process is similar to the way in which science operates and Kelly always used the analogy of "man the scientist". Piaget, also employed the "child as scientist" metaphor to describe the progression towards formal operations. There is some evidence that Piaget used the metaphor in terms of isolation of variables rather than general hypothesis testing, which Kelly referred to in his use of the metaphor.

Acting as a scientist involves each person erecting for themselves a model of the world, which is subject to change. Change occurs in response to the testing of constructions against external events in the search for better predictions of the future. A person, in this theory, is regarded as being in constant psychological motion, attempting to make sense of their external environment, constantly questioning, exploring, revising and replacing constructions of reality. In Kelly's theory, the emphasis is on the personal nature of meaning with the individual being the central and most important element of the theory.

According to Kelly (1955) we continually conduct experiments with our own behaviour to test hypotheses that are formulated when we rearrange constructs within our own system. We then revise our hypotheses in the light of the outcome of our behaviour and conduct different "experiments" to test new constructions that may emerge. Thus new behaviour emerges from our attempts to accommodate constructs to events, in our attempts to enhance our capacity to anticipate future experiences.

When Kelly (1955) promoted an alternative to the then current paradigm of "behaviourism" he joined Piaget (1952) in emphasizing internal psychological functioning and there are many parallels between the two theories. Both brought constructivist concepts into psychology. Both theories shifted emphasis from just behaviour, as this ignored too many other facets of human experience, to the cognitive processes by which events are represented and anticipated. Dewey (1910) also emphasised the anticipatory nature of behaviour but Kelly went further by contending that our lives are wholly oriented towards the anticipation of events.

Events are only meaningful to us because of our anticipations about them. Anticipations are confirmed or refuted and meaning arises from the testing of constructs against reality in the search for better prediction. Constructs become meaningful if they lead to successful prediction and control of events. This generation of meaning, tied to the search for better prediction and control, may lead to the development of new constructs and behaviours. According to Kelly, a person's processes operated within a "network of pathways" leading towards the future:

> Here is where we build into our theory its predictive and motivational feature. Like the prototype of the scientist that he is, man seeks prediction. His structured network of pathways leads toward the future so that he may anticipate it. This is the function it serves. Anticipation is both the push and pull of the psychology of personal constructs (Kelly, 1955, p. 122).

Personal construct theory also refers to itself as a theory and so is a system of constructs for viewing behaviour.

Learning

Learning, according to this theory occurs all the time, as each person's model of reality is constantly tested against his/her perception of events. A person's construct system sets the limits of his/her perceptions and the direction and possibilities of change. Change can only occur in the direction of possibilities determined by their existing permeable constructs. Constructs can be permeable, being able to be applied to new elements or impermeable, not being able to be applied to new events. Consequently, the direction of learning is difficult to predict without a knowledge of the person's existing constructs.

Kelly recognised learning as a personal exploration and saw the teacher's role as helping "...to design and implement each child's undertakings....To be a fully accredited participant in the experimental enterprise she (the teacher) must gain some sense of what is being seen through each child's eyes" (Kelly, 1970, p. 262).

Both the teacher's and the student's perspective of learning events is important as many of our constructs are taken directly from other people. The responsibility of the learner is seen as having to incorporate public knowledge into their own view of the world, with the teacher assisting the process. This is a similar position as espoused by Driver (1989, p.42): "The challenge is to help students construct these models *for themselves,* to appreciate the domains of applicability and to be able to use them".

According to Kelly a person could construe their environment in an infinite number of ways and these ways of looking at the world are only dependent upon the person's courage and imagination. Construing is seen as having cognitive and emotional bases of equal importance. Knowledge is regarded as relative, with the epistemological position being that of constructive alternativism (Kelly, 1955). This position holds that:

> "...man understands himself, his surroundings and his potentialities by devising constructions to place upon them and then testing the tentative utility of these constructions against such ad interim criteria as the successful prediction and control of events" (Kelly, 1966, p. 1).

Constructs are organised into a hierarchical system and learning is viewed either as new constructs being added, existing constructs modified or a change in the organisation of the construct system.

Constructs

While construct has a general psychological meaning, in PCP the meaning of construct is quite precise. Constructs can be regarded as a way of seeing some things as alike, yet different from others with these differences and likenesses being considered simultaneously. Constructs are personal tools that allow for the discrimination and organisation of events and allow the anticipation of future events. Essentially bipolar in nature, constructs consist of a personally relevant pole describing the similarity between events and a contrasting pole implying the opposite of the similarity. An example of a construct is *gills / no gills* which is a construct which may be personally useful for distinguishing between types of aquatic animals. Aquatic animals would be termed elements in this psychology. The use of this construct would allow the person holding the construct to group some aquatic animals together as they have gills and group some other aquatic animals together as they do not have gills. The aquatic animals, to which the construct is applied, are termed elements.

Constructs have a limited range of applicability called the range of convenience of the construct. Clearly the above example involving gills is not useful for distinguishing between horses or for distinguishing between types of fish. Both the range of convenience and the contrast pole will differ for different people using ostensibly the same construct. Knowledge of the range of convenience and contrast of a person's construct is necessary for the construct to be adequately understood by another.

Constructs are always part of an organised system. They can be organised vertically so that a construct can be superordinate or subordinate to another construct. Every construct is subordinate except for those at the very top of the system. Relatively superordinate constructs are likely to be more stable and more resistant to change than the lower order constructs. Core constructs are those constructs which Kelly defines as involved in the day to day processes of maintaining identity and a sense of continuing existence. Changing these constructs is very difficult, because of the links to identity, and changing these constructs represents a fundamental disturbance to the system. Peripheral, subordinate constructs can be changed more easily as reformulation of a system is much less complicated when these constructs are changed.

Most constructs are not highly intellectualised with precise dimensions of discrimination which can be clearly verbalised. Often constructs are tentative explorations and the distinction between constructs may be blurred and confused. Many constructs have no word labels (nonverbal or preverbal) and this does not stop these constructs from occupying important places in the person's construct system.

Tight constructs are closely interrelated to other constructs and loose constructs lead to more varying predictions. Tight and loose does not imply good and bad. As constructs are tested in day to day experiences they are successively tightened and loosened. A loose system does not allow accurate predictions and a tight system can be rendered ineffective as events proceed.

Specific constructs can undergo dilation or constriction in the process of learning. A person who broadens their perspective to new events will dilate their construct system to accommodate the event. This will lead to reorganisation of the construct system. A person can minimise the incompatibility between their system and events by constricting the system (drawing in the boundaries) to exclude the event.

Concepts, Constructs and Memory

At this stage it is appropriate to draw some comparisons between the usual psychology applied to learning in science, which can be broadly classified as cognitive, and the alternative psychology applied in this thesis. Specifically, it may be useful to draw comparisons between concepts and constructs and suggest some ways in which constructs may be stored in memory. It must be remembered that concepts do not exist in PCP and are not necessary in that psychology. However a comparison between concepts and constructs may assist in the understanding of PCP. Likewise a comparison between a memory scheme from cognitive psychology and a suggested scheme from PCP may also assist understanding.

Concepts and Constructs

Concepts link things which are naturally alike and different from all other things. This suggests that a concept is inherent in an external and objective reality. Constructs do not have this assumption but are personal inventions which are imposed upon reality. Ausubel, like Piaget, assumes that each individual organises and structures his or her own knowledge. The Piagetian model focuses on content independent, logical structures or operations but Ausubel postulates that knowledge is structured as a framework of specific concepts. The Ausubelian position is closest to Kelly's idea of constructs being just tools that allow discrimination and organisation of events and allow us to anticipate future events. A concept is not necessarily a specific, individualised construction and concepts may or may not be hierarchically related. Constructs are always specific and individualised and always fit into a hierarchical system. Because constructs are very individual, the limits of application of a construct are set by the person. A concept is less individual and more open to socially derived limits of application.

A concept, according to PCP, could possibly be regarded as a collection of similar elements and the constructs that can be applied to those elements. Elements, in PCP, are usually chosen to represent the area in which constructs can be applied. For example the concept of energy may involve elements such as solar energy, nuclear energy, potential energy and kinetic energy and the constructs able to do work, produce movement and cause wars. It is obvious that a concept when viewed this way is a very individual entity and is very fluid. If we accept that constructs involve affective elements then a student's concepts may be subject to much variation, almost on a daily basis. Older people with a more highly organised system, would have concepts which consist of stable elements and superordinate constructs.

Memory

White (1988) identified seven types of memory element; strings, propositions, images, episodes, intellectual skills, motor skills and cognitive strategies. As a link between Kelly's (1955) psychology and cognitive psychology, it can be useful to locate the meaning of construct somewhere amongst these memory elements.

An initial assumption that could be made is that constructs are elicited as strings. Strings are the verbal labels assigned by the person to the emergent and contrast poles of the construct. However, these strings are just convenient, and sometimes temporary, labels which are used to represent the meaning subsumed by the construct. The construct itself would be close to White's (1988) propositions and this is a second assumption. Constructs are similar to propositions but are a particular type of proposition which can encompass many elements. A construct is a proposition with a wider range of meaning than a proposition because it recognises the existence of the contrast pole. White (1988) describes propositions as external expressions of one memory part and lists examples such as acids are sour and metals are malleable (p. 27). From a PCP perspective, each proposition involves verbal labels (strings) and each label defines the opposite label. Consequently a construct would involve at least two memory parts. So knowing "sour" allows the existence of a label "not sour" and consequently it may be possible to distinguish between all acids along a continuum from "sour" to "not sour", depending upon their degree of sourness. In the same way, metals can be placed on a continuum from malleable to not malleable. As the construct can encompass many elements, then each element is at least one memory part. Consequently the recall of a construct involves the recall of two memory parts plus the memory parts involved in identifying the element located by the constructs.

This is still a simplified picture. Once construct and elements are recalled then the element needs to be located on the construct which involves cognitive processing. In this sense recall, in PCP, is a constructing process. However consistent recall can lead to the results of this recall being stored in memory and this is described below.

It can be seen that constructs are extended propositions, capable of encompassing more meaning and hence more elements and events than just a proposition involving only one pole. Construct theory allows for the individual definition of the contrast pole, which recognises the truly individual nature of meaning more so than propositions. For example, the proposition that fish have gills involves the verbal label "gill". To some people the opposite may be "No gills" to others it may be "lungs". Each implied opposite label allows the encompassing of a different range of events and hence different meaning. In this way, the apparently simple proposition "fish have gills" is capable of a wide range of interpretation and applicability depending upon its idiosyncratic opposite label.

Constructs are organised in a system and so various constructs in a person's system have inferential links to each other. White's "Image" in PCP can be regarded as the application of one construct or a particular group of linked constructs to an external event or element. This mental representation involves the location of the event on particular points of the constructs applied. Using White's (1988) example of the shape of a thistle funnel, then this could be constructed by a person using constructs like square/not square, symmetrical/not symmetrical and thistle like/not thistle like. The constructs applied, and the location of the event along those constructs, is a very individual business subject to change over time as learning proceeds. This location process, as mentioned above, can be a processing or recall task.

An episode is defined by White (1988, p. 23) as "Memory of an event one took part in or witnessed" and in PCP terms, this can be regarded in a similar way to an image. As mentioned above, memory is a constructing process and the constructs that apply to episodes are subject to change over time. This means that the way we feel about an event, for example, in our childhood is subject to change as we grow and change. Each construal of the event may be different to the last. However it could be assumed that if an event, like filtering a suspension or eating breakfast, is remembered often enough then the same constructs will apply each time and a "script" (Schank & Abelson, 1977) will be followed, relieving us of the burden of thinking about the task. Scripts, in PCP terms, could be defined as the consistent application of the same constructs to the same event. This consistent application can be stored in memory, meaning that the memory components associated with a construct involve a component for each pole, a memory component for the external element and a memory component for the location of that element on the construct.

Intellectual skills are performed with the assistance of scripts. These skills involve the application of permeable constructs to new events. This means that to perform the skill, and like White (1988) we are assuming this application is to a new event, the person must have constructs which allow the location of the new event somewhere on those constructs. Discrimination is possible if constructs exist that allow the positioning of the events involved at different points on the construct. According to PCP, if this is not possible then the construct is not a useful predictor and will not assume as important a position in the person's system. It will be replaced by a construct that will allow greater prediction and control. Similarly classes are automatically defined by which constructs can be applied to which events. Classification can be regarded as a natural and ongoing event in PCP. Rules can be regarded, in a similar way to scripts, as the consistent but sequential application of the same constructs. Rules may differ from person to person.

Cognitive strategies are the application of superordinate constructs to events. Each person's system has superordinate and subordinate constructs and a well organised system can use a few superordinate constructs in each particular situation. The constructs involved have been tried and tested in a variety of situations, through the use of strategies like the use of rules and scripts, and so are capable of very good prediction and control. The application of these high level constructs, because of their many inferential links to other constructs, represent collections of constructs into amalgamations that are theories and strategies.

In conclusion, Table 1 summarises the main points above.

Table 1

Links between White's (1988) memory elements and possible memory elements in PCP.

Element	Definition	Construct
String	A whole sequence of words	Verbal labels - emergent and contrast poles
Proposition	Describes concept's property	Similar to construct
Image	Mental representation of sensation	Images represented as applicable constructs
Episode	Memory of an event	Collections of constructs applied to reconstructed event
Intellectual skills	Capacity to perform class of tasks	Application of permeable constructs
Cognitive strategy	General skill involved in controlling thinking.	Use of superordinate constructs

Repertory Grids

Kelly devised the repertory role grid test, which enabled him to sample the constructs held by a person about external events. As originally devised by Kelly, the test used people, who fulfilled specific roles in the subject's life, as elements in the test. Elements are items in the test that are used for comparison purposes, in order to elicit the constructs that the person uses to distinguish between the elements.

One form of the test uses elicited constructs to rate every element in the test on a scale of 1 to 5 and this is the preferred form of the test for this study. The test has been used in many areas and although rarely used to elicit science constructs, the author has used the test successfully to elicit constructs held by a group of students and an expert regarding water (Fetherstonhaugh & Bezzi, 1992) and Energy (Fetherstonhaugh, In press).

		1	2	3	4	5	6		
Salty	1	3	2	1	1	2	3	1	Not salty
Product of rain/runoff	2	2	3	5	1	2	4	2	From clouds
Not mobile	3	3	4	1	2	5	1	3	Flows
On surface	4	2	3	5	4	3	1	4	Not on surface
Contains advanced life (Fish)	5	4	4	5	3	2	1	5	Single celled life (Less complex)
Drinkable	6	3	1	1	3	1	3	6	Undrinkable
Flow continually	7	2	1	2	1	3	4	7	Stagnant
Permanent bodies	8	5	5	5	2	3	1	8	Not permanent
Affected by tides	9	1	3	2	4	1	0	9	Constant level
Flow downwards	10	2	1	3	2	5	1	10	Hardly flow down
		1	2	3	4	5	6		
		River	Lake	Ocean	Groundwater	Run Off	Rain		

Figure 1. A student's constructs regarding water.

In the example shown in Figure 1 there are six elements; *river, lake, ocean, groundwater, run off* and *rain*. In this study, elements and constructs used in grids will be written in the text in italics. The elements were compared in groups of three and the student was asked the standard repertory grid question "In what way are two of these elements the same, yet different from the third ?" From the first group of three elements that were compared, the student wrote "Salty". The student was then asked to write down what in his mind was the opposite to salty ("Not salty"). These two elicited poles then formed a rating scale (1 corresponding to salty and 5 corresponding to not salty) which the student used to rate all the elements with the numbers being written in the appropriate place in the grid. From Figure 1 it can be seen that groundwater is regarded by the student as being as salty as ocean water. A zero is commonly used in grids to indicate that a construct cannot be applied to a specific element. This can be seen in Figure 1 where a zero is applied to the element *Rain* as the construct *Affected by tides / Constant level* cannot be meaningfully applied by the person completing the grid to the element *Rain*.

Because elements are rated by constructs forming a matrix of numbers, it is possible to apply statistical methods such as cluster analysis and principal components analysis to the grid. This can give insights into the cognitive structure of a person or, as Slater (1979) terms it, the person's intrapersonal space. Such insights can further reveal the hierarchical organisation of the person's construct system. Complex statistical analysis is not always necessary as much information is conveyed just by the constructs.

Issues relating to elicitation of constructs, analysis, reliability and validity of grids are examined in a later chapter dealing with methods of investigation.

Conclusion to the Chapter

This chapter has briefly introduced some concepts about PCP, learning, constructs and repertory grids. It is envisaged that there is sufficient detail for the reader to understand the links between the psychological theory and the derived learning approach which is described in the following two chapters.

CHAPTER THREE

Science Education and Personal Construct Psychology

Introduction

In this chapter, Personal Construct Psychology (PCP) is further elaborated with an emphasis on the meaning of the theory for science education. After discussing a general orientation towards science education based upon PCP, seven propositions are developed from the theory and literature. Following this, a table is presented which makes clear the connection between the propositions and the fundamental postulate and the corollaries in order to demonstrate the grounding of the propositions in PCP theory. This chapter concludes with a brief comparison between this approach and several other broadly constructivist approaches in order to demonstrate some differences and advantages.

A Personal Construct View

A society has systems of public meanings, many of which are science related. The essence of PCP is about how an individual constructs personal understandings and meanings through interaction with this system of public meanings. Learners must remain free to interact with the pool of public meaning and to interact with it in personally meaningful ways. In instructional terms, the task is not as Solomon (1983, p. 50) states "... that they (the pupils) should be able to think and operate in two different domains of knowledge and be capable of distinguishing between them", but that students operate in their domain and interpret highly abstracted science ideas in their own terms. The task of the self - organised learner, according to Harri-Augstein (1977), is to construct viable structures of meaning from within a repertoire of idiosyncratic needs and purposes.

Personal meaning can exist as a symbolic pattern of relationships which are continually constructed through interaction with the external world. These constructions are mediated by language. People, electronic media and newspapers are all sources of explanations of natural phenomena. Attempts to relate our system of science meanings to these external influences can assist the process of constructing more personally significant representations of our science knowledge. Reflection, about attempted constructions, can assist learners to create meaning if the ways in which they feel, think and act are made clear to them.

A personal construct view of science education would encourage the use of teaching strategies that allow the direct elaboration, that is the opportunity for change, of students' personal science constructs in the classroom. Elaboration would allow interaction with the public science meanings expressed usually via a science teacher, curriculum materials and practical activities. A teacher acting in accord with PCP would assist the elaboration by helping students test the validity of their beliefs so as to advance their understanding and discoveries. An excellent starting point in designing instruction in this theory would be to help make explicit to the student the existing constructs that the student holds.

Students would be encouraged to test their existing science constructs against their perceived reality of external science events. Events in this context can be as simple as writing on a blackboard or the teacher performing a demonstration or students doing an experiment. Events need to be clearly distinguished from each other by the learner before constructs can be generated. This elaboration process would culminate in the acquisition of personal knowledge by the student rather than the acquisition of an externally imposed view of reality.

Science education, viewed in this light, must be an experimental affair for the student where existing constructs are tested for their ability to predict and control external events. Consequently learning is a very individual affair, which has no single right way. Rather it would be a process which helps individuals build up for themselves a viable range of constructs. For teaching to be effective, the teacher must have some understanding of the constructs that the students possess, without necessarily sharing the constructs, so as to best allow students opportunity to elaborate their system. Such a view is similar to Driver and Erikson's (1984) view which stresses the need for teachers to be aware of the alternative frameworks which students have regarding the phenomena taught in science lessons.

Construct theory suggests a non prescriptive approach to science education. It also suggests a holistic approach which takes into account the viewpoint of the teacher, the viewpoint of the student as well as relevant others involved in the learning system as all these people have their own unique construct systems. These systems all need to be taken into account as, for example, the teacher's view of science may well determine the range of activities available to a student in a classroom.

Individual differences in students have usually been dealt with in terms of gradations along standard achievement measures. The dimensions by which students are measured are externally imposed but in construct theory the dimensions by which students are measured are internally erected by the individual and are essentially part of their construct system. People can differ, not only on the standard scales of the psychologist, but in the dimensions they erect themselves to make sense of other people and the world. These individual dimensions are fundamental individual differences which need to be considered in a classroom. These differences mean that students are never equal or the same but because of the acceptance of each individual's unique view of reality, equality is inherent in application of PCP to science education.

Propositions Concerning the Approach

In the process of developing the learning approach the above general ideas, the fundamental postulate and corollaries and other sources of theory pertaining to PCP were gathered together into seven main categories from which the practical classroom approach was ultimately derived. These seven categories are now described. Each category listed begins with a title in the form of a proposition which summarises the content of the category.

1. *The direction of learning is determined by the learner's existing constructs.*

According to PCP, people always learn, but what they learn is determined by their existing constructs. The nature of our existing constructs determine which events we regard as meaningful and each person is a victim of their own construct system, which imposes a limit on what the person can perceive. What one person experiences as a meaningful event may not even be perceived by another person with a less abstract or hierarchically organised system.

The direction of learning is towards better prediction and control and away from anxiety which occurs when events are outside the range of convenience of existing constructs. Learning is about generating meaning, which, in this system is defined as leading to constructs which have better predictive power. New behaviour occurs when attempts are made to accommodate constructs to events.

2. *Learning involves the elaboration of a construct system.*

Students and teachers are construing persons who impose their own private meanings on events which occur during lessons. Teacher and student then choose alternatives in their system of constructs which offer the greater possibility for extension and definition (elaboration) of their system (choice corollary). The meaning generated through the elaboration of a person's system can be inferentially incompatible with an existing subsystem of constructs (fragmentation corollary).

According to the fragmentation corollary, inconsistent subsystems can exist if they are not invoked simultaneously. If students are to gain personal knowledge that was consistent in its application across a wide range of instances then the challenge would be to invoke inconsistent subsystems so that the organisation of the subsystem evolves to remove the inconsistencies. This would lead to a more stable, and viable set of personal constructs.

Students regard events as meaningful only because they either confirm or deny their anticipations about the event and this confirmation or denial leads to the development of new constructs or reorganisation of the existing system of constructs (elaboration). The form and content of a person's knowledge system depends upon the person's interaction with the environment and is mediated by their existing construct system. Students generate tentative hypotheses then seek to confirm or refute these hypotheses in an effort to impose meaning. In a classroom, after new events are presented students need to be given further events to help in this confirmation or refutation process. As described before, the product of this elaboration can be stored in memory as a process of locating elements on constructs.

Personal knowledge of how we construct our reality can aid the process of elaborating our constructs. The use of a repertory grid would enable the student to see the assumptions that underlie their acts of judgement and can assist students to learn in terms of their own construct systems. Grid technique would be used to evaluate constructs as right or wrong but to reveal to students the personal basis for their knowledge.

3. *Learning, questioning and exploring occurs continuously and actively.*

Learning is regarded as a normal psychological process that is occurring all the time within a person and the purpose of this constant activity is to enable the learner to better understand and anticipate events. Motivation is not necessary, according to this psychology, as people are always in psychological motion, that is they are continually mentally active. Motivation in this psychology is not about drives and needs but instead focusses on reasons for choosing one activity from a range of alternatives. Consequently "motivation is framed in terms of factors influencing choice" (Head & Sutton, 1985).

It may be necessary to help students recognise new events through the suggestion of new constructs. Boredom may arise from attending to an event which offers little or no chance for the elaboration of a student's construct system. This can occur through attending to an event which is the teacher's, scientist's or a public event but which is outside the range of convenience of the student's existing constructs. Consequently, students need to be very aware of their existing constructs and must be free to choose the order of presentation of learning events.

External rewards or primitive drives are not required to interpret the dynamics of the learner. Students have their own in-built motivation for learning and the teacher is needed only to assist the process of exploration and discovery in a sensitive and flexible manner to enhance this natural process.

4. *Events can be interpreted in large number of equally valid and equally possible ways.*

The individuality corollary states that people differ in their construing of events. Individuals impose meanings on events in the light of existing constructs and existing constructs differ from person to person so it is reasonable to expect that the meanings of events will differ from person to person. Further the relationships between constructs that are generated about a recognised event will be different from person to person. Kelly (1955) doubted that two persons ever put their construction systems together in terms of the same logical relationships.

A person may learn about an event by generating constructs which are descriptive of the way the person feels about the event and how the person feels about similar events. This means learning is just as likely to be an emotional or affective process as a logical process.

5. *Learning involves change in a person's construct system.*

The change can involve the formation of new constructs and/or a reorganisation of existing constructs. Anticipations are successively revised in the light of recognising events and the construct system progressively evolves. This evolution can follow a learning cycle conceptualised by dilation - constriction - tightening - loosening of the construct system.

In encountering new events a person will dilate their construct system to encompass the event if permeable constructs exist to allow this to happen. The construct system may then be deliberately constricted to allow the implications of the new event to be processed. Constructs arising from the new event can be linked to other constructs (tightening) as the implications of the event are realised and then constructs can be loosened to explore varying predictions arising from questions of the "What if" type.

For example if a student has a construct like *Cause movement / Doesn't cause movement* in regard to energy then this construct may be permeable enough to encompass events dealing with kinetic and potential energy. If this student saw a spring move a toy car, then his/her construct system may dilate to encompass the event. A new construct may be formed, like *Kinetic / Not kinetic*, as a result of an idea from a teacher or fellow student. No new constructs may be generated (constricting) while the student explores the meaning of this construct in terms of their existing constructs (tightening). This may be followed by a loosening of the student's system to allow personal explorations about the new construct such as "Are these types of energy kinetic ?" and "What if all energy was just kinetic energy ?".

Constructs system change usually leads to the minimisation of inconsistencies. According to Kelly, each person sets up a unique hierarchical system (organisation corollary) which reduces the chaos of the external world so that consistent predictions can be made. If there is no organisation then different subsets of constructs can yield different predictions and the chaos of the external world is not reduced.

6. *Construing is a refining process leading to abstraction and generalisation.*

The experience corollary states that a construct system varies with each successive construing of the same event. Links are built between events as individual events are not wholly unique. Construing is a process that gives identity and regularity and the successive relevation of events generates working hypotheses. These working hypotheses lead to successive revisions of the construct system and if events continue to be encountered then it is likely that superordinate constructs will appear. For example, continual dealing with types of energy could lead to students developing a superordinate construct like *Can do work / Can't do work.*

These superordinate constructs are usually quite permeable, capable of encompassing a large range of events and also capable of accurate prediction. They can be applied in a wider range of contexts than less superordinate constructs.

7. *Learning in science involves construing the construction processes of scientists, teachers and students (sociality corollary).*

Learning science involves social construction. Students from similar cultural backgrounds and using the same language would be expected to hold some similar constructs regarding common events (commonality corollary). This basic assumption allows some form of communication to occur amongst individuals. By making explicit the constructs that we hold regarding an event and then comparing those constructs to another's constructs, we are performing a social role in the other's construing process. This sharing of meaning leads to change in each participant's construct system as the comparison of constructs results in the formation of new constructs or the change in the superordinancy of existing constructs.

Literal meanings such as definitions in a science classroom are meaningless as they are constructed by each student in an individual manner, dependent upon their existing constructs. The incompleteness, inherent ambiguity and flexibility of language should lead naturally to the negotiation of meaning within a classroom.

Cognitive imperialism (Berger, 1976) is seen to occur when inhabitants of one world impose their particular modes of perception, evaluation and action on those who have previously organised their construction of reality differently. Cognitive respect means that one takes seriously the way in which others define reality and this stance is consistent with the epistemological basis of Kelly's theory and is a necessary condition of the sociality corollary. In classrooms operating according to Kelly's theory there would always be discussion of meanings, sharing of interpretations, respect for differing views and recognition of the validity of each person's constructions of events. Classroom experiences would be organised to allow students to articulate their personal constructions and negotiate their personal meanings.

To conclude this section, Table 2 is presented to make explicit the links between the fundamental postulate and corollaries and the above propositions. This table makes explicit the grounding of the propositions in PCP.

Table 2

Links between the fundamental postulate and propositions.

Postulate or corollary	Proposition
Fundamental postulate	3. *Learning, questioning and exploring occurs continuously and actively.*
Dichotomy Modulation	1. *The direction of learning is determined by the learner's existing constructs*
Fragmentation Choice	2. *Learning is about the elaboration of a construct system.*
Individuality Range	4. *Events can be interpreted in large number of equally valid and equally possible ways.*
Organisation	5. *Learning involves a change in a person's construct system.*
Experience Construction	6. *Construing is a refining process leading to abstraction and generalisation.*
Commonality Sociality	7. *Learning in science involves construing the construction processes of scientists, teachers and students.*

Comparison with Other Constructivist Models of Science Learning

At this point it is relevant to briefly examine other models of science learning. There have been other attempts which are philosophically similar. The examination of other models can assist in making clear the unique features of this particular approach and can also highlight some advantages of this approach compared to other constructivist science learning models.

Osborne and Wittrock (1983) summarised 32 empirical studies, investigating students' ideas, ranging in time from 1966 to 1982. Their review of these studies produced three conclusions:

1. young children have firmly held views about science topics before encountering them at school;

2. views of the world and meanings for words held by young children which differ from the scientist's view are also held by older children who have considerable exposure to science teaching (science teaching has little effect on students' ideas); and

3. if children's ideas are changed then the change can be quite different from that intended by instruction.

PCP was considered by Osborne and Wittrock (1982) as a basis for their generative learning model. They considered PCP as "important and relevant and one which would be widely accepted by those working in the constructivist tradition" (p5). However they felt that the theory was not easy to comprehend without detailed study and needed translation into language interpretable by teachers. They also felt that the repertory grid would not be accepted by teachers because of the complex statistical analyses required to make sense of the data and that the repertory grid would not be useful in eliciting ideas about topics such as force and motion. This was written before the days of widespread and powerful desktop computers with a plethora of statistical and specialised grid software and given the situation today, the above objections can be refuted. Nonetheless, elements of Kelly's theories are evident in their generative learning model.

According to the generative model, a process of testing tentative meanings against sensed experiences occurs and successful meanings are stored in long term memory. These meanings can then be used in further testing against sensed experience. Interestingly, successful meanings are not defined in this model. This testing process is almost identical to the testing of constructs against perceived reality for their predictive power, which is said to occur according to PCP.

Osborne and Wittrock (1983) classified the implications for the classroom of their model under headings such as motivation, attention, processing information, generative learning, subsumption, restructuring and problem solving. A practical instructional approach was eventually produced (Cosgrove & Osborne, 1985) using three main phases of focus, challenge and application. Like other approaches, (such as Nussbaum & Novick, 1982) these phases were intended to enable students to become aware of their own ideas, to create cognitive dissonance and assist the restructuring of conceptions. This approach is compared to the instructional approach derived from PCP in the next chapter. However this model (Cosgrove and Osborne, 1985):

1. does not specifically take into account the thoughts, feelings, beliefs and attitudes of the teacher, although it recognises the teacher's existing science knowledge;

2. specifically requires motivation on the part of the learner before learning can occur whereas learning is said to occur all the time in PCP;

3. is unclear about the status for ultimate reality that is assumed;

4. specifically states that the goal of science teaching as the successful learning of scientists' ideas rather than the construction of these models for themselves;

5. cannot predict the direction of future learning whereas PCP theoretically can predict the direction of future learning, given knowledge of existing constructs; and

6. does not address the importance of, or suggest techniques to aid metacognition;

and hence a more sophisticated instructional model is needed and this is developed in the next chapter.

Posner et al., (1982) suggest that only those constructions of meaning which appear plausible, intelligible and useful will be incorporated in long term memory. Although their approach has been used with success in changing students' ideas (Fetherstonhaugh, 1990), not all students change their ideas and there is little evidence about the long term retention of changes that may occur. Posner et al.'s (1982) guidelines tend to view the learner as a reasoning person who can consider the intelligibility of arguments and assess the worth of ideas for their future value. Such a view neglects the affective world of the student and reduces learning to a rational, reasoned decision on the part of the student. As with the generative learning model the aim of the conceptual change model is to promote the successful learning of scientists' ideas rather than the construction of scientists' models for themselves.

Other criticisms of the conceptual change approach are that it does not suggest the origin of new ideas, it cannot predict the direction of future learning, it has no emphasis on the social construction of ideas, neglects feelings, neglects the learner's image of science and science knowledge, contains no metacognitive tool and does not suggest from where new ideas originate. Conceptual change and the role of cognitive conflict are examined in light of PCP and findings from this study in the conclusion to this thesis.

Neither of the above models emphasise the social construction process of learning. Solomon (1987) argues for a greater emphasis on the social influences on students' understanding of science. She categorises ways of constructing meaning into complementary social and personal elements and calls for research into the interactive aspects of school learning, linguistic and cultural effects and informal instruction from the media.

> Teaching, propaganda, and the world of Orwell's "1984" cannot, by themselves, lead to real personal understanding. On the other hand it is also true that belief in our own ideas is astonishingly hard to form or to maintain without the collaboration of others (Solomon, 1987, p. 63).

Kelly's individuality, commonality and sociality corollaries are consistent with the above position, not withstanding earlier comments about the different views of the social construction in the two theories.

Driver and Bell's (1985) constructivist learning approach emphasized six main propositions:

1. learning outcomes depend not only on the learning environment but also on the knowledge of the learner;

2. learning involves constructing meanings;

3. the construction of meaning is a continuous and active process;

4. meanings, once constructed are evaluated and can be accepted or rejected;

5. learners have the final responsibility for their learning; and

6. some meanings are shared.

Driver and Bell (1985) have implemented a learning approach using these general propositions and this is compared to the instructional model derived from PCP in the next chapter. Their approach is probably closest to the approach outlined in this thesis, but it has some disadvantages. In particular it neglects the teachers' beliefs and attitudes. Further, it cannot predict the direction of future learning, has no metacognitive tool and does not recognise that resequencing of content in line with the learner's sequence, as important.

However the above general guide-lines as to what constitutes a constructivist learning theory was a useful framework for the generation of a science learning approach based on PCP.

Conclusion to the Chapter

This chapter has applied the theory of PCP in a science education context. Seven propositions were stated. These propositions were derived from the theory and literature and the links between the propositions and the fundamental postulate and corollaries were listed in a table. At this stage of the derivation of the learning approach, there exists a set of general science learning propositions well grounded in the theory. However these propositions are still too general to apply in a science classroom and in the next chapter, a practical instructional approach, based upon the propositions in this chapter, is described.

CHAPTER FOUR

An Instructional Approach to Science Education Derived from PCP.

Introduction

This chapter presents the practical classroom instructional approach derived from the seven general propositions discussed in the last chapter. The aim was to construct an approach which was consistent with the propositions and able to be implemented by practising science teachers in a normal science classroom. After presenting the approach, the links between the model and the seven propositions are made explicit and presented in a table. Comparisons are then made between this derived instructional approach and other constructivist approaches developed by Cosgrove and Osborne (1985) and Driver and Bell (1988).

The Instructional Approach

The approach has a focus on individual constructions and the sharing of meaning which makes group work an essential part of this model.

The approach has five main features:

1. it is an holistic approach that considers all who are involved in the process;
2. it focusses on discussion of, and comparison of, personal ideas;
3. the learning sequence is determined by the student;
4. acquisition of personal knowledge by teacher and student; and
5. awareness of existing and new constructs by the teacher and student.

The model is basically cyclical in nature and the starting point is the determination of the teacher's and the student's existing constructs.

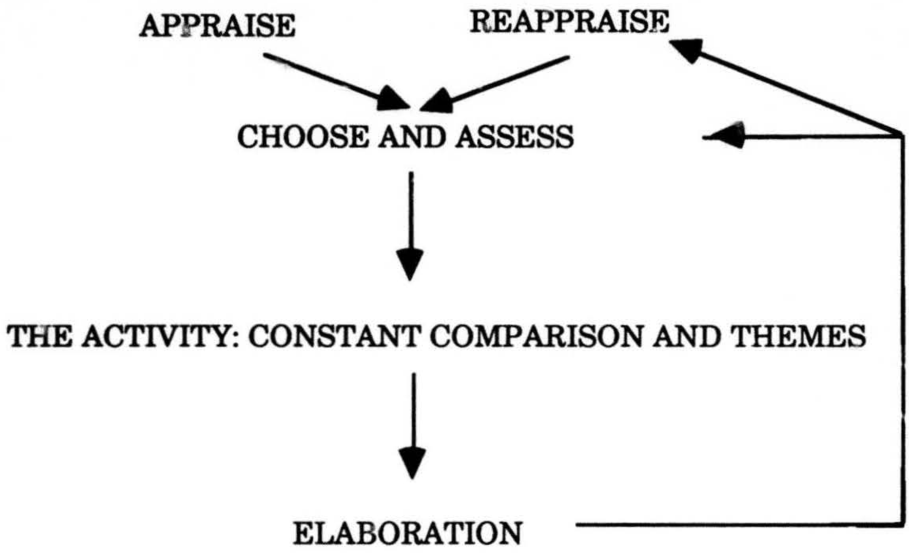


Figure 2. Diagrammatic representation of the instructional approach.

The approach has five main phases and these are now explained.

Appraise

At the start of each topic, the teacher's and the students' constructs about the science topic should be made explicit. The teacher needs to be aware of his/her construing of the topic as "... changes in the metacognition of students could only occur after changes in the teacher's attitudes, perceptions, conceptions and abilities; that is teacher's metacognition must precede that of the students" (Baird, Fensham, Gunstone & White, 1991). This is also consistent with the sociality corollary which informs us that students will enact a role in relation to how they construe the teacher's constructs. So to understand the teacher's view of the science topic and how the teacher has interpreted the abstract science involved in the topic, students need knowledge of the teacher's construct system. Likewise, to bring about effective learning, the teacher must understand the construing system of the learner.

Students' own ideas need to become known to them as part of the student's metacognitive processes. Students specifically need knowledge of their ideas to be able to chose the direction of their own learning, to be able to think about their own theories and repertory grid technique would seem an appropriate technique to accomplish this.

Choose and Assess

As the students are now aware of the existing constructs, and it is their existing constructs which determine the direction of learning, the student should be given the opportunity to choose which learning event to perform. Choice would be determined by the ability to recognise learning events and this is determined by the student's existing constructs. This means students must have a high level of awareness of their ideas and it is quite likely that a number of learning events presented will look similar to the student.

By presenting a list of objectives for the topic to the student, the student will be able to select which objective to address next. Only those objectives which are close to the student's existing constructs and able to be encompassed by their permeable constructs will be recognised by the student. The teacher's highly abstracted order is not necessarily the best way for an individual student to approach the subject.

By presenting the student with choice at this stage, the student is empowered. Responsibility is placed on the student for their own learning at an early stage in the process and this is a fundamental tenet of PCP.

The students chose from their list of elicited constructs those constructs which they think would best explain the event about to be encountered. This process assists the student in becoming aware of their own basis for making judgements and construing external events. Not all events lend themselves to this predicting process.

The Activity: Constant Comparisons and Themes.

The student performs their chosen learning event and all the usual science classroom activities can be adapted with minor modification to suit this approach. The students' and the teacher's constructs are always the focus of any learning activity. There is discussion and constant comparison of students' ideas within groups and the class. Whole class discussions, with the students' own ideas being the focus, would be conducted on a regular basis.

In everyday life agreement is reached with others about events and processes, through discussion. Concepts and theories are developed this way. A social process in negotiating meaning is an accepted way to deal with phenomena and this process can work in the classroom because students from a similar cultural background may have common, similar constructs about external events. Questions that could be asked of students working in groups might be similar to the following:

1. How does your prediction of the event differ from the others in your group? Which is the best prediction ?
2. After the event. How does your interpretation of what happened compare to the other members of your group's interpretation ? What is similar ? What is different ? Are there any ideas that you like which help to explain what has occurred ?

Although much of the social construction is listed in this section it can occur in any part of the cycle.

The learning materials would have questions that ask students to write down their own ideas and then compare their ideas to other students or to the accepted science view. The teacher would share his or her ideas with students by interacting with individual groups and would present the accepted science view during whole class discussions. The accepted science view would be introduced with the awareness that it may be reconstructed by the student to make personal sense of it. Showing films and videos can also act as a source of constructs and allow students to interact with the pool of public meanings, but the focus is always the students' own ideas which are bought to bear in the particular context by being the focus of the lesson.

Most learning activities would start with students writing down their ideas. At the end of the learning event the students would write down their ideas and check any predictions. Were they confirmed or refuted ? During the event, and after, the student reflects upon the learning event. What characteristics about the event make the event the same as what the student may have seen before and what characteristics make the event different to other events ? The student notes key characteristics of the event. This helps the student to identify the recurring themes in events which helps in identification of future similar events to which existing constructs may be applied. This process assists in the elaboration of the student's construct system.

The teacher can explore the student's interpretation of the event, either individually or in a group. This could be an exploration of constructs, answers to questions, diagrams drawn or whatever the learning event required the student to do. Classroom profiles (Shapiro, 1989) are an excellent method of comparing constructs from person to person and assisting in the social construction of constructs.

Elaborate

With the new constructs gained from performing the activity the student then has the opportunity to further elaborate their construct system. They get the opportunity to explain similar events they have previously experienced and to apply their knowledge in a variety of predictive situations. Remembering is a construing process and we come to know our universe through successive interpretations of it, so successive applications of new constructs can result in the new constructs occupying a secure place in the student's hierarchical construct system.

A further aim of elaboration is to invoke mutually inconsistent subsystems so that the system with the correct explanation replaces the system with less predictive power and control. Private paradoxes and vacillations are to be expected and the teacher at this time may have the opportunity to scan constructs and spot mutually inconsistent constructs.

Real life situations should be chosen which are within the range of convenience of the student's constructs. The accepted science view can be introduced again for comparison with the student's view in order to assess which system has the greater predictive power. The overall aim with this process is to allow the building of superordinate constructs which allow further elaboration of the construct system.

At the conclusion of this phase the student would then move back to the CHOOSE part of the cycle.

Reappraise

Periodically the student should monitor changes in their thinking. This can occur in the ASSESS part of cycle when the student chooses their next activity. Changes will always occur. Those constructs, according to the student, which have most predictive ability will be reinforced in their hierarchical position as learning occurs and new constructs will appear, old ones disappear.

Repertory grid again would be a useful means of assessing changes in construing, enhancing the metacognitive value of the grid. The teacher should also periodically note changes in the students' and his/her own construing. This noting of changes in construing may serve as an alternative assessment procedure.

Teacher's Role

The teacher has freedom in this approach to perform many roles. Apart from the usual responsibilities involved with classroom management, the main responsibility of the teacher is to ensure that students' own ideas are the focus of the learning activities. With that principle in mind, any of the usual activities involved in science teaching can be adapted for this approach. In most instances, minor modification of standard activities will render them suitable for this approach. Examples of this process of adaptation are given at a later stage when details of the classroom materials are provided.

Kelly (1955) provided eight techniques which he used in a counselling situation. Teachers could develop techniques based on the following suggested interpretations of students' constructs. Most appropriately the developed techniques could be used at the reappraise stage of the instructional approach, but could be used whenever the teacher interacts with the student.

1. The student has things the "wrong way round".

2. The student uses an inappropriate interpretation for the event being considered.

3. Un - verbalised assumptions may prevent the inclusion of a new idea in the construct system of the student.

4. Internal inconsistencies exist in the construct system of the student.

5. The student holds constructs which have not been tested as to their personal predictive validity.

6. Interpretations are being applied in too limited or too broad a way.

7. The meaning of constructs need redefining.

8. New axes of reference need to be erected to enable a new point of view to be encompassed.

Formal assessment of learning outcomes is not incompatible with this instructional approach as long as it is recognised that the assessment is mainly for the institution's benefit. The student's personal knowledge would have already been validated and tested against events, and so for the student, assessment would mostly be unnecessary. A new rationale for assessment would need to be developed possibly based on the ability of the assessment instrument to reveal something new to the student. Methods of assessment which concentrate on personal knowledge will need to be developed and applied and this issue is addressed in the conclusion to the thesis.

To conclude this section, Table 3 is presented. This table makes explicit the links between the seven propositions and the implementation of the propositions in the instructional approach. In conjunction with Table 2, this table makes clear the grounding of the learning approach in PCP.

Table 3

Links between the propositions and phases in the learning model.

Proposition	Phases of the model
1. ***The direction of learning is determined by the learner's existing constructs***	Choose, Assess
2. ***Learning is about the elaboration of a construct system.***	Constant Comparison, Themes, Elaboration
3. ***Learning, questioning and exploring occurs continuously and actively.***	Constant Comparison, Themes, Elaboration
4. ***Events can be interpreted in a large number of equally valid and equally possible ways.***	Constant Comparison
5. ***Learning involves a change in a person's construct system.***	Constant Comparison, Themes, Elaboration
6. ***Construing is a refining process leading to abstraction and generalisation.***	Elaboration
7. ***Learning in science involves construing the construction processes of scientists, teachers and students.***	Appraise, Reappraise

Comparison of the Instructional Approach with Other Approaches

The general constructivist ideas of Driver and Bell (1985) were introduced in Chapter 3. Using these very general principles, the scheme in Figure 3 was developed by three groups of 10 teachers, at the end of a year spent working under the guidance of a separate researcher. All three groups devised a teaching scheme which was designed to take account of students' prior ideas in a topic and to promote conceptual change. The sequence in Figure 3 is a result of input from researchers,

the literature and the teachers involved. The result is perhaps just one of many constructivist approaches that could result from Driver and Bell's (1985) general principles, depending upon inputs and teachers involved. However it represents an instructional approach which takes into account the many practical constraints operating in classrooms.

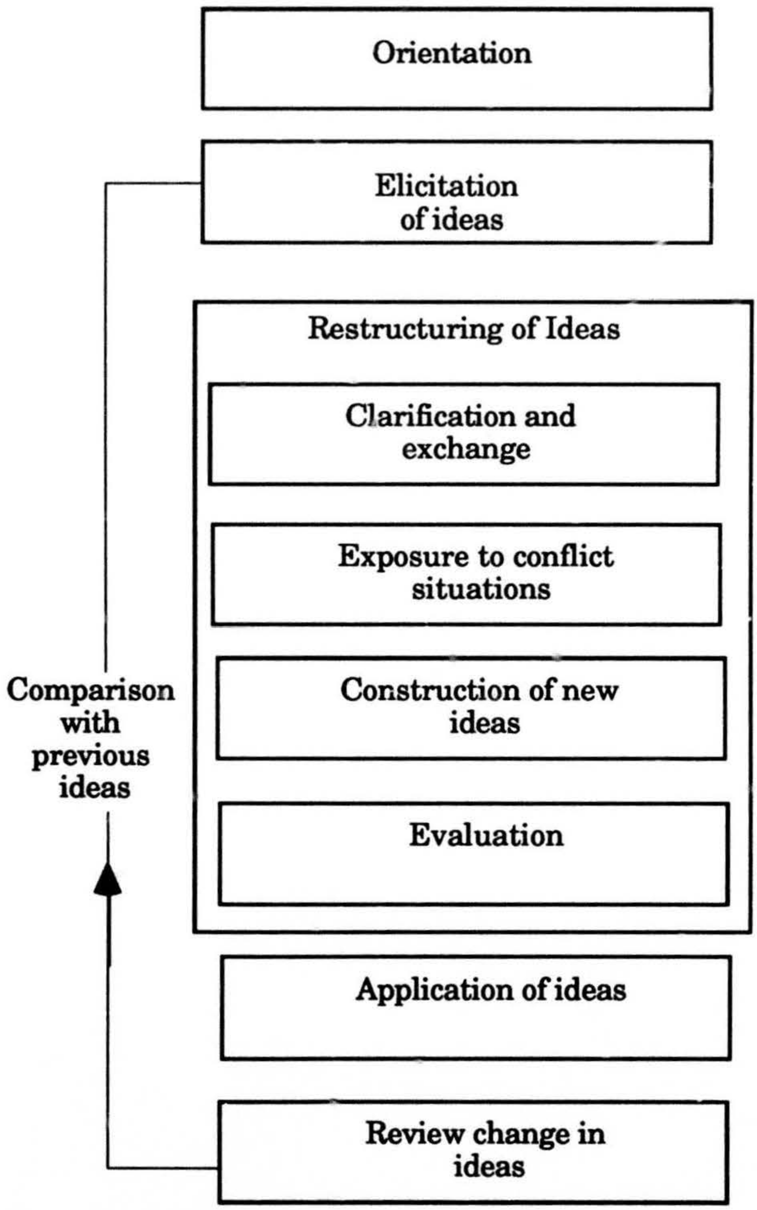


Figure 3: Structure of teaching sequence, from Driver (1985).

The teaching sequence above has four main phases; orientation, elicitation, restructuring, and application. Orientation has no direct parallel in the PCP instructional approach. Orientation is described as "...activity in which students attention and interest in the topic is aroused" (Driver, 1985, p.143). PCP has as a fundamental assumption that this is unnecessary.

Elicitation occurs in small groups and involves each group representing their ideas on a poster and then presenting their ideas to the class as a whole. Similarities and differences are noted by students and the posters are displayed. It is unclear whether ideas are discussed as a whole class at this stage. In the PCP instructional approach, ideas from students and teacher are elicited as a first step at the appraise stage. These ideas are then constantly compared throughout the learning activity and this constant comparison is a fundamental difference between these two approaches. The ideas are constantly discussed and recorded on an individual, group and class basis and are always the focus of the learning activity.

The restructuring phase of Driver's (1985) teaching sequence can involve some or all of the following; broadening the range of a conception, differentiation, building experimental bridges to a new conception, unpacking a conceptual problem, importing a different model or analogy, progressively shaping a conception and constructing an alternative conception. This phase is most like the elaboration part of the PCP instructional approach and most of the above process would occur in this part of the approach. If the word concept is replaced by construct in the above list then the processes occurring in the two approaches are very similar. However the PCP approach would incorporate Driver's (1985) application phase into the elaborate part of the approach.

As can be seen there are similarities between the two approaches. The PCP approach has additional phases. These are choose, assess and reappraise. Additionally the main activity of the PCP approach occurs during the constant comparison and themes stage whereas in the teaching sequence above the main activity seems to occur during the equivalent of the elaboration phase.

The general assertions of Osborne and Wittrock's (1983) generative learning model have been described in Chapter 3. The practical teaching model that resulted from those assertions (Cosgrove & Osborne, 1985) had three distinct phases called focus, challenge and application preceded by a preliminary phase.

In the preliminary phase, the teacher determined the students' scientific and historical views through surveys or other activities. This would correspond to the appraise stage of the PCP instructional approach.

The focus stage involved the teacher establishing a context, providing motivating experiences and the student becoming familiar with materials, thinking, asking questions, describing what he/she knows, clarifying own view and presenting their own view to the class. The activities of becoming familiar with the materials, thinking, asking questions, describing, clarifying and presenting would be contained in the constant comparison section of the PCP instructional approach. The constant comparison section contains many more operations than these. Establishing a context and providing motivating experiences are not necessary in the PCP approach as students will construct their own context for presented materials. The issue of motivation has been previously addressed.

The challenge phase involved consideration of the views of all the others in the class and comparison of the scientist's view and the class's view. This is the main focus of the approach derived from the generative learning model according to Cosgrove and Osborne (1985). All the activities in this phase are contained in the constant comparison section of the PCP instructional approach.

The application phase involved solving practical problems and the discussion and evaluation of the solutions to these problems and this corresponds to the elaboration stage of the PCP approach. However the elaboration stage has an emphasis on the successive interpretations of events, the invoking of mutually inconsistent subsystems and ongoing comparison of ideas with the ideas of others. Consequently, it is a more important stage than the application phase of the approach derived from the generative model (Osborne & Wittrock, 1983).

All of the stages of the approach derived from the generative learning model (Osborne & Wittrock, 1983) are contained in the PCP instructional approach and there are many similarities between the two approaches. This is not surprising given Osborne's familiarity with Kelly's work. The PCP instructional approach has some important differences apart from those mentioned already. The PCP approach puts more emphasis on the teacher's ideas in the appraise section, recognising the importance of these ideas as representative of the pool of public meaning. Students are given the right to choose the order of completion of activities because they are in the best position to choose, there is some assessment of the predictive power of a student's ideas before commencing an activity and there is a systematic reappraisal of a student's ideas to make apparent any changes in their construal of the topic. Finally the main difference between the two approaches is that there is much more comparison of ideas between teacher, students and groups than what is apparent from the generative approach.

Conclusion to the Chapter

This chapter has completed the process, begun in Chapter 2, of evolving a learning approach based upon a constructivist psychology. In this chapter, the practical instructional approach was presented together with a table showing the connections between the practical approach and the previously derived seven propositions.

CHAPTER FIVE

The Learning Materials

Introduction

In this chapter, a rationale is developed for the choice of science topic in which the model was trialled. This is followed by examples of the learning materials to illustrate how the instructional approach was translated into practical learning materials for use in a science classroom.

Why Energy ?

Any lower secondary school science topic taught in Western Australian schools would be suitable for this approach. The topic of Energy was chosen for the study because of the particularly abstract nature of the subject. Energy assumes a prominent position in the Western Australian secondary science curriculum. It is a subject which students can encounter in two different units in lower secondary school, as well as a concept that is used in many other units where it is often used as a unifying theme. Energy is a complex and abstract idea that is subject to idiosyncratic interpretation as students translate this school science idea into their own personal understandings. The reverse translation also occurs as students use their everyday, energy related terms in the abstracted and formal domain of science knowledge (Duit, 1984). The individual meaning given to concepts of energy can result in students constructing scientifically inappropriate frameworks around concepts such as the transfer of energy. For example, energy is thought by many students, as residing in an object rather than existing in an available state. This idea seems to be reinforced by the teaching of the idea that energy cannot be created nor destroyed; so it must be around and residing in objects (Solomon, 1985). Another example is provided by Ogborn (1986) who suggests that students link the diminution of sources of energy with the disappearance of energy itself. Because of the existence of these well documented scientifically incorrect ideas, they can be used to assess the impact of the teaching approach on students' alternative frameworks and personal knowledge.

"The teaching of energy is dogged by a variety of problems" (Boyes & Stanisstreet, 1990, p. 514) and in attempts to overcome these problems researchers have concentrated their efforts in two main areas; the identification of the general frameworks students have regarding energy and the specific conceptions held by students. An approach which allowed students to interpret the highly abstract ideas about energy into their own domain would seem to be of use in this curriculum topic. The abstract nature of the subject would provide a sound test for the approach.

The Learning Materials

According to Berman and McLaughlin (1979), three processes may occur when curriculum innovations interact with settings. Firstly, innovations may adapt to the indifference and resistance to change by the participants and no change takes place in the participants. The second process which may occur is one of non-implementation where no adaptation occurs by either the innovation or the participants. The third process which may occur is one of mutual adaptation where both the project design and the institutional setting change as a result of interaction. Also according to Berman and McLaughlin (1979) successful institutionalisation is dependent upon the degree to which individuals assimilate the innovation into their regular routine.

To encourage assimilation of this innovation into the participating teachers' classroom practice, the approach taken was to free the teachers of any additional preparation or work involved with the approach beyond usual legal requirements of the teachers. In the implementation of the learning approach, the decision taken was to base the learning around a student workbook which contained most of the learning events needed by the students couched in terms of the model to be implemented. This would free the teachers from acting in their traditional roles and allow them to assume a different role as required by the approach. This method would also ensure a consistent application of the approach (only in terms of making students' ideas always the focus) in the classroom setting. The teacher's role was defined in an earlier chapter and the question of role is addressed again in the final chapter of this thesis.

In the design of the materials, existing texts and activities were adapted and where necessary new activities were designed. What follows is a description of how the learning model was incorporated in the design of the curriculum materials.

The Student Workbook

Before commencing the topic, students and teachers completed a paper and pencil repertory grid episode designed to elicit their constructs regarding energy. This not only served the requirements of the APPRAISE section but served as a data gathering instrument which was used to assess changes in the teacher's and students' construing about energy. As such it is described more completely in the data gathering section of this thesis and the results from this grid episode are discussed in the results section of this thesis.

Following the repertory grid episode and before the start of the topic students were asked to CHOOSE which section of the energy topic they would like to commence with. This was done by presenting the students with a list of topics as below (abbreviated):

ENERGY - WHAT IS IT ?

WHAT HAS ENERGY

FORMS OF ENERGY PART 1

FORMS OF ENERGY PART 2

Figure 4. An abbreviated list of topics.

Each of the above titles had a page number listed which referred to the title page of the section. This page contained a description of the section to help students make their choice. The description from the section titled "Energy and the House" is presented here as an example:

> In this section we look at the use of energy in the house and how the use of energy might be reduced. How to read an electric meter, how to read an electricity bill and how to design a low energy house are the topics looked at in this section.

Students were also instructed to browse through each section to help make their choice of order.

Following the title page for each section, there was a page designed to help students ASSESS which of their ideas may be useful in that section. Instructions were identical to this:

BEFORE I START

Look at the grid you completed at the start of this topic

Write some constructs (ideas) which YOU THINK MAY BE USEFUL when talking about what energy is. You can write down both sides of the construct or just one side. You can also write down any ideas that occur to you which you have not written down before.

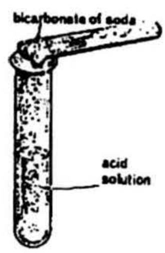
My useful ideas

Figure 5. Example of page used by students to list useful constructs.

After listing their ideas students performed the activities which generally were tried and proven classroom learning events, modified so that emphasis was on the students' own ideas. A typical page looked like this:

MIX DILUTE HYDROCHLORIC ACID AND SODIUM HYDROGEN CARBONATE.

1. What do you observe ?

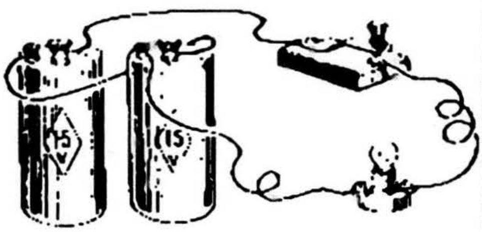


2. Is energy present in the test tube ? How do you know ?

3. How do you know the chemicals in the test tube had energy ?

SET UP A TORCH CIRCUIT

What happened when the switch was closed ?



Is energy present in the battery ?

How do you know ?

What has energy ? Page 5

Figure 6. Example of a learning event.

The event above was followed by a page which emphasised the student's ideas, the sharing of those ideas with other students and the comparison of their own ideas with scientists' ideas:

Now write YOUR defintion of energy here:

Discuss in your group,the different definitions of energy. See if you can agree on a shared definition of energy. Write your GROUP definition below:

When everyone has finished agreeing upon their group definition then your teacher will write your definitions on the board. He will also write a scientists' defintion of energy.

Copy the definitions in the space over the page.

What is energy ? Page 5

Figure 7. Example of a technique used for comparison of ideas.

The comparison of the learning event with other events usually occurred towards the end of each section. For example, students were asked questions similar to below, to assist in the recognition of recurring THEMES.

Discuss each of the following situations in your group. For each situation discuss things like where the energy was wasted, what was meant to happen and what could be done to save energy. Record your own ideas, when the discussion has finished in the space under the situation.

1. A person drives his car 100 metres to the corner shop to buy some milk.

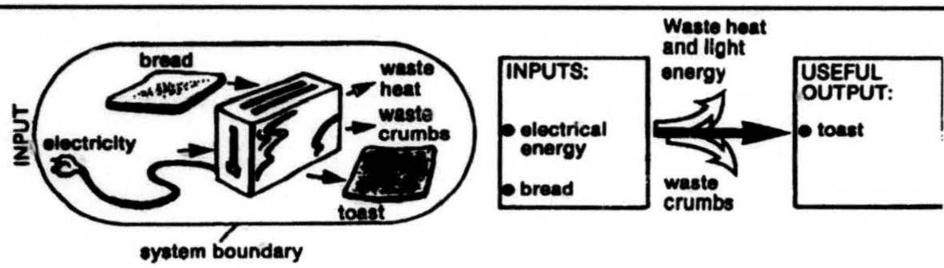
2. Should a two piece toaster be used to toast one piece of bread ? Should we toast bread at all ?

3. Should a jet plane be used to carry 50 passengers to Sydney, when its capacity is 250 people?

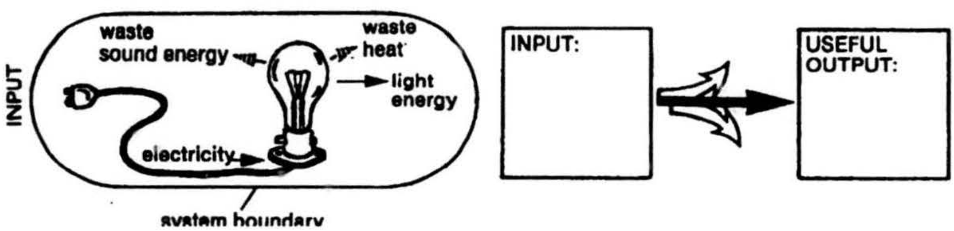
Efficiency Page 11

Figure 8. Example of technique used for comparison between learning events

Each student had many opportunities to compare their ideas. This occurred mainly in three ways: by comparing ideas with others in the group; through discussion with the teacher, either individually or in a group; and from classroom profile (Shapiro, 1989) episodes. The comparison of ideas with others sometimes was formally written into the learning materials as in Figure 9.



Discuss with another member of your group what is occuring in the above energy transfers. Write in your own words what is occuring.



Discuss with another member of your group what is occuring in the above energy transfers. Write in your own words what is occuring.

Efficiency Page 9

Figure 9. Example of how ideas may be compared between students.

Comparison of ideas occurred informally through the encouragement of discussion in groups or individually with the teacher. The teacher was encouraged to perform the role of a person who could provide yet another source of ideas that could be used as a basis for comparison. Classroom profile (Shapiro, 1989) episodes were also conducted and as discussed in the results section of this thesis, proved powerful learning episodes. Usually these events were conducted by the teacher displaying an overhead projector transparency of a cartoon representation of a situation to do with energy similar to Figure 10.

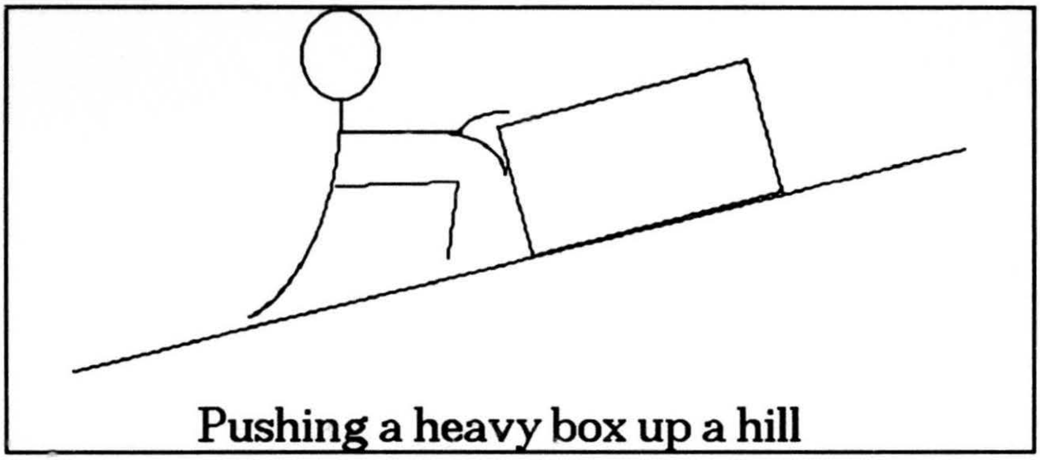


Figure 10. Example of diagram used in classroom profile episodes.

Students were asked to list their ideas before discussion and after discussion. Again this assisted the metacognitive aspects of their learning and helped in the comparison process. Comparison was also carried out by students answering questions at the end of each section:

> In your own words write down what were the most important ideas you have learnt by doing this section. Write just a brief summary of the ideas.
>
> Look back at the ideas you wrote at the start of this section. Which of the constructs (ideas) proved most useful to you in helping to learn while you were working in this section ?

Figure 11. Example of questions used at end of each section

These questions provided a check on the predictive power of students' elicited constructs.

The students were provided with an opportunity to ELABORATE their construct system through activities which were usually provided at the end of each section. These activities provided the students with a chance to apply their new personal knowledge in a variety of predictive situations. An example is shown in Figure 12.

Submit a one page report on one of the following topics. Will the world run out of energy ? How long will the sources of energy that we use everyday last ? Which nations use the most energy ? How "clean" are the common forms of energy that we use ? Design a house that uses alternative energy sources to those normally used. Choose a topic of your own in which you are interested. Discuss the topic with your teacher.

Figure 12. Example of elaboration exercise.

The REAPPRAISE part of the cycle occurred mostly in the ASSESS part of the cycle when students chose which constructs may be useful. A repertory grid episode to elicit students' ideas about energy was held about halfway through the topic to enable students to REAPPRAISE their ideas.

Conclusion to the Chapter

This chapter presented examples from the learning materials showing how the instructional model was translated into practical learning materials. A rationale for choosing energy as the topic for implementation was also presented in this chapter. As a conclusion to the Chapter it is useful to list the features of this approach which distinguish this approach from other approaches, both traditional and constructivist.

This approach:

1. determines students ideas before commencing topic (using repertory grid techniques);

2. asks students to assess their ideas in regard to their predictive power before commencing an activity and at the conclusion of the activity;

3. assists students to identify recurring themes;

4. allows students complete freedom of choice of order of completion of sections;

5. insists upon continual discussion between teacher and group and teacher and individual;

6. Constantly compares ideas between students and between students and teacher;

7. periodically and consistently assesses ideas held by the class (classroom profile); and

8. insists that students elaborate their ideas.

This approach does not:

1. insist that all students address the same content at the same time;

2. insist that students read text books;

3. make students answer set questions on content;

4. make students take notes or construct their own notes about content;

5. make students rote learn notes;

6. revise content;

7. make students sit in rows; and

8. insist that students only occasionally talk.

The main activity in the classroom where the approach was implemented was continual student and teacher talk. The main writing activity was the recording of student's own ideas and the ideas of others. In a traditional classroom there is usually minimal talking and a lot of writing in the form of notes, summaries and the answering of questions.

CHAPTER SIX

Data Collection Methods

Introduction

This chapter begins the second part of the thesis in which details of the implementation and evaluation of the learning approach are presented. In this particular chapter the methods used to gather data are explained together with the related issues of reliability and validity. Figure 13 lists the function and context of the data gathering methods. Each of the data gathering methods listed were used, in all three classes, before and after the implementation of the instructional approach except for classroom observation which was ongoing in the two classes which implemented the constructivist approach.

Sample

Students

The study involved three classes of Year 9 students attending an inner suburban senior high school in Perth, Western Australia. Students were allocated randomly at the start of the school year into classes and were therefore similar in range of ability. Students come mostly from a middle to upper socio - economic area and the school has an academic orientation with high numbers of students completing five years of secondary schooling. The classes in this study are identified by their teacher's names, which are not their real names.

In Sean's class there were 17 girls and 14 boys, in Rob's class there were 20 girls and 13 boys and in Rick's class there were 12 girls and 18 boys. Sean and Rob implemented the approach in their classes and Rick's class studied the topic in the traditional manner.

Teachers

Sean has a Mathematics degree, a Physics degree, a Diploma of Education and had completed a Master's preliminary course. Currently he is completing a Master's degree in Education. Rob has a Physical Science degree and a Diploma in Education as does Rick. Sean has been teaching for 15 years with four years at this school. Rob has been teaching for 20 years with 17 years at this school and Rick has been teaching for 12 years with five years at this school.

Description of Rick's teaching

Some description of the teaching that occured in the traditional classroom is necessary to enable valid comparisons to be made with the constructivist classrooms.

Rick was part of a group of five teachers who were responsible for most of the physical science teaching that occured at the school. In general the organisation of this teaching involved one teacher being assigned responsibility for the programming of a particular topic. This required the production of a document which listed the objectives, content, resources and text references for the particular topic. After the production of the programme, all teachers teaching that particular topic used that programme which ensured a uniformity of coverage of content amongst the various classes studying the topic. Such uniformity made comparability between classes easy in terms of assigning grades and because each class sat the same test and each class did the same larger assignments, grades were assumed to be comparable between classes. A small and varying amount of each student's assessment was able to be determined by the teacher of the particular class thus allowing some freedom in the coverage of the content and choice of assessment items.

In teaching the topic Energy Rick worked from a document produced as outlined above that had been in existence for a number of years. The approach taken by Rick in his teaching of the topic was regarded by the researcher to be reasonably typical of the approach taken by most science teachers in Western Australia.

Lessons usually involved some combination of the following strategies: practical sessions; teacher led discussions; book work; video watching and discussion; and library research sessions. In practical sessions students usually interacted for some time with laboratory equipment. These lessons would start with some teacher discussion of what was to occur in the lesson followed by an exposition of how to conduct the practical work. During this time students would follow a pre prepared worksheet which would also contain instructions on what to do. The worksheet would also usually contain tables for entering results and questions to answer during and after the practical session. The practical work was sometimes labelled an experiment though rarely could the practical work be deemed a true scientific experiment as mostly it just demonstrated some scientific principle. During the practical work students were free to interact with each other within the group. Interaction between groups was discouraged. Generally towards the end of the lesson students would pack away any equipment, complete worksheets and then sit back in their seats. The teacher would then discuss the session and students would sometimes write notes and/or answer questions about the scientific principles involved with the practical work.

In teacher led discussions, the teacher would discuss the topic with the class as a whole. These sessions would involve mostly the use of questions which students would answer supplanted by the exposition of new material. The questions would generally focus on the scientific principles involved and would rarely focus upon students' own idea. Attempts were usually made to relate the questions to concrete examples. Discussions would rarely last the whole session because students would become restless so they were occasionally supplanted with some note taking, written answers to questions or the performing of a calculation.

Bookwork involved students reading from a set text and then answering questions on the read material. The questions were found at the end of sections in the book and answers were usually to be found in the text. After most students had finished the teacher discuss the questions with the class and confirm that the students all had the right answer. In the Energy topic, students had to be able to perform some simple calculations involving energy quantities. These would be demonstrated by the teacher and then students would perform similar calculations with answers being checked by the teacher.

Video watching, which occured twice during the topic energy, involved students watching a video for about half the lesson followed by discussion of the content of the video. Some notes were taken by the students. A library research session was held once where students were given a set task to complete in the library within the period. If the work was not finished then students had to complete the task in their own time. The set task usually formed part of the student's assessment for the topic.

The students finished the topic with a set of notes which comprised summaries of important scientific ideas, calculations, results from practical activities and photocopied worksheets. This set of material comprised the content to be learnt for the topic test and students were helped in this task by the teacher conducting revision of the material close to test time.

Hands-on practical work and teacher lead discussions were the main approaches taken by Rick. Rick would be regarded as an excellent teacher (as would the other two teachers) having an agreeable classroom manner, relating well on a personal level with the students in his class and managing the class well.

Data Collection Methods

Data were gathered using a range of tests, interviews and observation. These are summarised in Figure 13.

Method	Function	Context
Repertory grid technique.	Identification of personal science knowledge about science topic, before and after instruction.	Performed with whole class in normal science class, in normal science time with researcher showing students technique.
Interview - About - Events technique.	Identification of 12 students' ideas about energy	Students interviewed individually in adjacent science classroom, in science time by researcher.
Questions - About - Events	Identification of all students' ideas about energy	Administered in science classrooms during science lesson time.
Recording of observations.	Identification of teacher's approach to implementation.	Recorded during learning activities being performed by students. Recorded in science classroom in science lesson time.
Energy questionnaire	Identification of students' beliefs about energy, before and after implementation.	Performed with whole class in normal science class time.
School science test	Identification of students' school science knowledge about energy, before and after implementation.	Performed with whole class in normal science class time.
Teacher interview	Identification of teacher's epistemology regarding science teaching	Teachers interviewed individually in adjoining room to science classroom, during a lunchtime. Post interview conducted with paper and pencil at teacher's leisure.

Figure 13. Delineation of context of methods

Each of the data gathering methods is now described in detail.

Repertory Grid Technique

Repertory grid technique was selected as an appropriate means of determining students' constructions about energy, because this was congruent with the philosophy of the learning approach with its emphasis on personal construction.

Repertory grids can yield data of breadth and depth from individuals. Unfortunately in a classroom containing 30 individuals, the technique is too time consuming to administer on an interview basis, which is the usual administration form. Consequently a paper and pencil version of the repertory grid was constructed in two forms. One form used supplied elements and elicited constructs and the other form used supplied elements and supplied constructs.

Supplying elements and constructs is an accepted repertory grid technique. Fransella and Bannister (1977, p. 19) suggest that supplied constructs present "the verbal label to which the person will attach his personal construct". They further suggest that it is essential that labels be meaningful to the subject. To achieve this personal meaning, it is usual practice to collect a sample of constructs from the sample group or a comparable group which can lead to the safe assumption that the most common constructs from the group will be individually meaningful.

An advantage of supplying constructs and elements is that it enables comparisons to be made between the ratings of the same elements on the same constructs before and after the teaching approach. Quantitative methods can be used to compare the class, as a group, before and after the teaching approach is implemented. The use of supplied elements and constructs reduces the grid to basically a questionnaire. As such the data represents students' view of school science. This form of the grid is often called a normative grid.

By allowing students to supply their own constructs, valuable information about how students individually view their world of energy can be obtained. By combining this essentially qualitative view of energy and the quantitative normative grid a comprehensive view of the class's and individual's construing of energy was obtained.

The supplied constructs for this study were derived from the list of objectives specified for the topic Energy 8341 (Curriculum Branch, Education Department of Western Australia, 1987, p. 59) and are a representative sample of the objectives listed in that document. Elements were also supplied from the same source and the elements were likely to be within the students' domain of discourse. Supplied elements were:

Solar energy

Electricity

Energy from food

Energy from coal

Nuclear energy

Energy in a moving bullet

Stored energy

Energy from chemicals

Heat energy

The 15 supplied constructs were:

Natural / Man made

Involved in photosynthesis / Not involved in photosynthesis

Used as energy for our bodies / Not used as energy for our bodies

Causes pollution when it is made / Does not cause pollution when it is made

Involved in respiration / Not involved in respiration

Can be used to do work / Can't be used to do work

Easily stored / Not easily stored

Can cause movement / Can't cause movement

Can exert a force / Cannot exert a force

Easily converted to other forms / Not easily converted to other forms

Visible / Invisible

Used by machines / Not used by machines

A common source of energy in Australia / Not a common source of energy in Australia

Can occur as waste energy / Does not occur as waste energy

Originally came from the sun / Did not originally come from the sun

Constructs were elicited on the last two days of the term preceding implementation of the learning approach and again immediately following the conclusion of the implementation. Preceding instruction, students were given a short introduction to the technique, using dogs as an example. Students own constructs were elicited first followed immediately by students completing the normative grid. No time limit was set and all students had finished within 30 minutes. A copy of both versions of the grid is supplied in Appendix 1.

Analysis of data from repertory grids

Data from grids, being basically a matrix of numbers, can be analysed statistically in many ways. Some ways of analysing these grids are briefly listed. The range of ratings can represent a measure of the range of convenience of a construct. The mean value can indicate general lopsidedness which is the tendency to rate towards one pole. Standard deviations indicate the degree of spread of ratings along a construct. Correlations, usually product-moments, show how each construct or element relates to every other and is generally regarded as a satisfactory association measure. Average (RMS) correlations can show the general level of association with other constructs and squared multiple correlations can demonstrate, in terms of variance, how each construct is influenced by the others. This allows some inferences to be made about hierarchical nature of the constructs. Fransella and Bannister (1977) indicate that higher correlations show a more superordinate construct.

Another very good general measure of association is Eta, derived from ANOVA techniques, which can be interpreted in a similar way to usual correlation coefficients. This measure "is the only effective measure" (Bell, 1987, p. 32). Eta squared shows the amount of variance in one construct that can be predicted by another and so can indicate asymmetric relationships between constructs from which hierarchical structure can be inferred.

Superordinancy can also be indicated by using Landfield's (1977) ordination index. This gives information about how well a person can differentiate along a scale of meaningfulness.

Essentially a within- construct measure, it is calculated using the following formula:

$$\text{Ordination} = \frac{\text{Number of score levels used} \times \text{Range of scores}}{\text{Maximum possible levels} \times \text{Max. possible range}}$$

The maximum possible number of levels is defined as the number of elements, the maximum possible range is defined as the maximum and minimum ratings in the whole grid. This measure makes the assumption that the more extreme an element is rated the more meaningful it is and hence the more superordinate is the construct. The ordination index could be used as a measure of change in a student's construct system to assess the fundamental assumption of learning in PCP that learning involves a change in a construct system. In this study, the measure was applied to normative grids to determine any changes in importance of supplied constructs. Ordination indexes will be calculated using the computer software package G - PACK (Bell, 1987).

Principal components analysis can be used with the normative grid to reveal specific relationships between elements and constructs, using a technique, attributed to Slater (1977), but deriving originally from Eckart and Young, (1936). This technique maps elements and constructs in the same metric space which, for convenience, is displayed as a two dimensional figure. The two axes of the figure are the first two components of the principal components analysis. In interpreting the map it is important to know the percentage of variance explained by each of the two components as elements and constructs may appear close on a two dimensional diagram but in reality be separated by a considerable distance on the third or higher component. The main use of this technique is to identify groupings of constructs and elements and this technique was used in this study as a general measure of association of elements and constructs.

Correlations between elements and constructs can be calculated from loadings on the two axes (components) displayed on a principal components map and are directly related to the angular separation of the elements or constructs which comprise and define the space involved. Specifically the correlation is related to the cosine of the angular separation. These measures of correlation can be used to determine the extent of change between any elements or constructs in a before and after situation. These correlations will not be calculated in this study as they imply a level of precision in the description of each person's intrapersonal cognitive space for which there is no theoretical basis. Instead less precise words such as close, closely associated with and near will be used to indicate groupings on the principal components map.

Cluster analysis can also be used to reveal associations between elements or between constructs but not both at the same time. The FOCUS algorithm as described in Shaw (1980) which is basically a single linkage clustering of city-block distances, is usually used.

Being essentially a qualitative, individualistic method, repertory grids elicited from groups need special techniques to gain some measure of group construing. Students in classes in this study completed grids where they supplied their own constructs and hence some measure of the class's construing, as a unit of study, needed to be developed based on students' own construing. A method was developed to examine all constructs from all participants and establish common groupings of constructs (Fetherstonhaugh, In press). The method assumes that the person doing the grouping attaches the same meaning to the verbal labels as does the respondent. This grouping method gives an indication of common construing and was used in the analysis of grids in this study.

Another method of analysing individual grids to create some common grid is the creation of a mode grid (Shaw, 1980). The creation of this grid involves treating all individual grids as if they were one single grid. This enables the most common ways of ordering the elements, based on all the constructs, to be established. This method indicates constructs that show high levels of agreements, across all participants, in terms of the patterns of ratings of the elements. Once mode constructs have been identified then a mode grid can be established which can then be subjected to all the above statistical analyses if deemed necessary.

With data from the normative grid, means for each rating of each element on each construct were found for each class. This enabled means for before and after tests to be t-tested for significant differences to assess changes in the classes construing. Principal components maps were then constructed from these grids and groupings of constructs and elements were identified.

Reliability of the repertory grid

At this stage it is appropriate to comment upon the reliability of the repertory grid technique. Firstly it should be stated that the repertory grid is not a test. Many people unfamiliar with the technique assume that because a matrix of numbers can be established, that quantitative ideas of reliability can be applied to the test. Repertory grid techniques which use elicited constructs have more in common with structured interviews than any other techniques (in fact many grids are elicited in a conversational manner) and concepts regarding reliability and validity that can be applied to techniques such as interviews are the applicable concepts to apply to repertory grids. However the reliability of grids has been addressed in more detail than has the reliability of interviews.

The grid format is just a convenient format for entering data. Elements in the grid are not selected at random and the purpose of repertory grid technique is to show the state of mind of the participant at one particular time. Nevertheless the question remains: To what extent will different repertory grid episodes at different times, using the same elements, elicit the same constructs ?

If the method, structure and context of elicitation remain the same then the repertory grid technique appears highly reliable and this means it should elicit much the same constructs at different times. This assumes that the person is not changing. Hunt (1951) found that 70% of constructs elicited in his study were repeated on a second occasion a week later. More elaborate experiments suggest a correlation of 0.80 between first and second sets of elicited constructs with similar figures found for elicited elements. Spearman rho indexes for two grids have been used in a large number of studies and these generally yield reliability coefficients in the range 0.60 to 0.80. Bannister (1962) showed that for 30 subjects the average reliability coefficient for one particular construct (good - bad) was 0.80. Bannister (1962) also showed that establishing a normative grid (common elements and constructs) can yield very high reliability. Normative grids have been used in this study partly because of their reliability. He reported a reliability coefficient of 0.98 using established norms. Kelly (1955) reported that about 70% of constructs used at any particular time will be used at later times.

In summary it can be stated that grid technique is capable of being highly reliable, if normal qualitative constraints are adhered to. In this study, in order to establish high reliability for the science constructs, students and teachers completed normative repertory grids that contained common elements and common constructs. Additionally, grids were also completed that contained all common elements which further enhances reliability.

Energy Questionnaire

The questionnaire was based on a very similar instrument used by Boyes and Stanisstreet (1990) and used 11 identical and six similar items from that instrument. The instrument comprised 31 statements on two pages preceded by a cover page with general information about the questionnaire and two practice items. It was administered in normal science class time to all participating classes.

Statements about the same topic were grouped together in the instrument with five groups of questions being formed. These groups comprised statements about plants and energy, animals and energy, Australia and energy, general statements about energy and miscellaneous statements about energy. For example general statements about energy included the following statements:

Fridges take energy from food

We sleep to get energy back

Pulling and pushing are examples of energy

Energy is invisible

Machines use up energy

When you lift something you give it energy

Students were asked to respond to each of the items by rating the item on a five point scale using the following criteria:

1	means	I am sure this is right
2	means	I think this is right
3	means	I don't know if this is right or wrong
4	means	I think this is wrong
5	means	I am sure this is wrong

The questionnaire in its original form was administered by Boyes and Stanisstreet (1990) to 1130 British students between the ages of 11 and 16 in 47 groups. Results from their study were analysed with regard to the frequency of response in each of their five categories and gave good information about both the strength of belief and the alternative frameworks that students held about energy. Factor analysis was used in a search for common themes in the students' thinking and no reliability estimates were reported. Similar analyses were conducted on data gathered in this study and results are compared to Boyes and Stanisstreet (1990). The questionnaire provides good information about the effect of the learning approach on students' personal knowledge and beliefs.

Content validity was established through reference to listed objectives for the unit Energy 4.1 (Western Australian Ministry of Education, 1987). Questionnaire items were found to be representative of the objectives listed, by a senior science teacher unconnected with the study. As the questionnaire allows students to express strength of beliefs it has face validity. Construct validity was confirmed by participating teachers. Reliability estimates for the completed questionnaires are reported in Chapter 10.

The questionnaire was administered prior to and immediately following the implementation of the learning approach. Students were informed that the questionnaire was not a test and no time limit was set for completion. Most students had finished within ten minutes. A copy of the questionnaire is included in Appendix 2.

School Science Test

A school science test was constructed, based on the objectives for the unit. The test sampled the objectives and comprised 20 multiple choice questions each with four distractors. Identical questions were used in the pre and post test. Content validity for the test was provided by the participating teachers who confirmed the representativeness and comprehensiveness of the test. Face and construct validity was also confirmed by the participating teachers. Reliability estimates for the test are reported in Chapter 11. The test was used to determine how students' school science knowledge was affected by using the learning approach.

Data gathered from the test were analysed, using ANOVA to test for significant differences, to assess the extent of differences between classes using the learning approach and the class not using the approach. Also the data were tested for differences within each class in a pre and post test situation.

The test was administered prior to and immediately following the implementation of the learning approach. Students were informed that the test would not be used for school grading purposes and no time limit was set for completion. Most students had finished within 15 minutes. A copy of the test is included in Appendix 3.

Interviews-About-Events

This procedure can be thought of as an interview schedule based upon a set of phenomena. The procedure avoids eye contact and focusses the interviewee's attention onto a specific domain. The stimuli presented are usually real world and are related to the context of interest which, in this study, is energy.

Osborne and Gilbert (1980) cite many advantages of the technique over traditional techniques such as paper and pencil tests. Interview-About-Events (IAE) is applicable over a wide age range, students cannot easily ignore questions or omit reasons for answers or produce an answer by guessing, imprecise and ambiguous questions can elicit understandings, the student's commitment to a particular view can be tested and it can reveal a student's understandings even though the students cannot verbalise an explicit definition of the concept. Generally the technique can uncover the student's personal understandings of the event under consideration and this is the prime motivation for using this technique in this study. It provided another means of assessing students' personal knowledge along with repertory grid episodes and the energy questionnaire.

Some limitations of the technique are related to the choice of events, the ordering of events and the conduct of interviews. The choice of events should be a "judicious combination of theoretical analysis, comments from experienced teachers and feedback from discussion of possible instances with children" (Osborne & Gilbert, 1980, p. 319). The author believes that events should be chosen in the same way as elements are chosen in repertory grid technique. that is, the events should be in the range of convenience of the sample's existing constructs and be representative of the sample's universe of discourse. This means simply that students should be able to recognise the verbal label associated with the event and be able to ascribe some meaning to it.

The order of presentation of events is important as previous events can make a student think about a latter event in a new light. Trials can uncover problems associated with the order of presentation. The IAE instrument was trialled in a science classroom with ten students of age 14 years and no problems with the order of presentation were revealed. Additionally all students responded to the line drawings and gave meaningful information about them. No modification was made to the drawings before they were used in the study proper.

The style of presentation of the interview is important. To uncover the student's understandings, rather than recall of learnt definitions, an atmosphere of open dialogue was encouraged and an atmosphere of oral examination was avoided. An attitude of "there is no right answer, I want to know what you think" was encouraged. The desirability of this attitude made it difficult for the student's science teacher to be the interviewer and in this study the author conducted the interviews.

Four students from each of the three classes participating in the study were interviewed before and after the implementation of the learning approach. Two boys and two girls, selected at random from each class, were presented with 11 events to do with energy (a copy of the events is provided in Appendix 4) and interviews were recorded and transcribed. Interviews were conducted in normal school science time in an adjoining room to the science classrooms. Each interview lasted from 10 to 20 minutes.

Data from the interviews-about-events were transcribed and the transcripts were analysed to identify students' ideas about energy. This technique was used to corroborate and expand data from the repertory grid episodes.

Questions-About-Events

Because of time constraints it was impossible to interview every student involved in the study, using an Interview-About-Events (IAE) approach. However there was a need for another probe of students' own understandings apart from repertory grid technique. Any alternative probe should be able to be used with a large number of students and allow students the opportunity to express their own understandings. To allow this to happen, the author developed a technique called Questions-About-Events (QAE). This technique is based on Interviews-About-Events and involves presenting students with events in cartoon form on a sheet of paper. Next to each instance was a small number of open ended questions with space left for students to write down their answers. Questions were open ended to allow students to express their understandings in their own words and to avoid the rote recall of school science. Clearly there is little opportunity for students to express their beliefs in great depth but this technique is a reasonable compromise between a school science test, which elicits just school science knowledge, and an Interview-About-Events approach which elicits the student's own beliefs. As such students' responses to this probe tended to be a mixture of school learnt science and students' own understandings.

In this study identical events were used in IAE and QAE. Ultimately this could be used to enable some comparison to be made about the type of knowledge elicited by the two techniques as students who were interviewed also completed a QAE episode. All students involved in the study completed a QAE episode immediately preceding and following the implementation of the learning approach. These episodes were conducted in science lesson time and all students were finished in 20 minutes. Data from the episodes was examined and students' ideas about energy were categorised. A copy of the QAE instrument is included in Appendix 4.

Teacher Interview

The two teachers involved in the implementation were interviewed prior to the implementation in a semi-structured fashion. Questions asked were designed to allow teachers to reveal the epistemological basis for their teaching approach. This was necessary to see if the implementation had any effect upon the way the teachers viewed teaching and learning.

The teachers were interviewed singly by the researcher during a school lunch time prior to implementation. Both teachers and interviewer were uncomfortable during the interview and many reasons may be postulated for this. Because of this discomfort, teachers were given questions on two sheets of paper to answer in lieu of interview, following the implementation. The questions were based upon their responses to the initial interviews and were different for each teacher. A copy of the questions asked pre and post implementation is provided in Appendix 5.

Teacher's responses were examined for changes in construing regarding the implementation of the learning approach and for factors which influenced the implementation.

Classroom Observation

Classroom observation was necessary to gather information to answer the broad question of how teachers implemented the model and the influence of the teachers on the learning of the students. Systematic observation was rejected for the following reasons. Checklists narrow the interpretation of, and meaning ascribed to, observed actions. Checklists ascribe meaning to observed behaviour, that is, the observer's meaning and not necessarily the student's meaning. To fill in a checklist it is important that the observer not become part of the observed world which is quite impossible.

Systematic observation relies on a limited number of pre-defined categories as a basis for describing classroom activities which is an inflexible approach. The inflexible approach stops observers responding imaginatively to classroom events and so meaningful events which can impact on elements on the checklist can go uncoded.

This kind of observation de-contextualises the phenomena under investigation and results in atomistic data. In this study, the mood of the children, the relationship between the students and the teacher and the relationships between the students all of which ebb and flow on a daily basis were all important and are all difficult to code on a checklist.

Generally systematic observation checklists can be labelled positivist and behaviourist and many discussions of methodology suggest that there should be a relationship between the philosophical views of the nature of knowledge and the research methods used. For these reasons a checklist approach was rejected for this study.

> "As a final note, I am also worried by the metaphor underlying experimental research. The notions of our students as human subjects of study whose performance is analysed with statistics rather than at an individual level reduces their status as human beings (Roth, 1992, p. 632).

Postivism, phenomenology, and hermeneutics

According to Eichelberger (1991), phenomenologists use thinking, feeling, perceiving and other mental and physiological acts to describe and understand human experiences. Data are gathered by observation, reading documents produced by participants, interviewing and developing classification systems to represent the beliefs of members of the group.

A phenomenologist assumes a commonality in human experience and searches for the universal. Rigorous use of bracketing ensures that results from one study can be related to, compared with and integrated with results from other phenomenological studies of the same phenomenon.

Hermeneutic phenomenology is the study of interpretive meaning and is essentially a writing activity. In this approach all interpretation is an attempt to understand and is similar to interpreting a text. This involves opening oneself to, and questioning, the text. Hermeneutists believe that educational studies should not be nomothetic but should provide individualised accounts that describe the meaning of events to participants. They are after the meaning people ascribe to activities and how this relates to their behaviour. Reality is constructed by the interpreter on the basis of their interpretation of data with the help of the participants in the study.

In this study observations were gathered by observation of the two classrooms implementing the approach. The observations were collected by the author and hence the orientation is that of a pedagogue and the initial theme was related to revealing how teachers implemented this approach. Observations involved talking to individual students, to individual teachers, groups of students and observation of classroom discussion. All observations took place in the students' normal science classroom and observations were recorded in a journal. This journal was then transcribed verbatim to computer disk, immediately following the observation periods.

Reliability and Validity

In this section details are presented of methods used to enhance internal and external reliability and validity of the qualitative methods used in the study. Steps were taken to ensure that the findings are dependable, credible, transferable and confirmable (Guba & Lincoln, 1981).

Qualitative studies are commonly criticised because they fail to adhere to commonly accepted ideas about reliability and validity, imported from quantitative approaches. LeCompte and Goetz (1982) have addressed this problem by translating and making relevant the tenets of external and internal validity and reliability, as used in positivistic traditions, to research conducted using qualitative methods.

External reliability in qualitative research, according to LeCompte and Goetz (1982) refers to whether independent researchers would discover the same phenomena or generate the same constructs in the same or similar settings. Similarly, internal reliability refers to the extent that other researchers, given a set of previously generated constructs, would match them with data in the same way as the original researcher.

Validity is concerned with the accuracy of scientific findings. The establishment of validity requires determining the extent to which findings represent the empirical reality and whether the constructs devised by the researcher represent the categories of human experience observed. Internal validity is concerned with the extent to which observations and measurements represent the reality and external validity is concerned with the comparisons of the observations and measurements across groups. External and internal reliability and validity are now addressed with emphasis on this study.

External Reliability

Reliability refers to the extent to which studies can be replicated and because of the qualitative methods employed in this study external reliability can at best be approached rather than attained. However external reliability of the data can be enhanced, according to LeCompte and Goetz (1982), by handling the five major problems of researcher status position, informant choices, social situations and conditions, analytic constructs and premises and methods of data collection and analysis.

Analytic constructs and premises

Replication is impossible without delineation of the constructs, definitions and units of analysis used in the study. Such replication requires identification of the assumptions and theories that underlie the choice of terminology and analysis methods.

The study took place in three science classrooms in a Western Australian secondary school and this automatically incorporates a set of cultural assumptions. The school, class and teachers have all been described.

The underlying assumptions and theories that determine the choice of terminology are explained in the literature review, as are the general theory of PCP, the learning approach and propositions concerning the learning approach. The theoretical premises underlying the learning approach are clearly explained and this means the teaching approach can be replicated. The units of analysis are class, individual students and the teachers.

Methods of data collection and analysis

According to LeCompte and Goetz (1982) replication is impossible without precise identification and thorough description of the strategies used to collect data. The data collection techniques to be used in this study are described in the first part of this chapter as are the strategies for analysing the data.

Researcher status position

The conclusions reached in this study are qualified by the role of the researcher in the study and the respectability of the study is dependent on other researchers occupying the same role, so this rôle needs to be clearly defined. In this study the researcher acted as a designer of the approach and teaching materials and as a classroom observer. Additionally the researcher conducted all interviews and performed initial analyses of the data. The orientation of the researcher as stated previously was always that of the pedagogue.

Informant choices

A threat to reliability is manifested by informant bias. This, as in most quantitative studies, is handled by careful descriptions of the informants and of the decision process made in their selection. Self selection of informants was avoided because the students who are attracted by the study and the researcher may be atypical of the group. In this study, 12 students from three classes were chosen as representative of their whole class, with representativeness being determined by usual random sampling methods. This resulted in two boys and two girls being chosen from each class. The classes and teachers chosen for this study may or may not be typical of students and teachers in Western Australia. The choice of classes depended upon pragmatic factors such as proximity to the researcher, availability of the classes and willingness of the teachers to collaborate. The latter factor is important because of the collaborative nature of the research. However, the class and teacher are carefully described. Such detailed description of the sample enhances external reliability.

Social situations and conditions

The social context in which qualitative methods are used determines the content revealed to the researcher. This problem has been recognised by researchers in science education for a long time and contexts need to be described in studies which use qualitative methods. The description of contexts of methods used were listed at the start of this chapter.

Internal Reliability

The extent to which different observers will ascribe the same meanings to the same events and arrive at the same conclusions about the events is a measure of internal reliability. The agreement sought in most qualitative studies is of inter-observer reliability and this was enhanced in the initial stages by the use of low level descriptors of data. These descriptors were concrete and precise as possible. Categories established from IAE and QAE episodes were verified by a senior science teacher on a systematic basis and no disputes occured about categorisations. Repertory grid groupings were not confirmed as this was not deemed necessary due to the broad groupings used to classify students' constructs. More precise details of verifications are provided in chapters dealing with results.

Mechanical recording was used to preserve data. Interviews were recorded so that the veracity of conclusions could be confirmed by other researchers and raw grid data, journal entries and worksheets were kept for the same reasons.

Validity

Validity can be defined in terms of internal and external validity. Internal validity refers to the question of whether what we measure or observe is actually what we think we are observing and measuring; external validity is related the application of findings across groups.

Internal validity

High internal validity is the major strength of qualitative research. This is because of the techniques employed. By existing amongst participants the researcher can obtain a high match between established categories and participant reality. Interviewing is always framed more closely to the empirical categories of participants than quantitative instruments and observation is always conducted in the natural setting which is close to the reality of the participants. Finally, qualitative studies always involve a degree of self monitoring on behalf of the researcher that exposes all phases of the research to questioning and self evaluation which does not exist in quantitative research with its reliance on standard instruments.

History and maturation effects, and mortality can threaten the internal validity of qualitative studies. By conducting this study over a short time period of ten weeks most of these effects were avoided. Observer effects can also threaten internal validity. These effects are analogous to testing and experimentation effects in quantitative studies.

What observers see is a function of their relationship with the participants. Some entanglement did occur between the participants and the researcher, as the researcher was often present as observing and asking questions of students. Any effects due to the above were minimised by retrospective analysis of the data which recognised the relationship. External readers read drafts of chapters and analysed conclusions for implied facts, relationships and judgements which could have resulted from a close relationship with participants.

Science educators have rarely addressed the problem of reliability of interviews. The reliability of an interview "...is seldom mentioned, let alone estimated" (Shavelson, Webb & Burstein, 1986, p. 80). Informants may lie or omit relevant data and although this was minimised by the use of Interviews-About-Events and by the use of a range of different techniques to triangulate the data and findings from interviews. Multiple informants (12) were also used in this study to counter this problem.

Unusual observer effects such as research exhaustion or saturation were not observed in this study due to the relatively short nature of the research and clearly defined boundary to the study.

External validity

This study was a single site study and generalisibility depends upon the similarity of this site to other sites. External validity depends upon the identification of phenomena which are likely to be useful for comparison with other groups. In this study careful description of the setting and participants occured at the beginning of this chapter. Generalisation also depends upon the level of abstraction of findings from the study. It is an aim of the study to produce highly abstracted findings about the outcomes that occur when students learn in a constructivist fashion. These findings can then be compared to future studies.

Conclusion to the Chapter

This chapter described the data gathering techniques used in the evaluation of the learning approach. Issues of reliability and validity were also examined in relation to the quantitative and qualitative techniques used in the study.

CHAPTER SEVEN

Results From Each Class Using Supplied Constructs and Supplied Elements

Introduction

In this chapter, the results of repertory grid episodes using supplied constructs and elements are presented. The exercises were conducted with the three classes involved in the study before and after implementation of the learning approach. Students had to rate the supplied elements using the 15 supplied constructs and hence were completing a normative grid. The constructs were based on objectives selected from the State curriculum for the energy unit and verified by teachers participating in the study as representative of the objectives for that unit.

Mean ratings of each element by each construct were calculated for each class. The means represent a standardised measure and give insight into how students apply supplied energy constructs. Grids comprising mean values were analysed using principal components analysis.

Comparison of grids before and after instruction is used as a measure of the impact of the different learning approaches on the students' use of State determined constructs and consequently results are used to answer the first research question.

Repertory Grids and Principal Components Maps

Each of the normative grids from each class is presented followed by the principal components map derived from the normative grid. Associations revealed by each map are then discussed and each class is discussed in turn. Grids elicited before the implementation of the instructional approach are discussed first followed by discussion of grids elicited after the implementation. Rob and Sean's classes implemented the instructional approach and Rick's class was taught with traditional methods.

Before Implementation of the Learning Approach

Students rated each element on a scale of 1 to 5 on each construct. A rating of one corresponds to the left hand side of the construct and a rating of 5 corresponds to the right hand side of the construct. To assist computer analysis, the means reported in Figure 14 have the decimal point removed so that the scale now ranges from 10 to 50 with a midpoint of 30.

		1	2	3	4	5	6	7	8	9		
Natural	1	11	40	12	26	40	46	34	41	16	1	Man made
Involved in Photo.	2	12	48	21	43	47	50	37	37	25	2	Not involved in Photo.
Used as energy for our bodies	3	29	48	10	49	48	49	25	33	23	3	Not used as energy for our bodies
Causes pollution when made	4	48	19	44	17	17	34	34	19	35	4	Does not cause pollution when made
Involved in respiration	5	32	48	21	48	45	47	32	36	27	5	Not involved in respiration
Can be used to do work	6	16	12	16	15	15	34	24	22	20	6	Can't be used to do work
Easily stored	7	27	19	22	25	28	43	16	31	34	7	Not easily stored
Can cause movement	8	23	12	19	17	22	19	27	25	21	8	Can't cause movement
Can exert a force	9	29	22	31	27	20	15	28	28	21	9	Can't exert a force
Easily converted	10	22	22	17	18	27	39	25	22	31	10	Not easily converted
Visible	11	40	32	41	38	33	38	43	32	35	11	Invisible
Used by machines	12	19	12	47	15	18	38	18	28	26	12	Not used by machines
A common source	13	22	12	19	15	34	41	18	32	23	13	Not a common source
Can occur as waste energy	14	36	29	24	28	24	33	28	23	23	14	Does not occur as waste energy
Originally from sun	15	11	30	21	32	33	40	29	38	15	15	Not originally from sun
		1	2	3	4	5	6	7	8	9		

HEAT ENERGY
ENERGY FROM CHEMICALS
STORED ENERGY
ENERGY IN A MOVING BULLET
NUCLEAR ENERGY
ENERGY FROM COAL
ENERGY FROM FOOD
ELECTRICITY
SOLAR ENERGY

Figure 14. Mean ratings of supplied elements on supplied energy constructs from Rob's class, pre implementation

Mean ratings can be used to infer how the class regards various types of energy and how the supplied constructs apply to the types of energy. The means can give an excellent picture of how the class construes energy. For example, in Figure 15, it can be seen that Rob's class, on average, regard *Solar Energy, Food Energy* and *Heat Energy* as quite natural sources of energy and *Coal Energy* and *Stored Energy* as neither *Natural* or *Man Made*. Italics and capitalisation will be used throughout this thesis to distinguish elements and constructs used in grids from normal text.

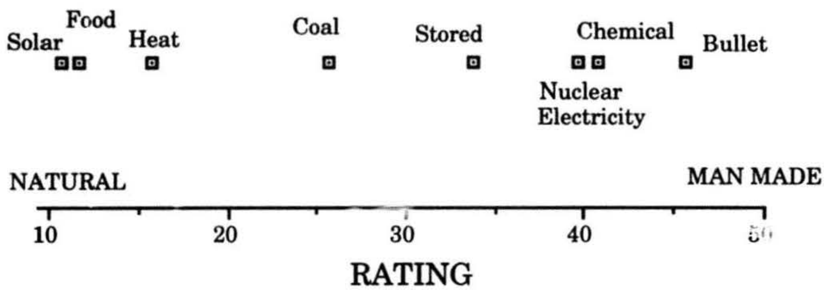


Figure 15. Mean ratings of elements on construct *Natural / Man Made* from Rob's class.

Similarly, Figure 16 shows how students in Rob's class perceive types of energy, in terms of easily stored or not.

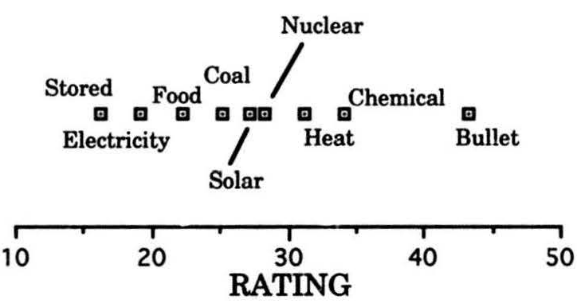


Figure 16. Mean ratings of elements on construct *Easily Stored / Not Easily Stor* from Rob's class.

Much information can be gained simply by examining the mean ratings but for the purpose of comparing normative grids, the means will be used for principal components analysis. Principal components analysis has the advantage of revealing the main groupings between construct and elements on the same figure.

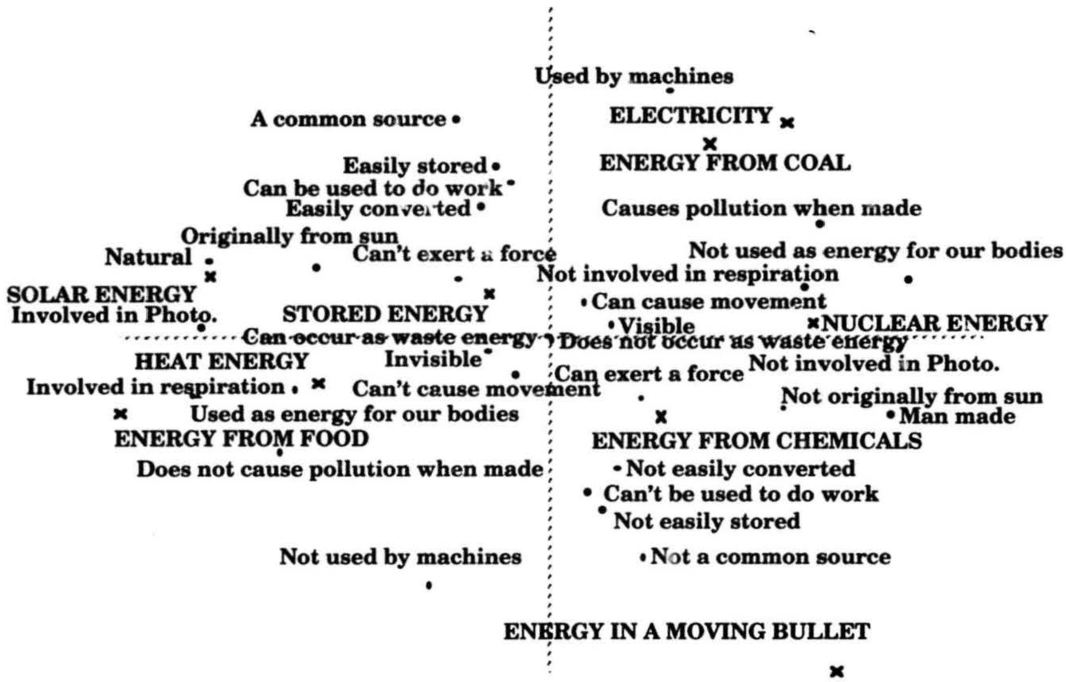


Figure 17. Principal components analysis of supplied energy constructs from Rob's class pre implementation

The first two components in Figure 17 account for 79% of the variance and the first three components account for 88% of the variance. Thus elements and constructs close together in Figure 17, which is a mapping based on the first two components, are still close together when the third component is considered. The third component is orthogonal to the other components and in the above map would be at right angles to the plane of the page. Some obvious groupings from Figure 17 are now described:

Energy from food is close to *Does not cause pollution when made*, *Used as energy for our bodies* and *Involved in respiration*. *Heat energy* is also close to *Involved with respiration*, *Solar energy*, *Involved with photosynthesis*, *Natural* and *Originally from the sun*. *Easily stored* is close to *Can be used to do work*, *A common source* and *Easily converted* confirming the cluster analysis. *Electricity* is associated with *Energy from coal*, *Used by machines* and *Causes pollution when made*. *Nuclear energy* is associated with *Not used as energy for our bodies* and *Not involved in* *respiration*. *Energy from chemicals* is close to *Not easily converted*, *Can't be used to do work*, *Not easily stored* and *Not a common source* and close in angular terms to *Energy in a moving bullet*. Visibility, ability to exert force and cause movement are not highly load on either factor and so can be regarded as relatively unimportant in this classes' construing of energy. Most of the above associations represent, in general, a scientifically correct view of energy.

		1	2	3	4	5	6	7	8	9		
Natural	1	10	35	16	24	40	41	33	34	19	1	Man made
Involved in Photo.	2	15	46	21	41	46	46	34	33	27	2	Not involved in Photo.
Used as energy for our bodies	3	28	40	12	43	47	44	27	33	24	3	Not used as energy for our bodies
Causes pollution when made	4	46	29	41	20	20	40	36	26	39	4	Does not cause pollution when made
Involved in respiration	5	27	43	19	41	45	45	34	36	28	5	Not involved in respiration
Can be used to do work	6	19	15	25	17	20	34	22	25	22	6	Can't be used to do work
Easily stored	7	23	19	25	27	27	39	20	30	30	7	Not easily stored
Can cause movement	8	27	21	25	30	29	17	26	25	23	8	Can't cause movement
Can exert a force	9	33	16	30	26	21	13	34	29	26	9	Can't exert a force
Easily converted	10	22	25	21	21	31	38	24	26	25	10	Not easily converted
Visible	11	41	29	39	36	38	34	39	29	38	11	Invisible
Used by machines	12	18	11	48	18	22	41	24	34	26	12	Not used by machines
A common source	13	16	10	17	18	36	36	26	28	23	13	Not a common source
Can occur as waste energy	14	36	33	27	26	27	31	31	24	27	14	Does not occur as waste energy
Originally from sun	15	10	29	17	29	34	42	32	37	18	15	Not originally from sun
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 18. Mean ratings of supplied elements on supplied energy constructs from Sean's class pre implementation

The means reported above in Figure 18 for Sean's class were derived in the same manner as means for Rob's class and can be used to display differences in this class's construing compared to any of the other classes. However, as for Rob's class, the analysis is restricted to identifying groupings of elements and constructs as displayed by the principal components map in Figure 19.

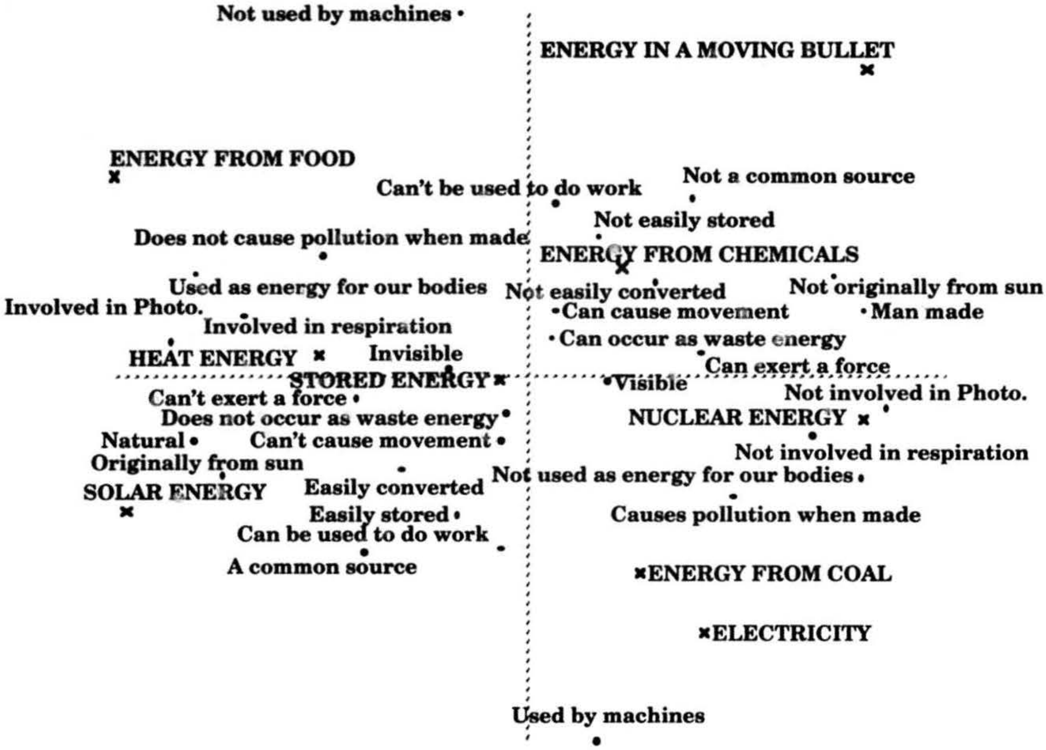


Figure 19. Principal components analysis of supplied energy constructs from Sean's class pre implementation

The first two components in the principal components analysis account for 81% of the variance and the third component accounts for an extra 7%. Some obvious groupings from Figure 19 are now described.

Solar energy is *Originally from the sun*, *Easily converted*, *Easily stored*, *Natural*, *A common source* and *Can't exert a force*. *Stored energy* is a relatively unimportant element to this class, being not highly loaded on either component and *Does not occur as waste energy*, *Can't cause movement* and *Visible* are relatively unimportant constructs. *Energy from food* is associated with *Does not cause pollution when made* and *Used as energy for our body*. *Heat energy* is associated with *Invisible*, *Involved in respiration* and *Involved in photosynthesis*. *Energy in a moving bullet* is *Not a common source*, *Can't be used to do work*, *Not easily stored* and *Energy from chemicals*. *Energy from chemicals* is also associated with *Not originally from the sun*, *Can cause movement*, *Not easily converted and Can occur as waste energy*. *Nuclear energy* is *Not involved in photosynthesis*, *Not involved in respiration*, *Causes pollution when made* and is *Not used as energy for our bodies*. *Electricity* is close to *Energy* *from coal* and *Used by machines*. Again these ideas form mostly scientifically correct groupings.

Construct		1	2	3	4	5	6	7	8	9		Contrast
Natural	1	11	38	16	33	41	37	33	38	19	1	Man made
Involved in Photo.	2	16	43	20	37	42	44	35	40	30	2	Not involved in Photo.
Used as energy for our bodies	3	37	44	14	43	45	44	33	36	28	3	Not used as energy for our bodies
Causes pollution when made	4	42	24	40	17	18	34	30	18	35	4	Does not cause pollution when made
Involved in respiration	5	37	43	21	44	43	43	35	37	34	5	Not involved in respiration
Can be used to do work	6	19	15	16	18	23	37	23	25	20	6	Can't be used to do work
Easily stored	7	22	25	24	24	24	40	16	25	33	7	Not easily stored
Can cause movement	8	28	18	21	26	24	16	28	26	22	8	Can't cause movement
Can exert a force	9	26	20	31	24	18	19	37	28	23	9	Can't exert a force
Easily converted	10	27	28	23	22	28	39	26	26	28	10	Not easily converted
Visible	11	36	21	36	31	30	31	32	31	32	11	Invisible
Used by machines	12	21	12	41	18	20	34	24	23	26	12	Not used by machines
A common source	13	19	13	16	19	40	36	26	33	23	13	Not a common source
Can occur as waste energy	14	31	36	26	24	23	31	27	26	30	14	Does not occur as waste energy
Originally from sun	15	11	30	21	35	36	43	32	42	19	15	Not originally from sun

1 2 3 4 5 6 7 8 9

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 20. Mean ratings of supplied elements on supplied energy constructs from Rick's class, pre implementation

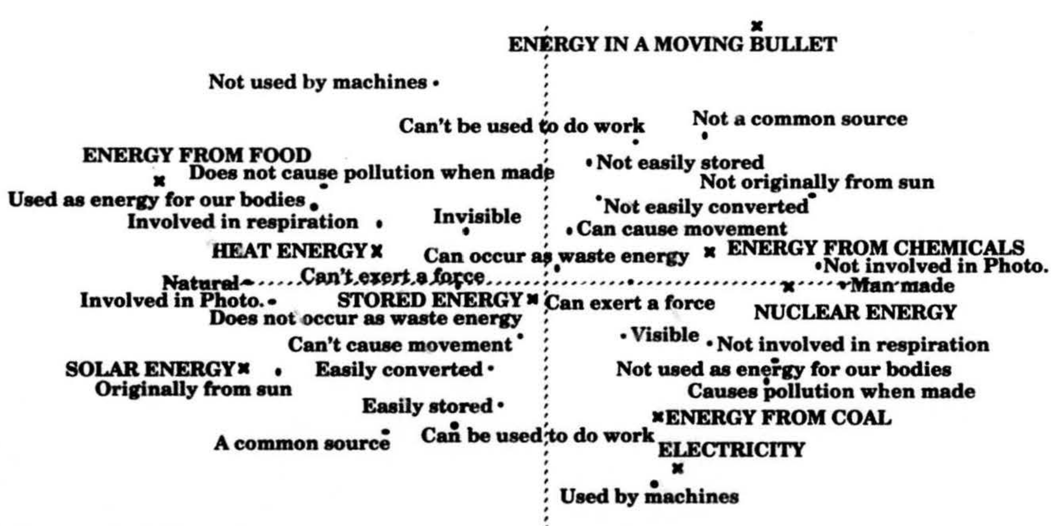


Figure 21. Principal components analysis of supplied energy constructs from Rick's class pre implementation

Means were calculated for Figure 20 in the same way as means for the other two classes and these means were used to construct Figure 21. Associations apparent from Figure 21 include the following; *Solar energy* is close to *Natural, Involved in photosynthesis, Originally from the sun, Can't exert a force. Easily stored* is close to *Can be used to do work, a common source* and *Easily converted. Electricity* is close to *Energy from coal, Used by machines* and Causes *pollution when made. Not used as energy for our bodies, Not involved in respiration, Nuclear energy, Visible* and *Can cause movement* are all close together. *Energy from chemicals, Can exert a force, Man made, Not originally from sun* are all closely associated. *Energy in a moving bullet* is close, in angular terms, to *Not easily stored, Can't be used to do work* and *Not easily converted.* These groupings represent mostly correct scientific ideas.

After Implementation of the Learning Approach

After the implementation of the learning approach, all three classes again completed normative grids using the same supplied elements and constructs used in grids completed before instruction. Completed grids were analysed using identical methods to those employed with pre implementation grids to assess any changes in the three classes' construing.

		1	2	3	4	5	6	7	8	9		
Natural	1	12	44	19	32	45	45	32	30	21	1	Man Made
Involved photo.	2	14	49	25	46	50	49	30	36	33	2	Not involved photo.
Energy for bodies	3	34	46	11	47	49	49	18	25	23	3	Not energy for bodies
Causes pollution	4	45	20	43	20	17	35	36	23	35	4	Doesn't cause pollution
Involved Resp.	5	36	47	19	47	48	47	29	26	35	5	Not involved Resp.
Used work	6	10	10	12	10	12	19	13	11	11	6	Can't be used work
Easily stored	7	16	15	16	21	30	37	11	23	27	7	Not easily stored
Cause movement	8	22	19	16	21	20	17	22	16	22	8	Can't cause movement
Exert force	9	29	22	29	25	19	13	28	25	25	9	Can't exert force
Easily converted	10	15	19	19	19	26	30	19	21	18	10	Not easily converted
Visible	11	38	38	41	40	40	35	41	34	39	11	Invisible
Used by machines	12	24	11	37	18	22	39	22	19	18	12	Not used by machines
Common source	13	16	12	12	19	43	31	17	19	13	13	Not a common source
Can occur as waste	14	31	28	31	30	27	29	29	23	20	14	Does not occur as waste
Originally from sun	15	12	22	14	17	33	34	22	22	15	15	Not originally from sun
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 22. Mean ratings of supplied elements on supplied energy constructs from Rob's class, post implementation

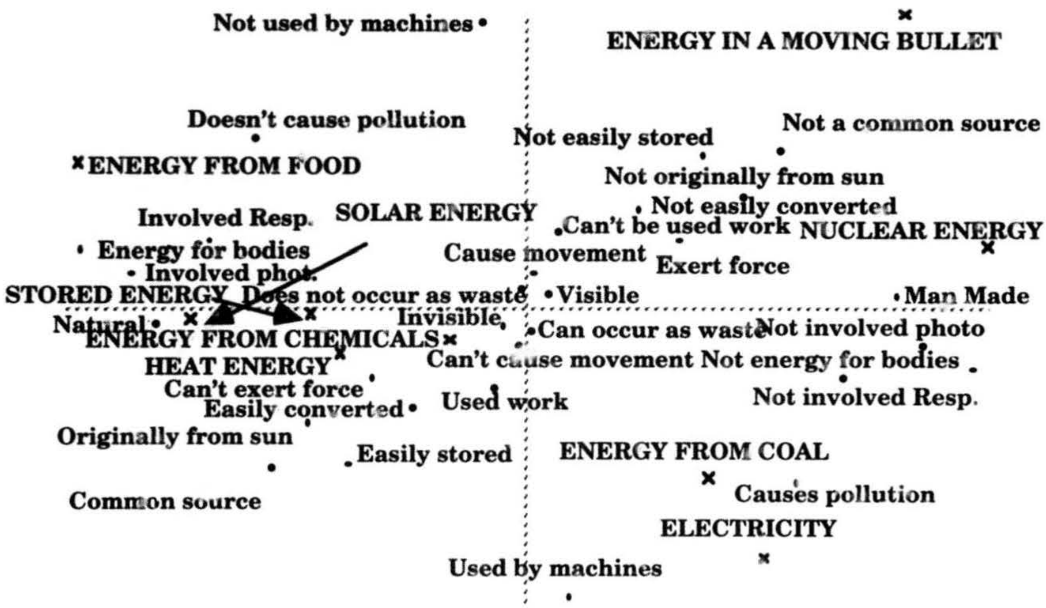


Figure 23. Principal components analysis of supplied energy constructs from Rob's class post implementation

The first two components in Figure 23 account for 79% of the variance and the third component accounts for a further 8%. Figure 23 reveals that *Solar energy* is close to *Natural*, *Involved with photosynthesis*, *Energy for our bodies*, *Energy from food*, *Involved in respiration* and *Stored energy*. *Energy from food* is also close to *Doesn't cause pollution*. *Heat energy* is close to *Can't exert a force*, *Easily converted*, *Originally from the sun*, *Common source* and *Easily stored*. *Energy from coal* is close to *Causes pollution*, *Electricity* and *Used by machines*. *Nuclear energy* is close to *Man made*, *Not involved in photosynthesis*, *Not energy for our bodies*. Finally, *Not a common source*, *Not easily stored*, *Not originally from the sun* and *Exert force* are close together and close, in angular terms, to *Energy in a moving bullet*. These associations represent generally scientifically correct associations.

The main changes that are evident after implementation are that *Energy from chemicals* is now closely associated with *Heat energy* and *Stored energy* whereas before it was associated with *Not easily converted*, *Can't be used to do work* and *Not a common source*. *Nuclear energy* is now clearly associated with *Not easily converted* and *Not originally from the sun*.

Figure 24 shows mean ratings for Sean's class, after the implementation.

		1	2	3	4	5	6	7	8	9		
Natural	1	12	37	11	31	41	36	27	38	16	1	Man Made
Involved phot.	2	10	49	21	49	49	49	33	31	26	2	Not involved photo
Energy for bodies	3	24	48	10	48	47	44	22	30	23	3	Not energy for bodies
Causes pollution	4	47	14	42	18	19	35	31	19	30	4	Doesn't cause pollution
Involved Resp.	5	29	49	19	46	45	44	30	29	25	5	Not involved Resp.
Used work	6	14	13	13	12	15	21	14	15	20	6	Can't be used work
Easily stored	7	28	22	19	24	30	44	16	22	30	7	Not easily stored
Cause movement	8	22	13	16	16	16	11	17	18	20	8	Can't cause movement
Exert force	9	29	17	27	24	19	13	32	21	22	9	Can't exert force
Easily converted	10	23	13	16	20	26	33	22	22	24	10	Not easily converted
Visible	11	43	40	47	44	40	40	45	38	40	11	Invisible
Used by machines	12	20	10	46	14	18	35	20	17	27	12	Not used by machines
Common source	13	16	12	13	15	45	34	18	23	18	13	Not a common source
Can occur as waste	14	34	29	26	26	20	30	34	21	14	14	Does not occur as waste
Originally from sun	15	10	35	18	20	29	39	28	28	16	15	Not originally from sun
		1	2	3	4	5	6	7	8	9		

1. SOLAR ENERGY
2. ELECTRICITY
3. ENERGY FROM FOOD
4. ENERGY FROM COAL
5. NUCLEAR ENERGY
6. ENERGY IN A MOVING BULLET
7. STORED ENERGY
8. ENERGY FROM CHEMICALS
9. HEAT ENERGY

Figure 24. Mean ratings of supplied elements on supplied energy constructs from Sean's class, post implementation

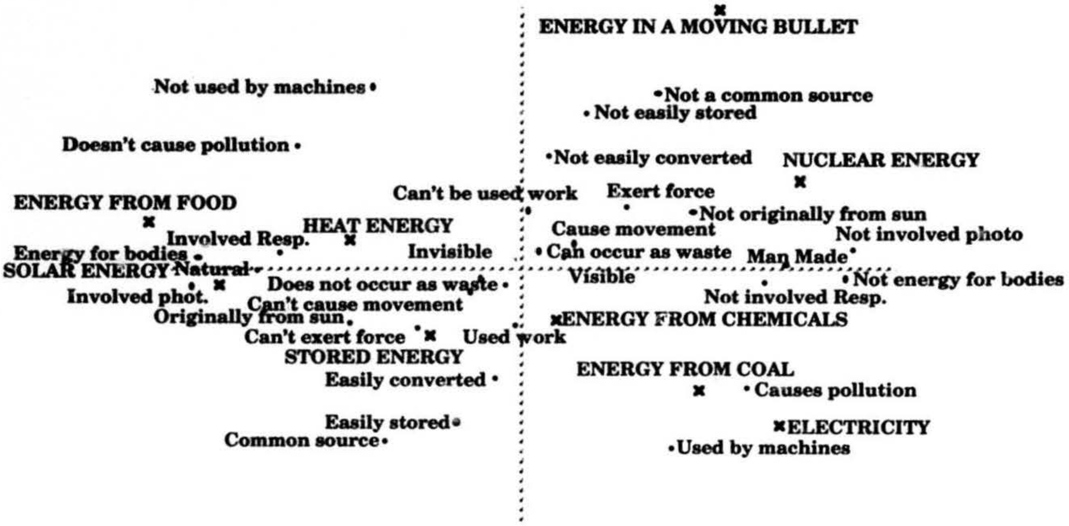


Figure 25. Principal components analysis of supplied energy constructs from Sean's class post implementation

The first two components in Figure 25 account for 78 % of the total variance and the third component accounts for a further 8%. Associations revealed from the above figure are very similar to associations displayed in Figure 23, the principal components map, post implementation, from Rob's class.

From Figure 25 *Energy from food* is closely associated with *Heat energy*, *Involved with respiration*, *Energy for our bodies*, *Solar energy*, *Natural* and *Involved with photosynthesis*. *Stored energy* is associated with *Can't exert force*, *Used to do work* and *Easily converted*. *Easily stored* is close to *Common source*. *Nuclear energy* is Not *originally from the sun* and *Not a common source* and Not easily stored are midway between *Energy in a moving bullet* and *Nuclear energy*. *Man made* is close to *Not involved with photosynthesis*, *Not energy for our bodies*, *Not involved in respiration*. *Energy from chemicals* is also close to this group and adjacent to *Used to do work*. *Energy from coal Causes pollution when it is made* and is close to *Electricity* and *Used by machines*.

Changes apparent from the principal components analysis from Sean's class prior to implementation include the following; *Solar energy* is now much more closely associated with *respiration* and *photosynthesis* than prior to implementation. *Energy from chemicals* is now more closely associated with *Easily converted* and *Easily stored* than before and is closer to *Energy from coal* and *Causes pollution when made* than prior to implementation.

		1	2	3	4	5	6	7	8	9		
Natural	**1**	**10**	**36**	**17**	**23**	**41**	**35**	**29**	**28**	**15**	**1**	**Man Made**
Involved phot.	**2**	**13**	**47**	**21**	**47**	**48**	**47**	**25**	**23**	**26**	**2**	**Not involved photo**
Energy for bodies	**3**	**36**	**43**	**10**	**46**	**48**	**47**	**15**	**19**	**18**	**3**	**Not energy for bodies**
Causes pollution	**4**	**47**	**20**	**40**	**24**	**13**	**36**	**36**	**28**	**32**	**4**	**Doesn't cause pollution**
Involved Resp.	**5**	**32**	**49**	**12**	**47**	**49**	**46**	**28**	**25**	**25**	**5**	**Not involved Resp.**
Used work	**6**	**15**	**11**	**11**	**11**	**12**	**16**	**17**	**14**	**16**	**6**	**Can't be used work**
Easily stored	**7**	**21**	**19**	**17**	**20**	**31**	**43**	**10**	**26**	**30**	**7**	**Not easily stored**
Cause movement	**8**	**22**	**18**	**16**	**22**	**20**	**12**	**25**	**20**	**22**	**8**	**Can't cause movement**
Exert force	**9**	**35**	**21**	**29**	**26**	**17**	**13**	**31**	**24**	**28**	**9**	**Can't exert force**
Easily converted	**10**	**19**	**17**	**21**	**19**	**29**	**36**	**17**	**22**	**29**	**10**	**Not easily converted**
Visible	**11**	**40**	**38**	**41**	**40**	**38**	**39**	**42**	**38**	**40**	**11**	**Invisible**
Used by machines	**12**	**23**	**10**	**43**	**16**	**28**	**36**	**17**	**24**	**25**	**12**	**Not used by machines**
Common source	**13**	**14**	**10**	**12**	**14**	**39**	**31**	**16**	**23**	**15**	**13**	**Not a common source**
Can occur as waste	**14**	**35**	**35**	**36**	**34**	**28**	**26**	**39**	**27**	**18**	**14**	**Does not occur as waste**
Originally from sun	**15**	**10**	**29**	**14**	**18**	**38**	**41**	**30**	**32**	**15**	**15**	**Not originally from sun**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 26. Mean ratings of supplied elements on supplied energy constructs from Rick's class, post implementation.

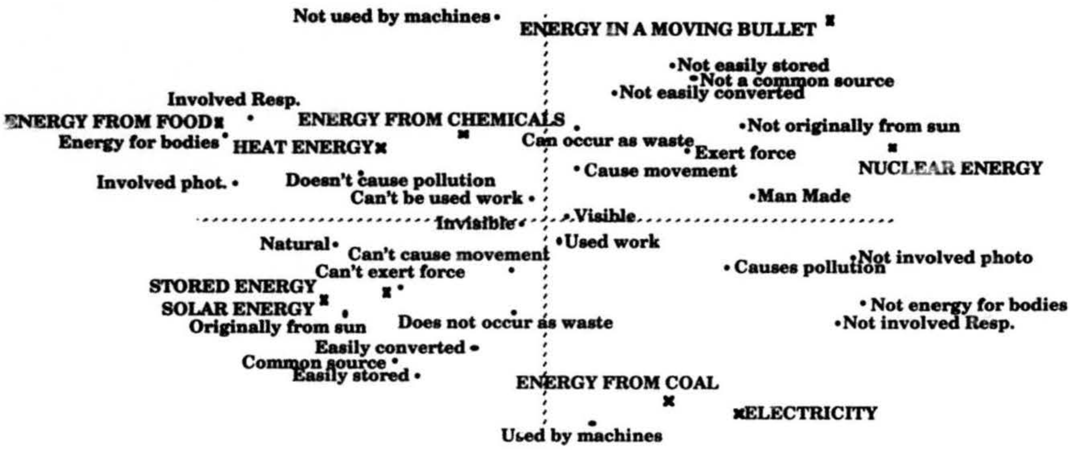


Figure 27. Principal components analysis of supplied energy constructs from Rick's class, post implementation

From Figure 27 it can be seen that *Solar energy* and *Stored energy* are closely associated and are very close to *Natural*, *Can't exert force*, *Originally from sun*, *Can't cause movement*, *Does not cause waste*, *Easily converted*, *Common source* and *Easily stored*. *Energy from coal* is close to *Electricity* and *Used by machines*. *Energy from food*. *Energy from chemicals* and *Heat energy* are close to *Involved in respiration*, *Energy for our bodies*, *Involved with photosynthesis*, *Doesn't cause pollution*. *Nuclear energy* is associated with *Not originally from sun*, *Exert force* and *Man made*. *Energy in a moving bullet* is close to *Not easily stored*, *Not a common source* and *Not easily converted*. *Not used by machines* is associated midway between *Energy in a moving bullet* and *Energy from chemicals*.

The element *Energy from chemicals* is most changed in its associations after completion of the energy unit in Rick's class. Prior to instruction, *Energy from chemicals* was regarded similarly to *Nuclear energy* and after instruction it is closest to *Heat energy*. Little change is apparent in other associations.

Changes in Ratings of Supplied Elements on Supplied Constructs Before and After Implementation.

The initial analysis method chosen and conducted on the pre and post implementation data consisted of multiple t-tests. As there were no previous studies to guide the researcher in the analysis of grid data in this context, this seemed a reasonable starting point. Because of the large number of t tests involved (405), some adjustment to the alpha level was necessary to control for Type 1 error. One approach in this situation is to use an additive (Bonferroni) inequality in which the alpha level for each test is given by the overall alpha level divided by the number of tests. In this analysis this resulted in an alpha level of 0.00012. However such a low alpha level has a high risk of Type II error. Consequently the initial analysis of the data used multiple t-tests with an alpha level of 0.01 and this accords with Clarke, Coladarci and Caffrey who state that "the compromise value that most research workers in psychology and education seemed to have settled on is .05 or .01" (p. 254).

This level, by chance alone, should result in only four significant changes with an equal chance of the changes occuring in any of the classes.

Another way of controlling for Type 1 error is to use ANOVA or MANOVA techniques and this would seem appropriate as a next approach to the analysis. The usual reason stated by researchers for conducting a MANOVA or ANOVA is to determine if group differences exist pertaining to a single variable or group of variables. However multiple ANOVAS are usually viewed as suffering from the same problems as multiple t-tests in regard to Type 1 errors. The usual justification for conducting MANOVA instead of multiple ANOVAS is to control for Type 1 error with the rationale being that if MANOVA yields significance then the researcher can carry out multiple ANOVAS with interpretations based on those ANOVAS. However the idea that an initial MANOVA completely controls for Type 1 error has been repeatedly questioned in the literature. The main basis for questioning this rationale is that the alpha value for each ANOVA would be less than or equal to the alpha value for the MANOVA, only when the MANOVA null hypothesis is true. It appears that the decision to conduct MANOVA or ANOVA should be more properly based on "the purpose of the research effort" (Huberty & Morris, 1989, p303).

While conducting a MANOVA as a preliminary to multiple ANOVAS is a conventional route to take, it is not only unnecessary but irrelevant as well "...a myth the idea that one is controlling for Type 1 error" (Huberty & Morris, 1989, p307). The research questions addressed by the two techniques are different and "to require MANOVA as a prerequisite of multiple ANOVAS is illogical, and the comfort of statistical protection is an illusion" (Huberty & Morris, 1989, p307). Multivariate analysis is appropriate if the outcome is to be variable selection or ordering, or in describing some structure in the variables. The structure amongst variables in this study is explored using another multivariate technique, principal components analysis, which gives a pictorial representation of the structure amongst constructs and elements.

It would appear then that ANOVA could be a better technique for analysing changes as it has the potential to control for Type 1 error better than t-tests because of the problematic nature of selection of significance levels. It also appears that, for the above reasons, it is not necessary to conduct an initial MANOVA. However ANOVA is not perfect as a preferred analysis method. This is because redundant information will usually be obtained with multiple ANOVAS if outcome variables are highly correlated which is almost always the case in repertory grids. This means that some changes could be regarded as significant only because they are highly correlated with other changes which are significant. A second reason for using ANOVA with caution is that the Scheffé test has low power in univariate contexts as does the procedure for adjusting or Type 1 error probability. In conclusion it can be said that neither ANOVA or multiple t-tests are conclusive and final determinants of statistically significant change in this situation but can only offer tentative conclusions. At a higher level the points raised above highlight difficulties in using statistical techniques in the behavioural sciences.

Recognising the above disadvantages and following the above mentioned t-tests, a multiple ANOVA analysis was conducted of the data using a significance level of 0.01, the same as chosen for the t-tests. This analysis resulted in less significant changes than the t-tests suggesting that some Type 1 errors are present in the t-test data. Consequently only the results of the ANOVA analysis are presented and discussed. The results are reported in Table 4.

Table 4

Significant differences between ratings of supplied elements on supplied constructs before and after implementation as determined by multiple ANOVA.

	E1			E2			E3			E4			E5		
Construct	Ro	Ri	S	Ro	Ri	S	Ro	Ri	S	Ro	Ri	S	Ro	Ri	S
1	*	*	*	*	*	*		*					*	*	*
2		*		*	*	*				*	*	*	*	*	*
3				*	*	*	*	*	*		*		*	*	
4	*	*	*												
5				*	*	*				*	*	*	*		*
6	*	*	*	*	*	*	*		*	*	*	*	*		*
7		*	*												
8			*	*	*	*					*		*	*	*
9	*		*	*	*	*				*			*	*	*
10				*	*	*				*	*	*	*	*	*
11				*	*					*	*	*	*	*	*
12	*	*	*				*	*	*	*	*	*	*	*	*
13									*				*	*	*
14						*									
15		*	*		*										

*

	E6			E7			E8			E9		
Construct	Ro	Ri	S	Ro	Ri	S	Ro	Ri	S	Ro	Ri	S
1	*	*	*									
2	*											
3			*	*		*						*
4				*								
5												
6			*	*		*	*		*			
7				*	*	*	*	*				
8	*	*	*		*		*	*	*			
9	*	*	*		*							
10	*											
11					*		*	*				
12						*	*	*				
13												
14					*	*					*	
15		*	*									

Note. E1 = Solar energy, E2 = Electricity, E3 = Energy from food, E4 = Energy from coal, E5 = Nuclear energy, E6 = Energy in a moving bullet, E7 = Stored energy, E8 = Energy from chemicals, E9 = Heat energy, Ro = Rob, Ri = Rick, S = Sean.

*** $p < 0.01$, Scheffé test.**

Rob's class had 49 significant changes, Rick's class had 52 changes and Sean's class, 51 changes. Element 5, *Nuclear energy* had the greatest number of changes in its ratings followed by *Electricity*. The construct *Used by machines* had the greatest number of changes followed by the construct *Used to do work*.

Ordination Index Data

Superordinancy of supplied constructs was calculated using Landfield's (1977) ordination index. In this study the ordination index is used as a measure of change in importance of the supplied constructs used in the normative grids. Ordination indexes were calculated using the computer software package G - PACK (Bell, 1987) and are displayed in Table 5.

Table 5

Ordination index data for all classes based upon supplied constructs, pre and post implementation.

Construct	Rob Pre	Rob Post	Sean Pre	Sean Post	Rick Pre	Rick Post
Used as energy for our body / Not used	4	1	1	1	4	1
Used by machines / Not used by machines	2	8	2	2	2	2
Natural / Man made	3	3	3	3	6	5
Involved in photosynth. / Not involved in photosynth.	1	2	5	7	3	8
Easily stored / Not easily stored	6	6	10	9	10	3
Originally from sun / Not originally from sun	7	9	4	8	1	4
Causes pollution when made / Doesn't cause pollution	9	4	6	4	7	6
Involved in respiration / Not involved in respiration.	8	7	7	6	11	7
A common source / Not a common source	5	5	8	5	5	9
Can exert a force / Can't exert a force	12	10	9	10	9	10
Can occur as waste energy / Does not occur as waste	14	12	15	12	13	11
Can cause movement / Can't cause movement	13	15	13	13	14	12
Easily converted / Not easily converted	10	11	12	11	12	13
Can be used to do work / Can't be used to do work	11	13	11	14	8	14
Visible / Invisible	15	14	14	15	15	15

Ordination data can show changes in the level of constructs with more superordinate constructs having smaller indices. According to PCP, learning can result in a change in the relative superordinancy of a construct in a person's construct system. As constructs become more useful predictors, then they will assume a more prominent position in the person's hierarchical construct system. For example it can be seen in the above table that, in Rob and Rick's classes the construct *Used as energy for our body / Not used as energy for our body,* has become more superordinate as the ordination index has changed from 4 to 1. Data from Table 5 is discussed at the end of this chapter.

Discussion of Class Results

The normative grids used above, together with principal components analysis, are capable of providing a detailed picture of how students connect the supplied elements and constructs. All classes held remarkably similar ideas and associations and the associations between their constructs and elements could be considered to be generally scientifically correct both before and after instruction. The mean reliability of all six grids was 0.71 (Cronbach's alpha).

Learning occured in all classes during the period of implementation of the two modes of learning as evidenced by changes in the associations of ideas revealed by principal components analysis. Ordination data, which reports the degree of superordinancy of constructs, also supports the idea that learning has occurred. However, there was only minor change in the students' ideas about energy before and after instruction, as shown by ordination indices.

It can be seen from Table 5 that there is little difference in the level of superordinancy of most constructs held by the different classes prior to instruction. Rob's class rated *Causes pollution* and *Easily stored* at a lower level than the other two classes. Rick's class rated *Originally from the sun* a more superordinate construct than the other two classes and *Natural* as a more subordinate construct. After instruction, Rob's class rated *Causes pollution* and *Used as energy for our bodies* as more superordinate constructs and *Used by machines* a more subordinate construct. Sean's class rated *Originally from the sun* as a more superordinate construct after implementation with little change in other constructs. Rick's class, like Rob's class, viewed *Used as energy for our body*, *Involved in respiration* and *Easily stored* more superordinate constructs after instruction. *Easily stored* and *Involved in respiration* became more subordinate after instruction. Interestingly, the most important construct related to the personal use of energy.

The ordination data demonstrates that the classes were similar in their construing prior to instruction, in fact ANOVA demonstrated no significant differences. The small number of changes in the ordination indexes after instruction indicates that a minimal amount of learning, as reflected in the use of the supplied constructs and elements, has occurred. However some significant changes did occur.

Used to do work was less highly loaded, in principal components analysis, after instruction in all classes suggesting that this particular construct is not useful in distinguishing between types of energy; students know that energy is the ability to perform work. ANOVA data reported in Table 4 demonstrates 18 significant changes in the application of this construct to the nine elements

ANOVA data was generally supported by the principal components analysis of the mean ratings but caution should be exercised in interpreting the results because of expected high correlations between the elements and between the constructs. The construct *Energy from chemicals* had 11 significant changes in its ratings before and after instruction and is used as an example of changes supported by principal components analysis. Before implementation, Rob's class associated *Energy from chemicals* with *Not easily converted, Can't be used to do work, Not easily stored* and *Not a common source*. Sean's class associated *Energy from chemicals* with *Not easily converted, Can cause movement* and *Can occur as waste energy*. Rick's class associated *Energy from chemicals* with *Waste energy, Can cause movement, Can exert a force* and *Not involved with photosynthesis*. After instruction Rob's class associated this energy with *Natural, Stored energy, Invisible* and *Heat energy*. Sean's class associated it with *Energy from coal* and *Used to do work*. Rick's class associated it with *Heat energy*, and *Can occur as waste*.

In conclusion, it can be stated that before and after implementation all classes were remarkably similar based on analysis of mean ratings from grids. Grids of this type, using supplied constructs and elements, seem able to detect changes in learning. As the supplied elements and constructs are derived from school science objectives, it appears that students in all classes are able to learn the school science and that the grid technique is able to detect this learning.

The constructs supplied were very superordinate constructs and it appears, at least on these big ideas, that students' ideas before and after instruction were generally scientifically correct. The supplied superordinate constructs represent the tips of the icebergs of meaning. It is the individual generated meanings, subsumed by the superordinate constructs used in the above analysis, which demonstrate the richness of each individual's learning. It is the students' own ways of viewing which are important in constructivist settings. Details in the individual ways of looking at energy are described in the next chapter.

The technique

The above method of using supplied elements and constructs is a useful way of detailing changes in the class's construing and has classroom applications. It is not necessary, in classroom applications, to analyse the means using principal components as much information is gained through examination of the ratings of the elements on the constructs. For example, Figure 28 shows mean ratings plotted on the same rating axis. Such plots enable changes in the class's construing to be easily identified.

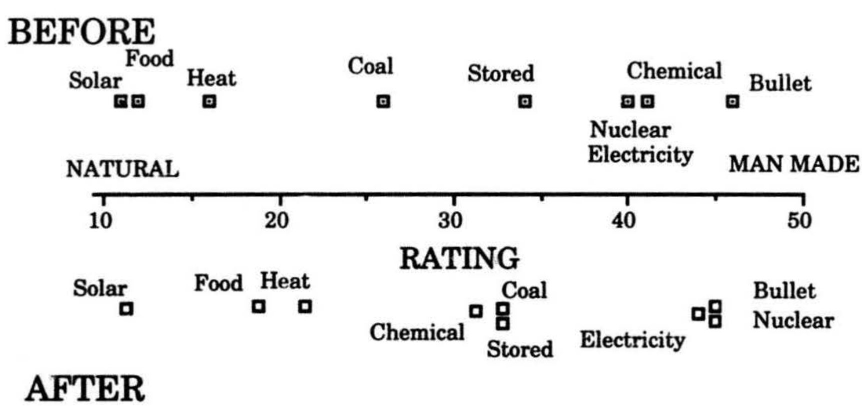


Figure 28. Mean ratings from Rob's class for construct *Natural / Man made* before and after implementation

Between class comparisons are also possible. Figure 29 demonstrates the difference between Rob and Ricks' classes for the construct *Natural / Man Made* after implementation. It can be seen that the two classes rate each element in a similar fashion despite the differences in learning approach.

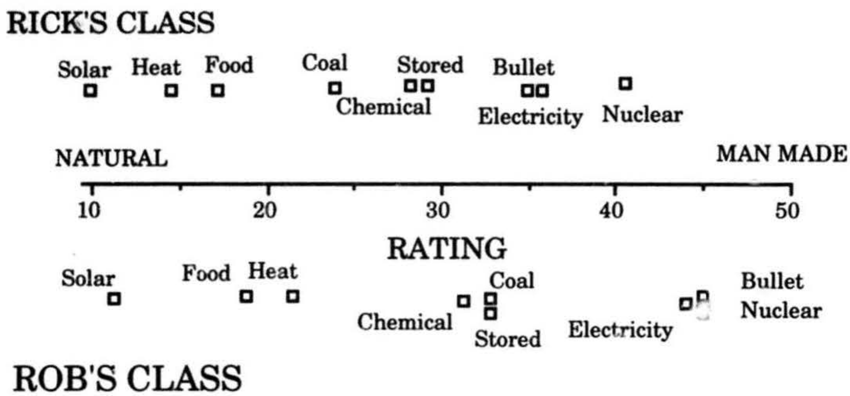


Figure 29. Mean ratings for Rob and Rick's class for construct Natural/Man made before and after implementation.

Conclusion to the Chapter

This chapter presented the results gathered through the use of repertory grids using supplied elements and constructs. Analysis of these normative grids showed that all classes had learnt as demonstrated by changes in the relationships between elements and constructs on principal components maps and by ordination indices. Little difference between classes was detected despite the difference in approach. Research question one can now be answered. There is little difference in how well students learn school science between students taught with traditional methods and students undergoing the constructivist approach.

The technique of using supplied elements and constructs does not demonstrate how individual student's views of energy have changed during implementation. However the technique can be useful in providing a gross measure of how a class's view of a topic may change as a result of instruction.

CHAPTER EIGHT

Results from Each Class Based on Students' own Constructs

Introduction

This chapter presents results which represent the students' views of energy before and after the implementation of the two learning approaches. In contrast to the preceding chapter, the results presented here represent each classes' view of energy expressed in terms of students' own constructs. As such, the results are used to answer research question two. The chapter begins with a description of how the students' constructs were elicited and this is followed with a description of how the constructs were combined to present a picture of how each class viewed energy prior to implementation. A summary of students' ideas prior to implementation is then presented. This grouping process is repeated for students' constructs elicited after implementation and then a comparison is made between students' constructs before and after implementation. The results obtained are discussed and a conclusion to the chapter is stated.

Obtaining and Grouping the Data

Each member of each class was presented with a grid sheet, before the class normative grids were administered, which had nine supplied elements. Students individually made triadic comparisons between elements to elicit their constructs and then the students rated each supplied element on each elicited construct. The researcher placed the elicited constructs in groups according to the construct labels. The groups were established by the researcher assigning meaning to each label and so the groupings are essentially the researcher's. However, groupings were validated by an external observer on a random basis. About 10 % of the elicited constructs were checked and there was no discrepancy between the groupings generated by the observer and the researcher's. Elicited constructs were not difficult to assign to the broad groups established.

The grouping process was repeated for each class before and after implementation. Those groups which had four or more constructs, representing a construct held by four or more students in a class, are reported in tables. In this way a composite picture of each class's construing was established based upon the students' own views of energy.

Means of construct ratings could be established for each group of constructs and these means could be used to construct a grid which could then be analysed by cluster or principal components methods. Grids were not constructed. This was not done because firstly there was not a large match between constructs before and after implementation and so there is little point in assessing changes in associations between ideas and secondly because the emphasis is on the number and type of constructs elicited as a measure of the degree to which science ideas had been translated into students' own constructs.

Constructs Elicited from Classes before Implementation of the Learning Approach.

Table 6

Constructs elicited from Rob's class, pre implementation.

Construct group	Number of constructs in group (Total N=131)
Natural	18
Stored	13
From sun	10
Used in living things	8
Chemical	7
Produce heat	6
Renewable	6
Fast	6
Dangerous	4
Used by people	4
Pollute	4
Immediate	4
From Heat/Explosion/Burning	4
Other	11

From Table 6 it can be seen that most students in Rob's class, pre implementation, viewed energy in terms of whether it is *Natural*, *Stored* or *Originally from the sun.*

Table 7

Constructs elicited from Sean's class, pre implementation.

Construct group	Number of constructs in group (Total N=126)
Natural	20
Heating	13
Dangerous	12
Made by chemicals	7
Stored	6
Manufactured, mechanical, processed, activated by man	5
Widely used	5
From coal	5
Used in living things	5
Used at home	4
Provides energy	4
Other	14

Sean's class had four constructs in common with Rob's class. These were *Natural, Stored, Used by living things* and *Dangerous. Chemical* in Rob's class is similar to *Made by Chemicals* in Sean's class and *Produce heat* is similar to *Heating*.

Table 8

Constructs elicited from Rick's class, pre implementation.

Construct group	Number of constructs in group (Total N=119)
Natural	15
Manufactured, mechanical, processed, activated by man	15
Used in living things	11
Used at home	8
Heating	6
Strong/Big/Solid	5
Stored	5
Widely used	5
Dangerous	5
Environmental clean	5
Other	13

The constructs *Natural, Stored, Dangerous* and *Used in living things* are common to all three classes. Other constructs may be similar in meaning to constructs in other classes. For example *Strong* may be similar to *Dangerous*.

Summary of Students' Own Ideas Prior to Instruction

Students' views of energy, examined on a class basis, centre around the constructs *Natural, Stored, Dangerous* and *Used in living things* with a few additional constructs, held by small numbers of students in each class.

If this constructivist learning approach is to be judged successful in translating "school science" into the students' own domain, then after implementation, there should be an increase in the number of constructs held by the class. Further there should be evidence of science constructs appearing in the elicited constructs. These could be manifested as constructs, similar to those used in Chapter 7 as supplied constructs, appearing in the classes' own construct systems.

Constructs Elicited from Classes After Implementation of the Learning Approach.

Table 9

Constructs elicited from Rob's class, post implementation.

Construct group	Number of constructs in group (Total N=452)
From sun	32 (26)
Widely used/everyday	26 (25)
Stored energy	24
Natural	21
Used in home	17
Kinetic energy	17
Makes heat	16
Connected heat	16
Harmful/Kill/Dangerous	16
Potential	14
Uses chemical energy	13
Used humans	13
Renewable	12
Associated movement	11
Used a lot Aust	11
Light energy	10
Used in body/food	10
Used industry/machines	10
Invisible	9
Easy to harness/convert	9
Sound	8
Does work	8
Photosynthesis	8
Can be converted	7
Associated electricity	7
Associated respiration	6
Power	5
Associated pollution	5
Made from chemical reactions	5
Efficient	4
For survival	4
Useful	4
From plants	4
Involved radiation	4

Note: Numbers in brackets in the above table indicate the number of students holding the construct as some constructs were repeated by students. Repeating a construct is regarded in PCP as an indication of importance of the construct to the individual.

Table 10

Constructs elicited from Sean's class, post implementation.

Construct group	Number of constructs in group (Total N=434)
Natural	25 (23)
Makes heat	25 (24)
From sun	23
Kinetic energy	17
Used in body	17 (16)
Harmful/Kill/Dangerous	16
Used in home	14
Widely used, everyday	14
Associated movement	11
Potential energy	11
Stored energy	11
Used industry/machines	11
Associated pollution	12
Easy to harness/Convert	12
Uses chemical energy	9
Sound energy	8
Makes electricity	4
For survival	8
Connected heat	8
Does work	7
Photosynthesis	7
Not easily stored	7
Light energy	7
Invisible	7
Causes light	6
Not waste product	6
Expensive	5
Used a lot Aust	5
Associated electricity	4
From earth's resources	4
Power	4
Made from chemical reaction	4
Hot	4
Controlled	4
Contained in coal	4
Chemical potential energy	4

Table 11

Constructs elicited from Rick's class, post implementation.

Construct group	Number of constructs in group (Total N=188)
Natural	18
Used industry/Machines	13
Associated heat	12
Used humans	12
Harmful/Kill/Dangerous	11
Used in home	10
Stored	8
From sun	7
Kinetic energy	7
Useful	6
Waste	6
Associated chemical energy	5
Big	5

In terms of research question two, posed in Chapter 1, it is sufficient to compare differences in the number of constructs elicited and differences in the nature of the elicited constructs between classes and pre and post implementation. The comparisons are made in the following section.

Comparisons Between Classes, Pre and Post Implementation.

Table 12

Summary statistics of elicited constructs per student, from each class, pre and post implementation.

Statistic	Rob's class		Sean's class		Rick's class	
	Pre (N = 31)	Post (N = 29)	Pre (N = 27)	Post (N = 30)	Pre (N = 25)	Post (N = 29)
Minimum	2	7	2	3	1	2
Maximum	7	34	7	24	8	10
Median	4	18	5	17	5	6
Standard dev.	1.41	5.54	1.62	5.11	2.15	2.23

Table 12 shows that there is a much larger number of constructs elicited from each student in Rob and Sean's classes, post implementation, compared to Rick's class. Table 13 shows the results of ANOVA to determine if differences in classes prior to and post implementation are statistically significant.

Table 13
ANOVA results from comparison of mean numbers of constructs per student, from all classes, pre and post implementation.

Source	SS	df	ms	F	p
Total	7091.60	170			
Between groups	5097.42	5	1019.50	84.35	0.00
Within groups	1994.21	165	12.09		

Table 14

Scheffé test of significant differences between mean numbers of constructs per student, from all classes, pre implementation.

	Rick		Sean		Rob	
	Scheffé F	p	Scheffé F	p	Scheffé F	p
Rick			0.002	1.00	0.065	1.00
Sean	0.002	1.00			0.046	1.00
Rob	0.065	1.00	0.046	1.00		

Table 14 indicates no significant differences between the classes in the number of constructs elicited from each student prior to implementation.

Table 15

Scheffé test of significant differences between mean numbers of constructs per student, from all classes, post implementation.

	Rick		Sean		Rob	
	Scheffé F	p	Scheffé F	p	Scheffé F	p
Rick			20.73	0.00	27.10	0.00
Sean	20.73	0.00			0.48	0.79
Rob	27.10	0.00	0.48	0.79		

Table 15 indicates that there is a significant difference in the mean number of constructs elicited from each student, post implementation. Students in Sean and Rob's classes, who used the new instructional approach, gave significantly more constructs per student than students in Rick's class. There is no significant difference between the mean number of constructs elicited from each student in Rob and Sean's classes. Table 16 displays results from Scheffe comparisons to determine if there is a statistically significant difference in the number of constructs elicited per student, pre and post implementation.

Table 16
Scheffé test of significant differences between mean numbers of constructs per student, from all classes, pre and post implementation.

	Rick		Sean		Rob	
	Scheffé F	p	Scheffé F	p	Scheffé F	p
Rick	0.66	0.66				
Sean			28.63	0.00		
Rob					41.12	0.00

From Table 12, it can be seen that all classes showed an increase in the number of constructs elicited after implementation. Rick's class reported an increase of 1 in the median number of constructs elicited, per student, which was not significant. Sean and Rob's classes reported an increase of nearly 12 and 14 constructs per student, respectively, which was significant at below $p < .01$.

Discussion of Results

All students involved in this study completed the same number of elicitation episodes and in the same order so results cannot be attributed to familiarity with grid procedures. Constructs were elicited before students completed the class normative grids.

Table 12 shows that the number of constructs held by each student increased in all classes, before and after instruction. According to PCP, this means that students in these classes have all learnt. However the enormous increase in the number of constructs elicited from each student in Rob and Sean's classes indicates a similarly large increase in the learning of students in those classes. Elicited constructs are the constructs that students would use to run their lives from day to day. Students from Rob and Sean's classes have a larger number of constructs which they can use in their day to day lives and therefore are cognitively more complex individuals. Students from Rick's class hold constructs which are not much different in number, and the increase is not statistically significant, from the constructs they held prior to instruction. This means that the method of instruction has had little affect on their personal ideas about energy and that they have only an insignificant small increase in the number of ideas about energy after instruction. If there is not a qualitative change in the constructs they hold, then it can be concluded that the method of instruction has had little affect upon their own ideas.

The increase in cognitive complexity in Rob and Sean's classes is further demonstrated by the number of categories necessary in each class to group the elicited constructs. Constructs from Rick's class could be grouped into 13 groups after instruction but Sean and Rob's classes required 33 and 36 groups respectively. This means that students in Rob and Sean's classes not only have a larger number of constructs that they can use in relation to energy but also have a more diverse range of constructs that they can use in situations involving energy.

One method to determine if school science has been translated into the students' constructs is to ascertain to what extent the students' constructs match the supplied constructs used in the normative grids which were described in Chapter 6. These supplied constructs were derived from State determined objectives for the energy unit and are representative of school science. Table 17 displays this data.

Table 17

Numbers of students' constructs matching supplied constructs in each class, pre and post implementation.

Supplied construct	Rob Pre	Rob Post	Sean Pre	Sean Post	Rick Pre	Rick Post
Natural	18	21	20	25	15	18
Inv. photosynth.		8		7		
Energy body		10		16		
Cause pollution	4	5		12	5	
Inv. resp		6				
Used work		8		7		
Easily stored	13	24	6	7	5	8
Cause movement	3	11	2	11	3	
Exert force						
Easily converted		9		12		
Visible		9		7		
Used machines		10		11		13
Occur waste				6		6
Originally sun	10	32		23	3	7
Total	48	153	28	145	31	54

The students' own constructs were elicited before completion of the normative grids. In Rob's class, post implementation, students held constructs that matched all of the categories of the supplied constructs apart from *Force* and *Waste*, in Sean's class students held constructs that matched all of the categories of the supplied constructs apart from *Involved respiration* and *Force* but in Rick's class the only new constructs to appear were *Used by machines* and *Can occur as waste*. These figures can be interpreted as more evidence of the translation of science constructs into the students' own construct system in Rob and Sean's classes, which underwent the implementation, and to a very limited extent in Rick's class.

Further evidence of the translation of school science ideas into students' personal knowledge is provided by the appearance of constructs, which can be classified as science constructs, appearing in students' elicited constructs. For example *Kinetic energy* (17), *Potential energy* (14) appear in Sean and Rob's classes but not in Rick's class. Because of the larger number of constructs held by students in Rob's and Sean's classes about energy, they will be more able to encompass future learning events concerning energy within their construct system.

Conclusion to the Chapter

Research question two can now be answered. Students who underwent the implementation hold, on average, more constructs than students taught with usual methods. Students who underwent the implementation incorporated more school science constructs into their construct systems. It can be concluded that students taught with the constructivist approach have increased personal knowledge concerning energy.

From the elicited constructs, it can be stated that this constructivist learning approach is successful in increasing students' personal knowledge about energy, in enabling them to become more cognitively complex individuals and in facilitating the transfer of abstract school science into the students' own domain. These findings are confirmed by results gathered using a different technique and are presented in the next chapter.

A final conclusion is that the repertory grid methods used to elicit students' constructs in this chapter are a successful means of revealing students' personal science knowledge.

CHAPTER NINE

Questions - About - Events

Introduction

Questions - About - Events (QAE) is a unique technique which, after trial in a pilot study, was further refined for use in this study. As mentioned in Chapter 6, the technique provides another probe of students ideas which can be used with a large number of students overcoming one of the disadvantages of interviews. Because of time constraints it was impossible to interview, using an Interview - About - Events (IAE) approach, every student involved in the study. However there was a need for another probe of students' own understandings apart from repertory grid technique, which would probe the ideas of a large number of students and allow students the opportunity to express their own understandings. This technique is a reasonable compromise between a school science test, which generally elicits just school science knowledge and an IAE approach which generally elicits the student's own beliefs. Results gathered using this technique are used to answer research question two.

In this study identical events were used in IAE and QAE enabling some comparison to be made about the type of knowledge elicited by the two techniques. Six of the events were very similar or identical to events used by Watts (1983) and the remaining events were representative of the knowledge described by objectives for the course. In his study, Watts (1983) used the term instances in relation to the cartoon representations used as stimuli for his interviews. This researcher believes that these instances could be more correctly called events as the cartoons do not represent instances of a concept but rather events to do with energy and no non-events were used in the interviews. Non-events may not have been used because of the difficulty in finding a non-event to do with energy.

All students involved in the study completed a QAE episode immediately preceding and following the implementation of the learning approach. Students were presented with two sheets of paper containing 11 events. Each event asked the questions "Is there energy here ?", "If so, in what forms ?" and "Is it being used ? If so, what for ?" and space was left alongside each presented event for students to write their answers. These questions were the same questions used by Watts (1983) in his Interviews-About-Instances as beginning questions for his interviews. It was possible with his interviews to probe at depth students' ideas. This was not possible with QAE and consequently the student frameworks identified by Watts (1983) in his study cannot be used as a basis for comparison with results from QAE.

Analysis of Data

Students' responses to the question "Is there energy here ?" were coded as a "Yes", "No" or "No answer" response for each event and grouped into classes. Responses to the question "If so, in what forms ?" were categorised according to the form of energy listed by the student and responses were categorised in classes. Data concerning the frequency of recognition of types of energy are then reported in table form. Responses to "Is it being used ? If so what for ?" were similarly treated.

Responses to Question "Is energy present here? If so, in what forms ?"

From responses to the question "Is energy present here?" it can be stated that students in all classes generally recognised the presence of energy in the events presented, before implementation, with very occasional exceptions. However many students stated that energy was present but did not state the form of energy present.

Table 18

Number of students in each class stating energy was present in each event but did not state a form of energy, pre implementation.

Event	Rob's class	Sean's class	Rick's class
Pushing a box	5	4	7
Ice melting	0	2	2
Power station	6	2	4
Chemical react.	2	3	3
Electric circuit	4	5	5
Eating meal	6	3	2
Sun and tree	3	1	2
Ball rolling	2	2	3

Not being able to state a form of energy present in specific events indicates that these students have a very small number of constructs which can be applied to the events presented. It would appear that the only construct that they are applying in each event is a construct like *Present / Not present.*

All students in all classes, post implementation, stated that energy was present in all events with the exception of one student in Rob's class who stated that energy was not present in the event of a person eating a meal.

Responses to the question "If so, in what forms" over all events were used to construct Table 19. Responses were categorised for all classes, pre and post implementation. Only the frequency of the three most common types of energies, pre and post implementation are reported. In the column labelled "Types of energy present", a line separates the three most common energy types pre implementation from the three most common energy types post implementation.

Table 19

Most common forms of energy recognised and their frequency, pre and post implementation, from each class.

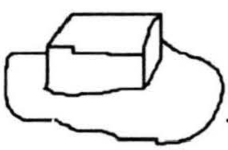
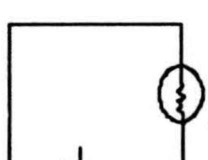
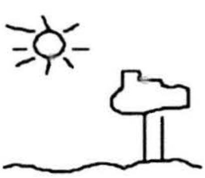
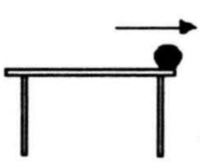
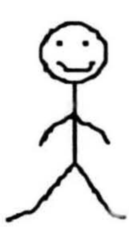
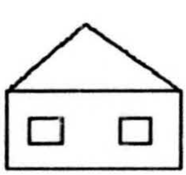
Event	Type of energy present	Pre Implementation Rob's class (N=31)	Pre Implementation Sean's class (N=27)	Pre Implementation Rick's class (N=25)	Post Implementation Rob's class (N=29)	Post Implementation Sean's class (N=30)	Post Implementation Rick's class (N=29)
	Human	10	9	3	0	0	3
	Push	2	7	4	0	0	4
	Friction	4	8	1	4	5	1
	Kinetic	1	1	0	28	28	6
	Heat	1	2	0	15	17	23
	Potent.	0	1	0	23	23	3
	Heat	19	19	12	29	25	23
	Solar	4	1	0	1	4	0
	Gravity	3	2	1	0	0	0
	Heat	19	19	12	29	25	23
	Kinetic	1	2	0	22	23	6
	Potent.	0	0	0	13	9	3
	Electric.	17	23	17	24	20	24
	Coal	1	4	2	0	0	0
	Nuclear	2	2	2	0	3	0
	Electric.	17	23	17	24	20	24
	Heat	3	0	1	18	20	7
	Kinetic	0	0	0	24	20	9
	Chem.	10	13	10	23	16	22
	Heat	2	5	2	21	23	9
	Gas	0	3	0	0	0	0
	Chem.	10	13	10	23	16	22
	Heat	2	5	2	21	23	9
	Kinetic	1	0	0	21	18	8
	Electric.	16	20	12	16	16	25
	Light	2	4	0	23	17	12
	Battery	1	4	0	0	0	0
	Electric.	16	20	12	16	16	25
	Light	2	4	0	23	17	12
	Heat	2	1	2	25	20	11

Table 19 (Continued)

Most common forms of energy recognised and their frequency, pre and post implementation, from each class.

Event	Type of energy present	Pre Implementation Rob's class (N=31)	Pre Implementation Sean's class (N=27)	Pre Implementation Rick's class (N=25)	Post Implementation Rob's class (N=29)	Post Implementation Sean's class (N=30)	Post Implementation Rick's class (N=29)
	Food	12	12	13	7	2	5
	Nutrit.	1	2	5	0	0	0
	Physica	2	4	1	0	0	0
	l	0	0	0	22	19	0
	Kinetic	2	2	1	14	14	12
	Chem.	0	0	0	20	12	4
	Potent.						
		11	15	15	17	15	12
	Solar	7	5	3	19	23	12
	Heat	3	2	1	10	20	13
	Light	11	15	15	17	15	12
	Solar	7	5	3	19	23	12
	Heat	3	2	1	10	20	13
	Light						
		5	8	5	0	23	0
	Gravity	0	5	3	28	23	26
	Kinetic	2	2	3	0	0	0
	Move.	0	5	3	28	23	26
	Kinetic	0	3	0	23	13	17
	Potent.	0	0	0	12	9	26
	Heat						
		9	3	2	7	5	1
	Food	10	3	1	0	0	0
	Body	0	4	3	0	0	0
	Move.	0	0	0	15	22	11
	Kinetic	0	0	0	17	14	8
	Potent.	1	0	1	12	16	11
	Heat						
		7	4	0	8	15	0
	Elect.	7	0	2	10	10	8
	Light	1	2	1	13	19	6
	Heat	1	2	1	13	19	6
	Heat	0	0	0	10	14	7
	Sound	7	0	2	10	10	8
	Light						

From Table 19, it is clear that, post implementation, similar numbers of students in Rick's class could recognise the most popular form

of energy as students in the other two classes. However, examining responses to the next two most frequently recognised types of energy, post implementation, reveals that the rate of recognition from Rick's class was almost always much less than the rate from the other two classes who learnt using the constructivist approach. It can be tentatively concluded that students who underwent the implementation can recognise more types of energy from the presented events. This conclusion is supported from data presented in Table 20 which presents the number of different types of energy recognised by the class in each presented event, post implementation. For example, in the first situation dealing with pushing a box up a hill, the students from Rob's class could recognise seven different types of energy. For a type of energy to be counted, only one student from a class had to recognise the energy as being present.

Table 20

Numbers of different types of energy present in each situation, by class, post implementation.

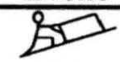
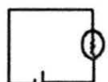
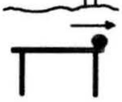
Event	Rob's class	Sean's class	Rick's class
	7	10	5
	5	8	4
	8	13	8
	7	8	5
	8	10	6
	7	12	6
	9	13	7
	6	9	4
	14	13	7
	11	11	7
Mean number recognised	8.2	10.7	5.9

Table 20 demonstrates that in every event presented, the number of energy types recognised by students from Rick's class was always less in number than from the other two classes. This table also demonstrates that students in Sean's class could recognise more types of energy than students in Rob's class in all events presented apart from the person. The differences between classes were also statistically significant. Using a two tailed t-test to compare the means of the number of energy types

recognised showed there was a significant difference between Rob and Rick's classes ($t=3.74$, $p< .01$), between Sean and Rick's classes ($t=14.70$, $p< .01$) and between Rob and Sean's classes ($t=3.93$, $p< .01$). Rob and Sean's classes underwent the implementation.

The mean number of students from each class recognising the eight most commonly reported types of energy from the ten events presented, are reported in Table 21. This table was constructed by totalling the number of students in each class who could recognise, as an example heat, in each of the ten events presented and calculating the mean of that number. For example, an average of 17 students from Rob's class could recognise heat in all the events presented.

Table 21

Mean number of students recognising each type of energy in the presented events, by class, post implementation.

Type of energy	Rob's class	Sean's class	Rick's class	p
Heat	17	19	13	
Potential	14	10	4	**
Kinetic	19	19	9	**
Sound	7	14	4	*
GPE	2	9	2	*
Chemical	8	9	5	**
Electrical	5	6	5	
Light	6	8	4	*

Note: ** The means for both Rob and Sean's classes were significantly different to the mean for Rick's class at $p< .05$
* The mean for Sean's class was significantly different to the mean for Rick's class at $p< .05$.

From Table 21, it can be seen that less students in Rick's class, taught with traditional methods, could recognise the common types of energy than students in the other two classes.

Table 21 shows there are significant differences between Sean and Rob's classes, which both implemented the constructivist approach. There was also a significant difference, at the 0.05 level between Sean and Rick's class with regard to the recognition of sound ($t=9.67$, $p=0.00$), gravitational potential energy (t=4.32, p=0.00), light (t=4.47, p=0.00) mechanical energy (t=3.28, p=0.01), chemical potential energy (t=0.17, p=0.00) and solar energy (t=3.50, p=0.01) in addition to those already reported.

"Correctness" of Responses

It is clear that students in Rob and Sean's classes could recognise more types of energy in the events presented than students in Rick's class. The scientific correctness of those response is important. Figure 30 illustrates that the number of responses categorised into common, scientifically correct (as judged by the researcher) energy forms were very similar in all three classes, pre implementation. The figure was constructed by totalling correct responses across all events.

After the implementation, it can be clearly seen that students in Rob and Sean's classes gave a much higher number of correct responses in all categories than Rick's class. Additionally it can be seen that students in Sean's class could recognise a wider range of "correct" energy types present in the events presented than students in the other two classes. This again indicates that there may be differences in the implementation of the instructional approach in the two constructivist classes.

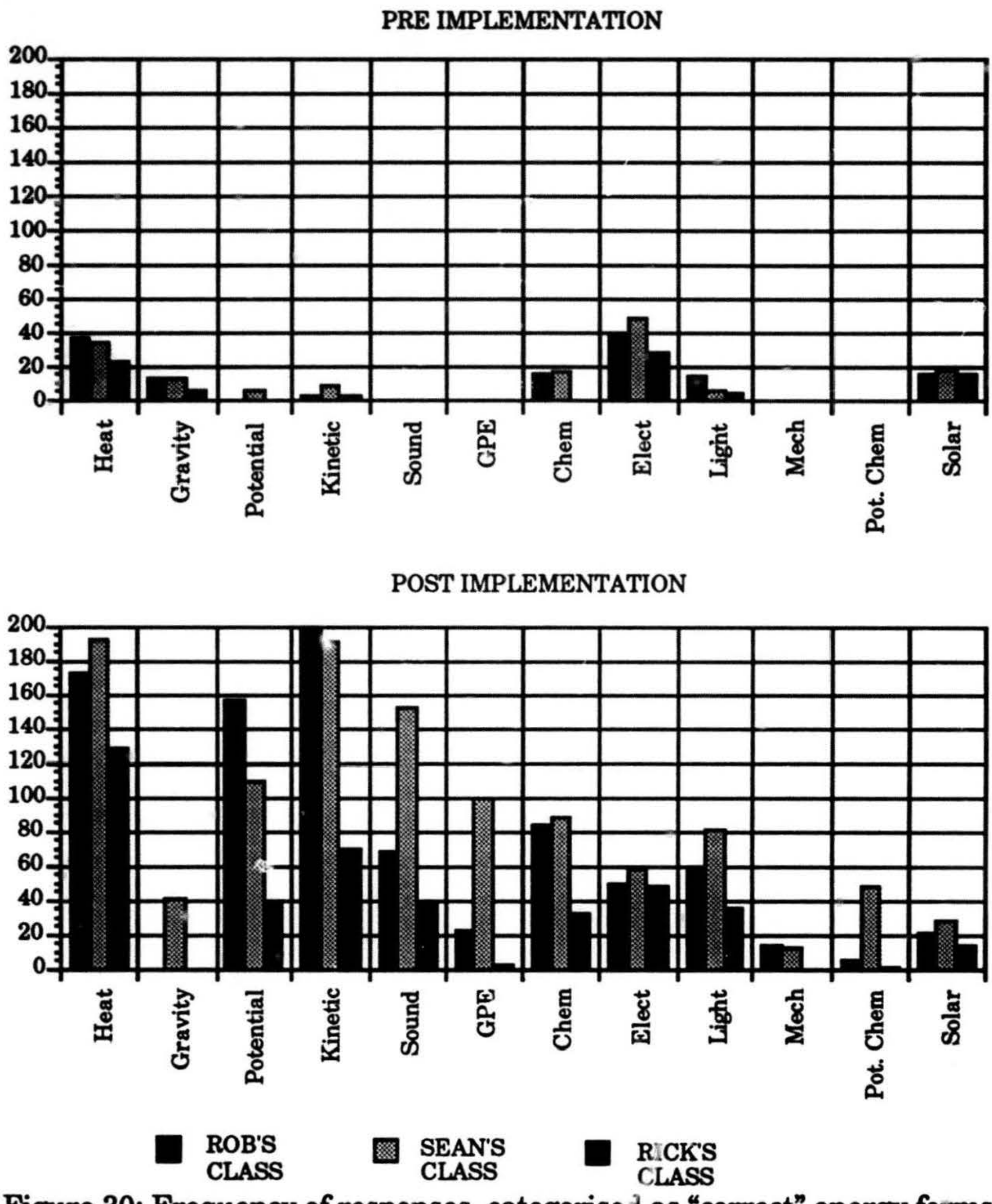


Figure 30: Frequency of responses, categorised as "correct" energy forms, to all events from all classes, pre and post implementation.

To conclude this section Figure 31 illustrates the responses to the event regarding the electric circuit and globe and is an example of the range of responses to a particular event.

The horizontal axis on the graphs has less scientifically correct responses on the right hand end of the scale and more scientifically correct responses towards the left hand end. This enables easy comparison to be made about the "correctness" of responses between pre and post results. Most, but not all, students in all classes could recognise the presence of electrical energy in a circuit, pre implementation. Various other types of energy were recognised at a low level of response, including one student who could recognise the presence of nuclear energy.

Electric Circuit with Battery and Globe

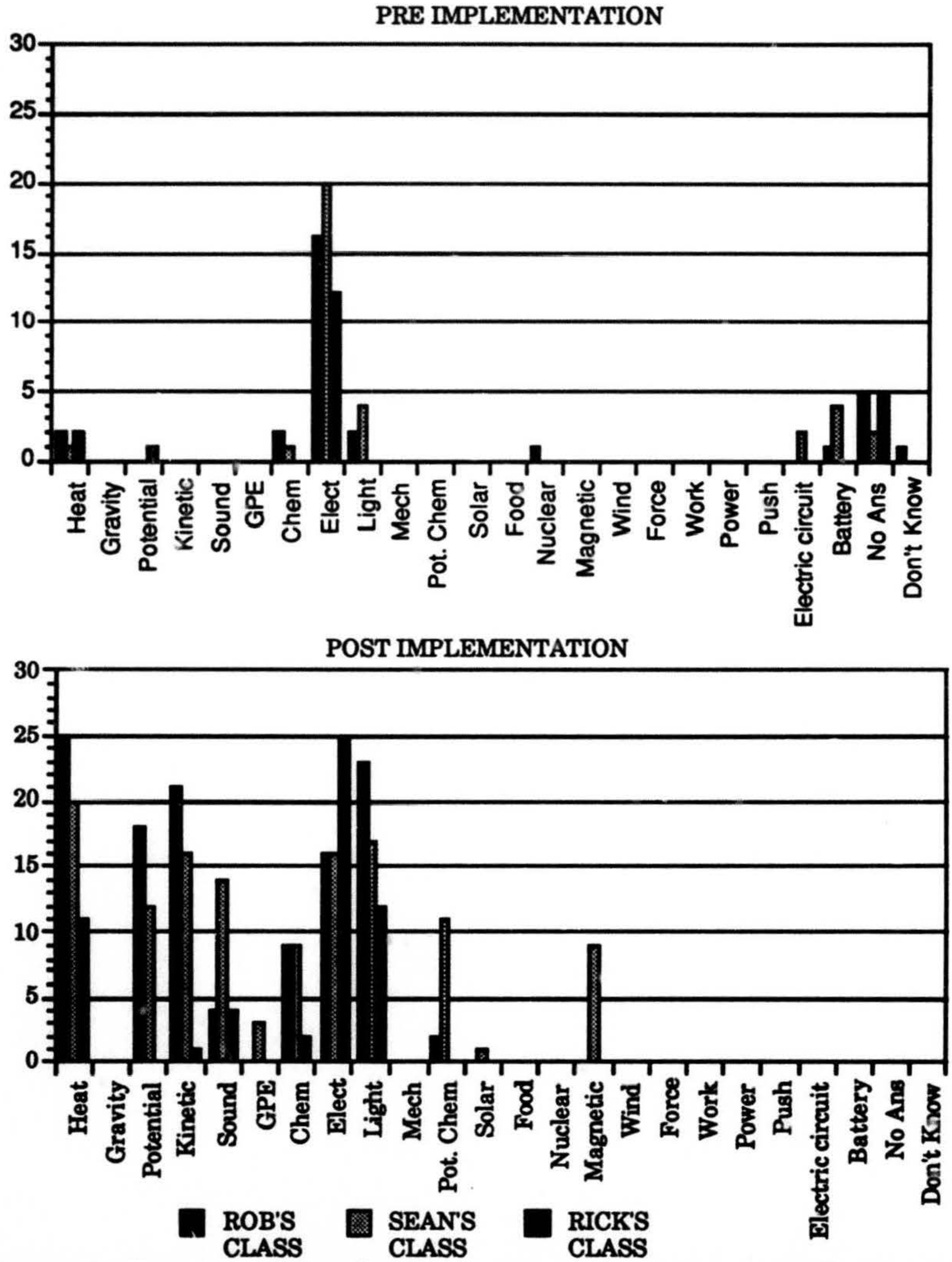


Figure 31. Frequency of students' responses to question regarding forms of energy present in an electric circuit, pre and post implementation, by class.

Post implementation, most of the responses (45%) from Rick's class were confined to electricity with the next most frequent response being heat (20%). No student in Rick's class recognised the presence of potential energy in this situation whereas 18 students from Rob's class and 12 students from Sean's class could. Again students in Rob and Sean's classes could recognise more types of energy. Students in Sean's class could recognise the presence of magnetic energy and had a higher response rate to the recognition of sound and potential chemical energy than the other classes.

Can We Make or Destroy Energy ?

Table 22

Students' responses to the question "Can we make energy ?" pre and post implementation, by class.

	Pre implementation			Post implementation		
Class	Yes	No	No ans	Yes	No	No ans
Rob	24	3	0	8	17	4
Sean	25	5	2	8	18	6
Rick	19	1	6	1	27	0

Before implementation, most students believed it is possible to create energy with no significant differences between the classes. Post implementation, students mostly believed it was not possible to create energy, this time there being a significant difference between the classes (Pearson chi - square value: 8.3, 2 df, $p < .02$). More students were convinced that it was not possible to create energy in Rick's class than in the other two classes.

Table 23

Students' responses to the question "Can we destroy energy ?" pre and post implementation, by class.

	Pre implementation			Post implementation		
Class	Yes	No	No ans	Yes	No	No ans
Rob	13	5	9	2	20	5
Sean	14	13	5	3	22	2
Rick	12	4	10	2	21	5

About the same number of students believed it was possible to destroy energy, pre implementation, in each class. Post implementation, most students believed it was not possible to destroy energy with no significant differences between the classes.

Responses to Question "Is energy being used? If so, what for ?"

Responses to the above question were categorised for all classes, pre and post implementation, and only the frequency of the three most common uses are reported. The most common uses were determined by totalling uses for each event across all three classes. As in Table 19, a line separates the three most common responses pre implementation from the three most common responses post implementation. Table 24 displays these data.

Table 24

Most common uses of energy and their frequency for each event, pre and post implementation, from each class.

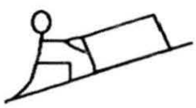
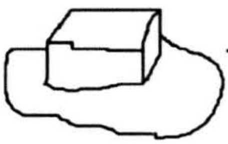
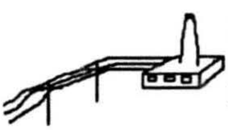
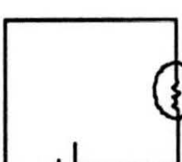
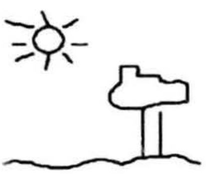
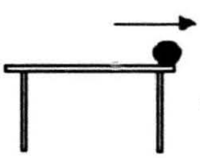
Event	Use for energy	Pre implementation Rob's class (N=31)	Pre implementation Sean's class (N=27)	Pre implementation Rick's class (N=25)	Post implementation Rob's class (N=29)	Post implementation Sean's class (N=30)	Post implementation Rick's class (N=29)
	Pushing	21	21	14	15	10	13
	Move.	2	3	2	0	0	0
	Friction	0	3	0	0	0	0
	Pushing	2[illegible]	21	14	15	10	13
	Kinetic	0	0	0	17	12	10
	PE-KE	0	0	0	7	7	4
	Melting	22	21	14	26	25	21
	Melting	22	21	14	26	25	21
	Kinetic	0	0	0	15	8	3
	Potent.	0	0	0	3	4	0
	Fact. or homes	5	6	5	12	11	8
	Electric.	2	4	3	18	16	5
	Power	2	0	4	0	0	0
	Fact. or homes	5	6	5	12	11	8
	Electric.	2	4	3	18	16	5
	Sound	2	0	0	11	3	3
	React	2	4	5	8	0	0
	New sub	4	5	1	3	5	2
	Mix	2	0	0	0	0	0
	Heat	0	0	0	13	12	0
	Chem.	0	0	0	18	5	0
	Chem. React.	2	0	0	4	12	11
	Electric.	16	20	12	16	16	25
	Light	2	4	4	23	17	17
	Heat	2	1	2	25	20	11
	Heat	2	1	2	25	20	11
	Electric.	16	20	12	16	16	25
	Light	2	4	4	23	17	17

Table 24 (Continued)

Most common uses of energy and their frequency for each event, pre and post implementation, from each class.

		Pre implementation			Post implementation		
Event	Use for Energy	Rob's class (N=31)	Sean's class (N=27)	Rick's class (N=25)	Rob's class (N=29)	Sean's class (N=30)	Rick's class (N=29)
	Eat	13	14	3	7	2	9
	Person	5	0	5	0	0	0
	Move	0	1	5	0	0	0
	Kinetic	0	0	0	17	19	2
	Chem.	0	0	0	23	14	0
	Heat	0	0	0	3	2	2
	Photo.	7	11	8	19	19	10
	Grow	4	4	2	3	6	5
	Life	4	5	6	0	2	1
	Photo.	7	11	8	19	19	10
	Grow	4	4	2	3	6	5
	Heat	4	0	1	4	2	4
	Move	5	2	9	0	0	0
	Roll	5	4	1	0	0	0
	Heat	4	0	0	3	8	0
	Kinetic	0	0	0	17	9	15
	PE-KE	0	1	0	10	11	1
	Sound	0	0	0	5	14	0

From Table 24, it can be seen that, pre implementation, responses from the three classes are reasonably similar with responses from Rick's class to the events regarding pushing the box uphill and eating a meal being considerably less frequent than the other two classes. After the implementation, the frequency of responses from students in Rick's class to the most common use, is considerably less in most events. This gives an indication that students in that class can suggest fewer uses for various types of energies. Table 25 presents data detailing the total number of uses for energy from each class. This was calculated by simply totalling the different uses suggested by students from each class without regard to the frequency of the response. Even if only one student

suggested the use, it was included in the total. This means that , for example students in Rob's class suggested a total of ten uses for the energy recognised in the event regarding pushing a box uphill.

Table 25

Numbers of different uses of energy present in each event, by class, post implementation.

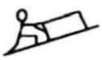
Event	Rob's class	Sean's class	Rick's class
	10	11	6
	8	4	4
	15	15	7
	11	14	5
	19	18	4
	14	12	7
	8	12	6
	8	9	5
Mean number of uses	11.6	11.9	5.5

Table 25 shows that in every event presented, students in Rick's class could state less uses than students in the other classes. Using ANOVA to test for significant differences in the mean number of uses of energy in each class, demonstrated a statistically significant difference (F=8.88, df=2,23, p=0.002) between the two implementation classes and Rick's class (Scheffé F=6.39, p=0.007 for Rob's class and Scheffé F= 6.92, p=0.005 for Sean's class).

Table 26 displays the mean number of students stating each use of energy over the ten events. This was calculated by selecting the five most common uses (Conversion from one form to another, Used for kinetic energy, used for potential energy, used for heat, used for sound) and calculating the mean response across all events for each class.

Table 26

Mean number of students stating each use of energy in the presented events, by class, post implementation.

Use of energy	Rob's class	Sean's class	Rick's class
Conversion	8	8	2
Kinetic	12	8	5
Potential	4	4	0
Heat	7	9	2
Sound	7	6	1
Mean number of uses	7.6	7.0	2.0

Table 26 demonstrates that students in Rick's class can suggest fewer uses for energy than students from the other two classes. Using ANOVA to test for significant differences in the mean number of uses from the above table, demonstrates a significant difference ($F=8.98$, $df=2,14$, $p=0.004$) between Rick's class and the others (Scheffé $F=7.44$, $p=0.008$ for Rob's class and Scheffé $F= 5.93$, $p=0.016$ for Sean's class).

To conclude this section, some data gathered from a typical event is presented to illustrate students' identification of the uses of energy. This is necessary as considerable data reduction and abstraction has occured and it is necessary to show from where the data originate. Figure 32 shows some typical data gathered from the event to do with a chemical reaction.

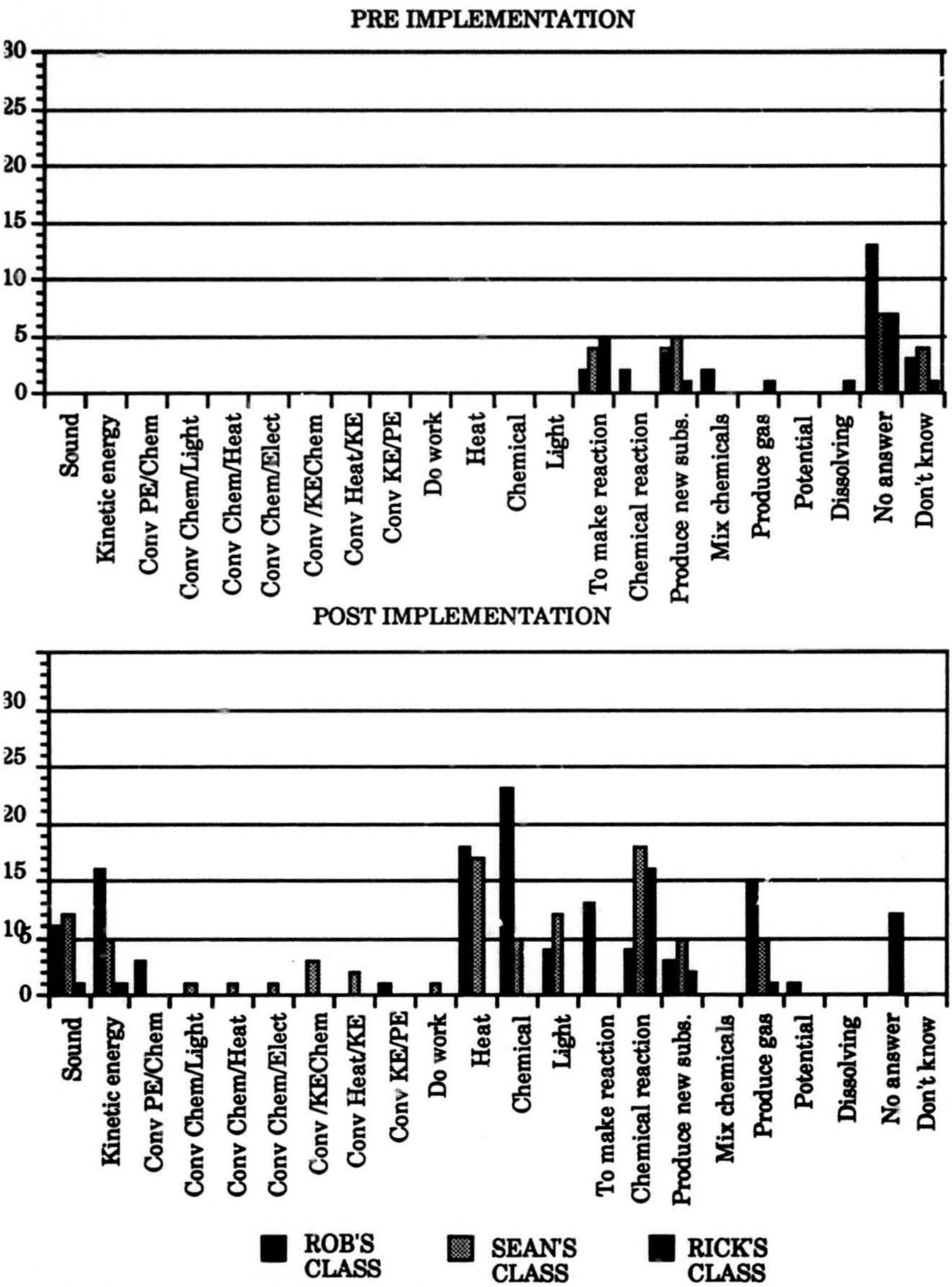


Figure 32. Frequency of students' responses to question regarding the use of energy in a chemical reaction, pre and post implementation, by class.

Most students had little idea what the energy could be used for in a chemical reaction, pre implementation and these responses are demonstrated graphically, above, as an example of the general change in students' ideas, pre and post implementation. Those students who proffered a use for energy tended to suggest the energy was used for making the reaction and for producing new substances. The response rate was low and there was little differences between the classes.

Post implementation, students in Rick's class still preferred to think that the energy was used for making a reaction or producing a new substance and their responses were mainly restricted to these categories. In contrast, students in Rob and Sean's classes were able to offer a variety of uses such as making heat, making chemical energy, making light, making sound, producing a gas and making kinetic energy.

Conclusion to the Chapter

Questions-About-Events has been successful in allowing students to express their ideas, in a limited fashion, about the presence, form and use of energy in a variety of situations. The analysis of the results from the classes was restricted generally to forms and uses of energy thus ignoring the context in which the energy was stated and any information linking ideas expressed. That is, the data from the students is richer than analysed. Nevertheless the following statements can be made based on the data gathered.

1. Students in Rob and Sean's classes are able to identify a wider range of forms of energy across a variety of events than students in Rick's class who experienced traditional teaching

2. Students in Rob and Sean's classes are able to identify a wider range of uses for energy than students in Rick's class who experienced traditional teaching.

The difference between classes was more marked in questions which are abstract and outside students' immediate experience, such as chemical reactions and power stations, than in situations which are concrete, familiar and likely to be used as examples by the teacher, such as balls rolling on tables and trees using sunlight for photosynthesis.

3. Even though students in Rick's class recognised less forms and uses of energy than students in the other classes, the forms recognised are scientifically acceptable.

4. Sean's class could generally identify more forms of energy and a wider number of energy uses than Rob's class in many events.

5. More students reported that it was not possible to create energy in Rick's class than the other two classes. This interesting result is referred to in later chapter when students' constructed views of energy are examined from interview data.

Results from this chapter can be used to answer research question two. There is a difference in students' personal knowledge concerning energy between students taught with traditional methods and students undergoing the constructivist approach. This is manifested by students in the constructivist classes having the ability to recognise more forms of energy and more uses of energy in various situations than students in the traditional class.

According to PCP, a student's ability to recognise events is dependent upon the student's existing constructs. These constructs must be permeable enough and have sufficient range of convenience to encompass the new event. It can be concluded then, that because of their increased ability to list forms of energy and uses for that energy, students in Rob and Sean's classes have more constructs which can encompass the events presented than students in Rick's class. They are generally more cognitively complex individuals with their egard to their knowledge of energy.

These results reinforce results from the previous chapter which demonstrated both a qualitative and quantitative difference in students' constructs about energy between students experiencing the constructivist approach and students taught in the traditional way. It can now be stated with some certainty that the learning approach is successful in increasing students' personal knowledge about energy and in translating formal, abstract science into their domain.

CHAPTER TEN

Energy Questionnaire

Introduction

This chapter presents results regarding the students' commitment to beliefs about energy, before and after the implementation of the two learning approaches. The chapter begins with a brief description of the instrument used to assess students' strength of belief. Following this is a discussion of those students' beliefs which underwent a statistically significant change, pre and post implementation. This discussion is necessary to assess the affect of the instructional approach upon students' beliefs and to answer research question two.

The Questionnaire

The questionnaire was based on an instrument developed by Boyes and Stanisstreet (1990) and comprised 31 statements about energy. It was administered in normal science class time to all participating classes prior to and immediately following implementation.

Statements about plants and energy, animals and energy, Australia and energy and general statements about energy were included. Students were asked to respond to each of the items by rating it on a five point scale using the following criteria:

1	means	I am sure this is right
2	means	I think this is right
3	means	I don't know if this is right or wrong
4	means	I think this is wrong
5	means	I am sure this is wrong

The instrument was designed to assess students' commitment to beliefs and is similar to an approach advocated by Rowell, Dawson and Madsen (1993).

Analysis of the results are restricted to a search for differences in responses amongst the three classes participating in the study pre and post implementation.

Results

Table 27 was constructed using a two tailed paired t-test of significant difference with the level of p being < 0.01, consistent with levels used in previous chapters, as it is a level appropriate to small sample sizes. Table 27 displays the differences between the mean scores on each question, pre and post implementation, for each class. Statistically significant differences are indicated with an asterisk. Following Table 27, only those questionnaire items which had significant differences in any class, are discussed. The reliabilty of the questionnaire, pre and post combined, was 0.64 (Cronbach's alpha).

Table 27

Differences between mean pre and post test scores on energy questionnaire by class.

Question	Rob's class (N = 29)		Sean's class (N = 26)		Rick's class (N = 30)	
	Mean diff	Sig.	Mean diff	Sig.	Mean diff	Sig.
1	-0.90		-0.40		0.50	
2	-0.79		0.08		-0.50	
3	0.07		0.03		-0.04	
4	0.34		-0.33		-0.38	
5	-0.72		-1.07	*	-0.15	
6	-0.10		0.07		-0.12	
7	-0.90		-1.30	*	-0.27	
8	-1.03	*	-1.13	*	0.19	
9	-0.79	*	-0.60	*	-0.15	
10	0.00		-0.03		0.12	
11	-0.86	*	-1.30	*	-0.69	
12	-0.69		-0.60		-0.62	
13	-0.07		-0.50		-0.65	
14	0.14		-0.03		-0.15	
15	0.34		-0.13		0.50	
16	-0.38		-0.90	*	-0.46	
17	-0.28		-0.53		-0.42	
18	-0.24		-0.53		-0.04	
19	2.66	*	2.60	*	0.83	
20	-1.62	*	-1.80	*	-0.15	
21	-0.97		-2.17	*	-0.62	
22	0.07		0.03		0.35	
23	-1.17	*	-0.13		-0.31	
24	1.76	*	1.13	*	1.15	
25	-0.10		-0.73		0.32	
26	-0.93	*	-0.73	*	-0.46	
27	1.48	*	0.50		2.65	*
28	-0.21		0.23		0.50	
29	-0.07		0.07		0.08	
30	-0.07		0.13		0.12	
31	-0.10		0.00		0.15	

Note: * indicates $p < 0.01$ for a two tailed t-test for paired data.

Significant differences were found between pretest and posttest on questions five, seven, eight, nine, 11, 16, 19, 20, 21, 23, 24, 26 and 27. There were nine significant changes in Rob's class, 10 significant changes in Sean's class and one significant change in Rick's class. Each of these questions is now examined in detail to assess the effects of the different learning approaches on the students' beliefs.

Plants Get Their Energy From Water

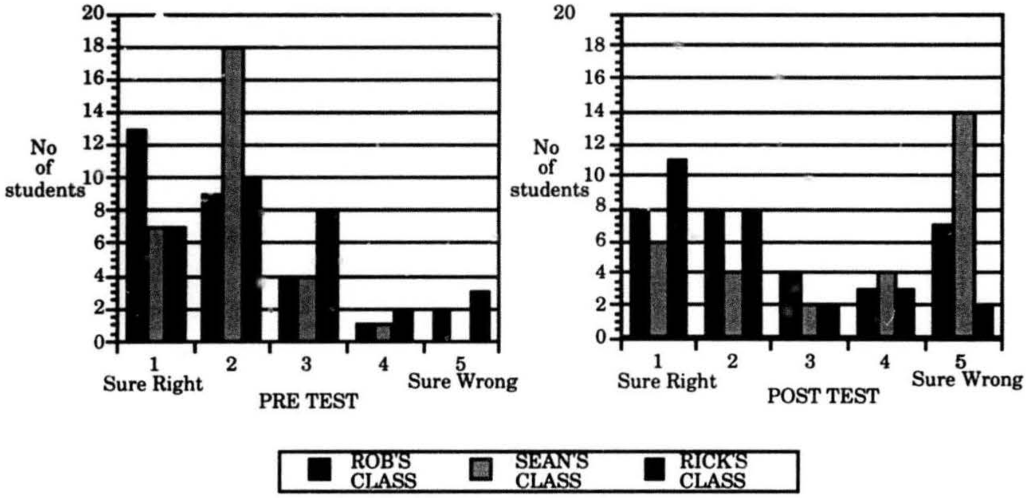


Figure 33. Student responses to the statement "Plants get their energy from wa implementation.

The scientifically incorrect idea that plants get their energy from water was popular amongst students from all three classes prior to implementation with 22, 25 and 17 students from Rob's, Sean's and Rick's classes, respectively, either thinking this is right or sure this is right. Two, zero and three students, respectively, were sure this was wrong prior to implementation.

After implementation, the number of students who thought this was right or were sure this was right actually rose in Rick's class from 17 to 21 whereas in Rob and Sean's classes the numbers thinking the same way dropped from 22 to 16 and from 25 to 10 respectively. The number of students who were sure this was wrong after implementation in Rob and Sean's classes rose from two to seven and from zero to 17 respectively. It can be stated that normal instruction reinforced this particular idea in Rick's class and that the learning approach was successful in changing significant numbers of student's beliefs about this statement in the trial classes.

Animals Get Their Energy From Sleeping

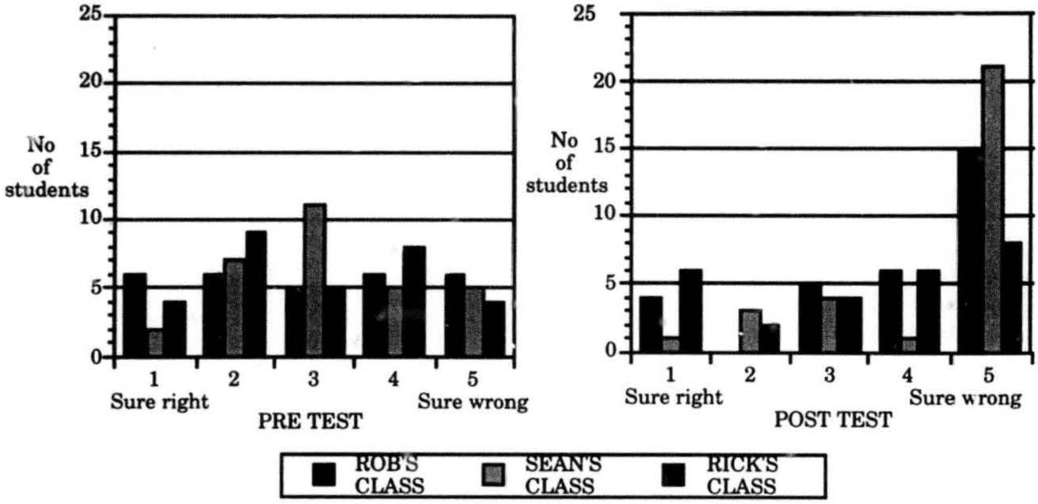


Figure 34. Student responses to statement "Animals get their energy from sleeping", by class, pre and post implementation.

The idea that animals get their energy from sleeping was thought to be wrong or thought sure to be wrong by 12, 10 and 12 students from Rob, Sean and Rick's classes respectively, prior to implementation. After implementation these numbers increased to 21, 22 and 14. There was little change in numbers in Rick's class. It can be stated that the constructivist approach is more successful in changing students' ideas about this proposition than traditional methods, with Sean's class undergoing greatest change.

Animals Get Their Energy From Water

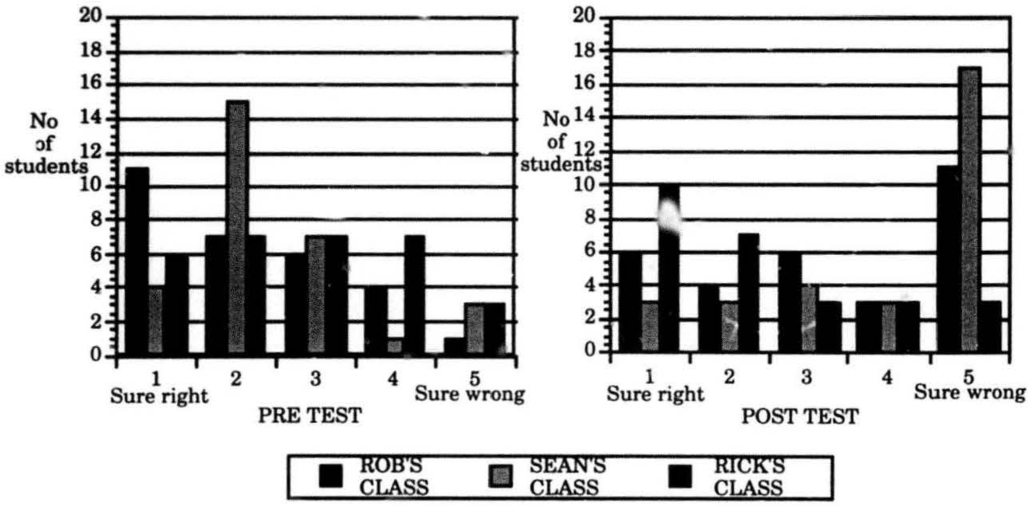


Figure 35. Student responses to statement "Animals get their energy from water", by class, pre and post implementation.

Only one, three and three students respectively from the three classes were sure the statement animals get their energy from water, was wrong pre implementation. An additional four, one and seven students thought it might be wrong. After implementation 11, 17 and three students were sure the idea was wrong confirming a similar pattern to the previous questions where there is little change in Rick's class and significant change in Rob and Sean's classes. Again the amount of change in students' ideas is greatest in Sean's class. The number of students who were sure this idea was right rose in Rick's class from six to 10 students and it would appear that traditional instruction has actually increased the number of students who firmly hold an incorrect idea, in contrast to the constructivist classes where the incidence of the alternative framework fell.

Animals Get Their Energy From Keeping Water

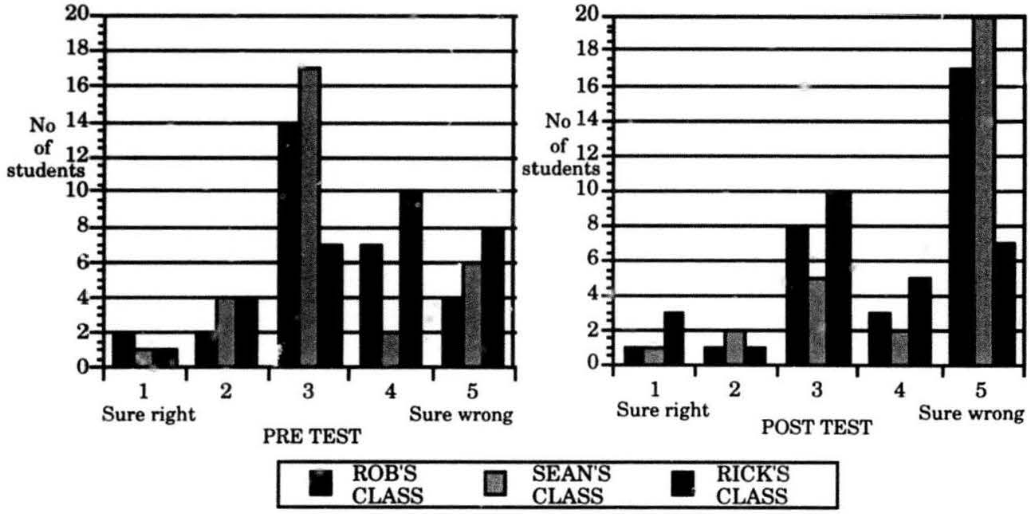


Figure 36. Student responses to statement "Animals get their energy from keeping water", by class, pre and post implementation.

Four, six and eight students in Rob, Sean and Rick's classes responded correctly pre implementation. After implementation the numbers were 17, 20 and seven, respectively, with numbers increasing very significantly in Rob and Sean's classes and decreasing slightly in Rick's class. It can be concluded that the constructivist learning approach was more successful in changing students ideas about this proposition compared to traditional instruction.

Animals Get Their Energy From the Air They Breathe

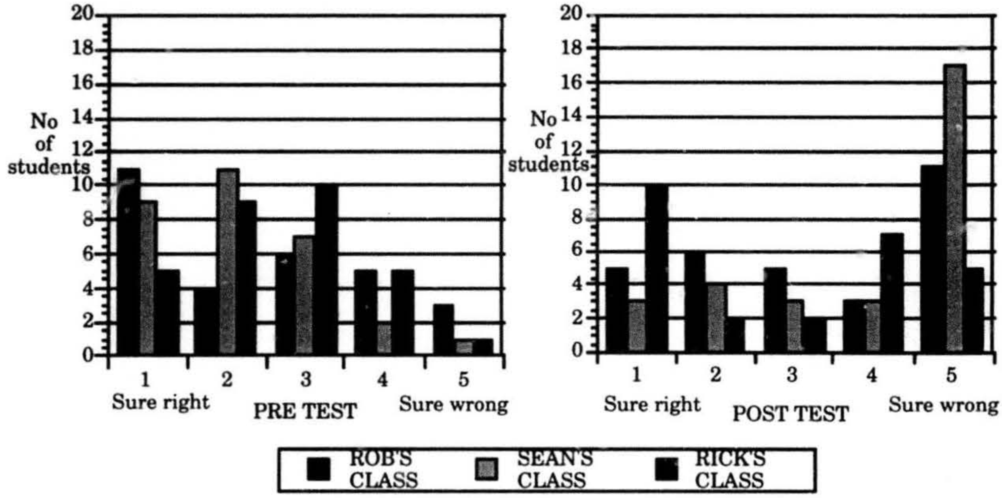


Figure 37. Student responses to statement "Animals get their energy from the air pre and post implementation.

A similar trend to the last two questions is evident in this proposition with three, one and one students, respectively from each class sure that this statement was wrong, pre implementation. After implementation, 11, 17 and five students were sure this was wrong demonstrating that students in the constructivist classes were more likely to change their ideas about this proposition than students taught in the traditional manner. The change is most marked in Sean's class. The number of students who were sure this was right decreased in Rob's and classes (11 to five, nine to three) and increased in Rick's class from five to 10. Again, usual instruction has increased the incidence of this alternative framework

Australia Gets Its Energy Mainly From Factories

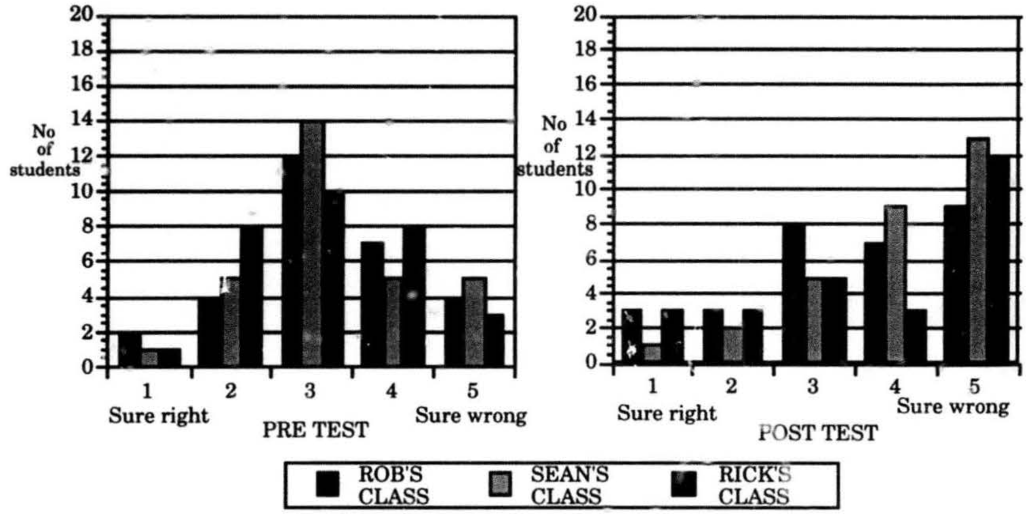


Figure 38. Student responses to statement "Australia gets its energy mainly from factories", by class, pre and post implementation.

Most students were not sure if this statement was right or wrong with similar numbers believing this in all three classes pre implementation. After implementation, the numbers of students who thought this statement was either wrong or who were sure it was wrong, rose from 11 to 16, from 10 to 22 and from 11 to 15 respectively. Only in Sean's class was the change statistically significant. Many students (eight, five and five) did not know if this was right or wrong after completion of the unit.

Fridges Take Energy From Food

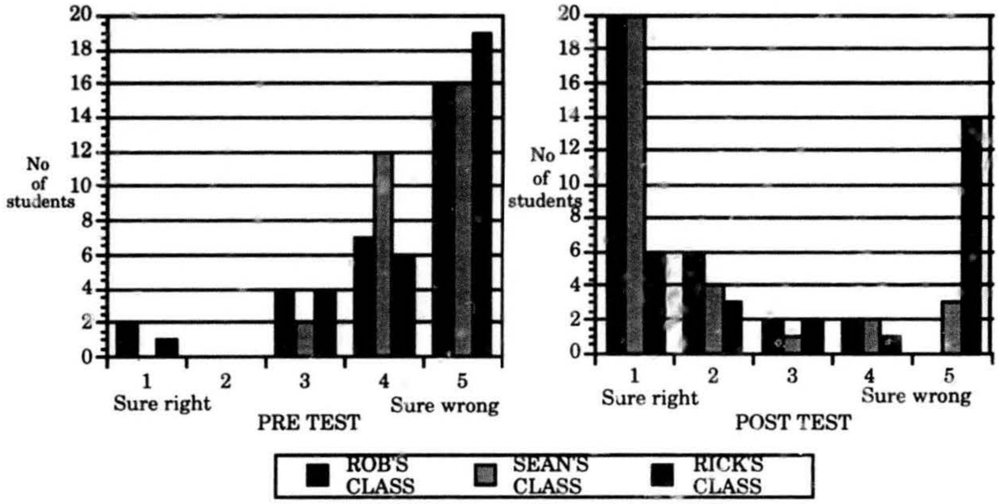


Figure 39. Student responses to statement "Fridges take energy from food", by implementation.

The fundamental idea that if energy is removed from a body then its temperature will drop seemed wrong to most students (23, 28, 25) prior to implementation with most (16, 16, 19) students being sure this was wrong. After implementation most (20, 20) students in Rob and Sean's classes were sure this idea was correct and only six students were sure of this idea in Rick's class. In Rick's class 15 students still thought the idea was wrong compared to two and four students in Rob and Sean's classes. The constructivist learning approach seems successful in allowing students to reconstruct, accommodate or change a fundamental idea dealing with energy. Traditional instruction has had little impact on students' alternative frameworks in this abstract situation.

We Sleep to Get Our Energy Back

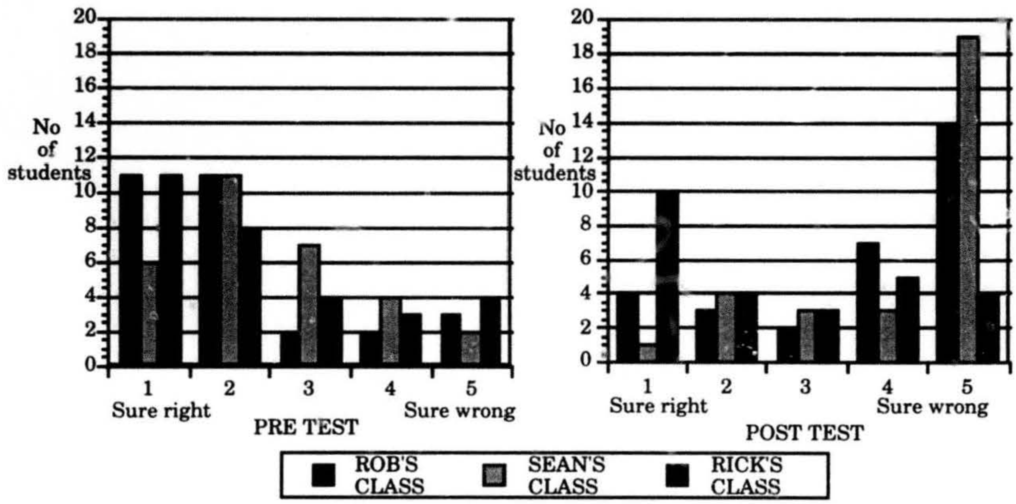


Figure 40. Student responses to statement "We sleep to get our energy back", by implementation.

Sleeping to get energy back is a correct idea according to 22, 17 and 19 students prior to implementation. After implementation, seven, five and 14 still believed this to be correct with little change in numbers of students from Rick's class who believed this idea. The numbers of students who were sure this idea was wrong were three, two and four prior to implementation and 14, 19 and four after implementation indicating that the constructivist approach was more successful in students incorporating the correct idea in this situation than the traditional approach.

Pulling and Pushing are Examples of Energy

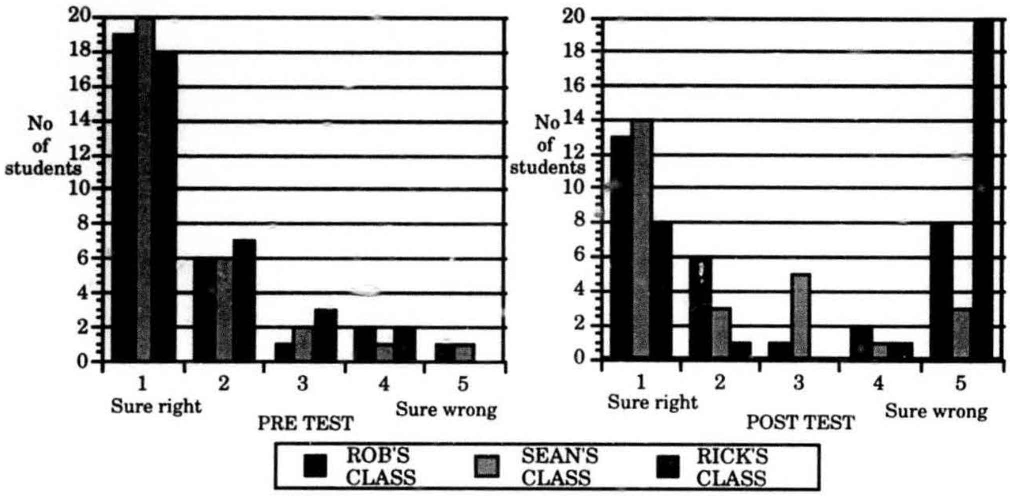


Figure 41. Student responses to statement "Pulling and pushing are examples of energy", by class, pre and post implementation.

Most students (19, 20, 18) in all three classes were sure pulling and pushing were examples of energy. After implementation 13, 14 and eight students were sure with eight, three and 20 students sure this idea was wrong. It appears that the constructivist approach is not as successful as traditional instruction in convincing students that this idea is scientifically incorrect.

Energy is Invisible

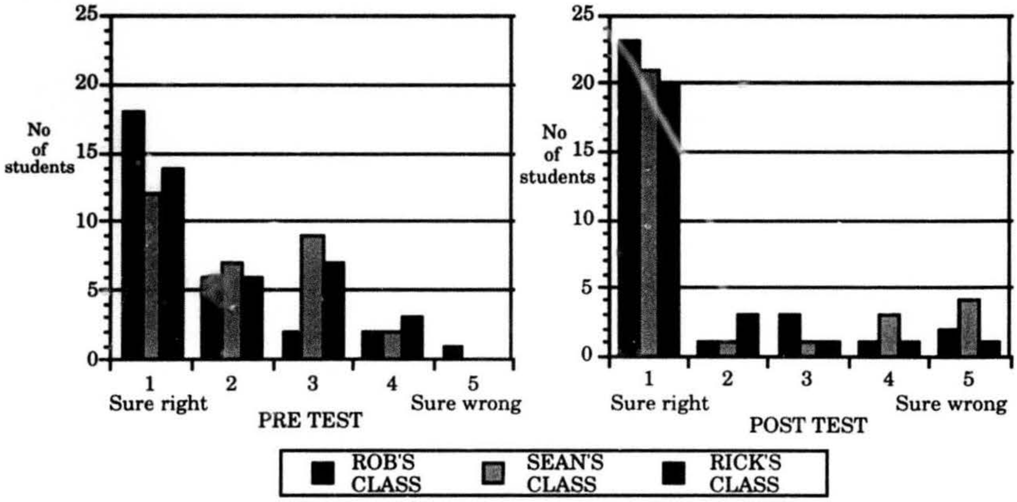


Figure 42. Student responses to statement "Energy is invisible", by class, pre and post implementation.

Both approaches were successful in increasing the number of students who thought energy was invisible with both approaches having similar effects. The students who changed their minds during instruction seemed to be mostly students who did not know if this idea was right or wrong prior to instruction. Sean's class underwent the most change in their beliefs about this idea.

When You Lift Something You Give it Energy

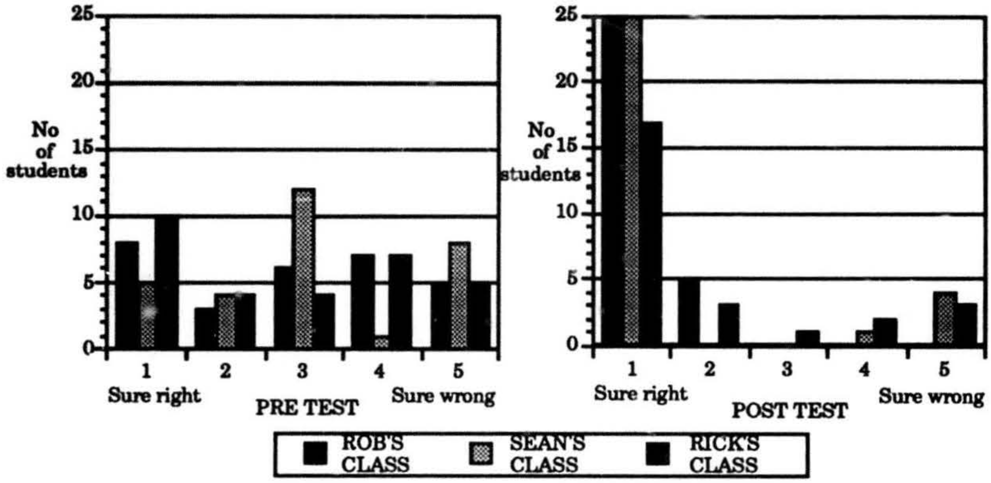


Figure 43. Student responses to statement "When you lift something you give it energy", by class, pre and post implementation.

This statement was really asking students whether potential energy increased with height. Before implementation 11, nine and 14 students thought this was correct and after implementation 30, 25 and 20 students believed this to be correct. The changes were significant in Rob and Sean's classes but not in Rick's class.

Only Living Things Can Ever Have Energy

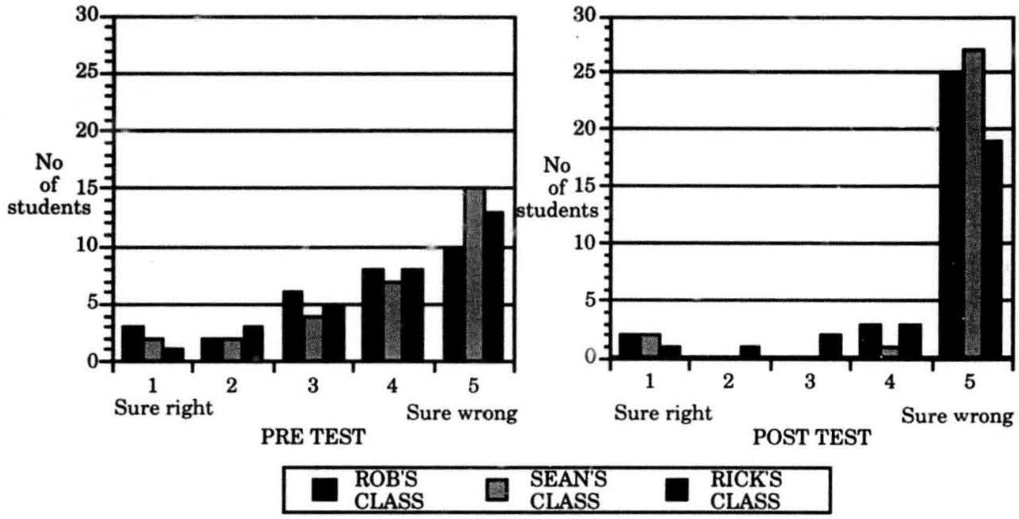


Figure 44. Student responses to statement "Only living things can have energy", by class, pre and post implementation.

Only living things can ever have energy was an idea which underwent significant change in Rob and Sean's classes but not in Rick's class with 18, 22 and 18 students thinking this was wrong pre implementation and 28, 28 and 21 students thinking this was wrong post implementation.

Energy Cannot be Created or Destroyed

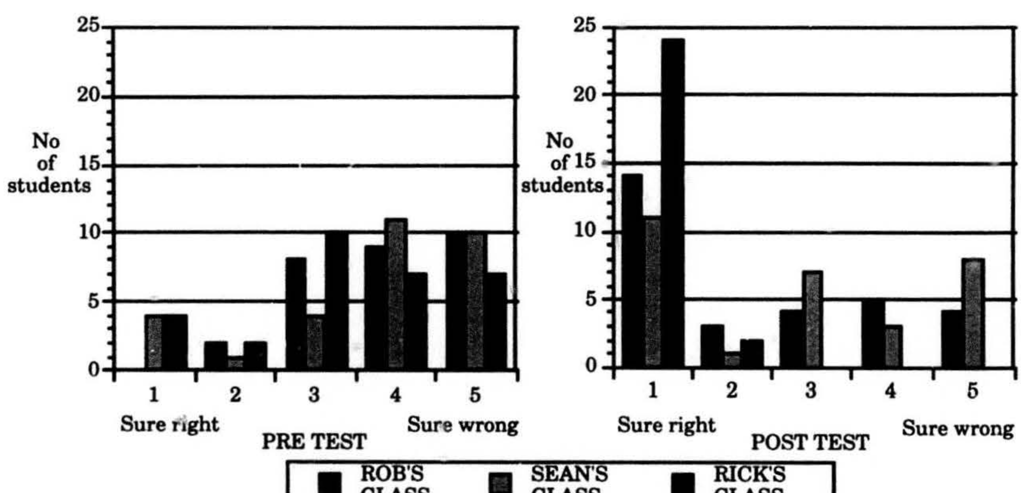


Figure 45. Student responses to statement "Energy cannot be created or destroyed", by class, pre and post implementation.

This final proposition was also regarded differently by students pre and post implementation. No one in Rob's class and few students in each of Sean and Rick's classes were sure this was right pre implementation. After implementation 17, 12 and 26 students were sure this idea was correct with the change being significant in Rob and Sean's classes. The learning approach has bought about change in students' ideas but the change has not been as great as that bought about by traditional instruction.

Conclusion to the Chapter

This questionnaire was designed to determine students' commitment to beliefs about energy, a domain of students' thinking which is usually not measured with conventional assessment.

The constructivist approach implemented in the two classes has bought about a statistically significant change in students' beliefs in 12 situations to do with energy. Eleven of these changes were towards a more scientifically correct view of energy and one change in a less scientifically correct direction. Students taught with usual methods changed their beliefs significantly about only one situation which was to do with energy being created or destroyed. In statements dealing with plants getting their energy from water, animals getting their energy from water, animals getting their energy from keeping water, and animals getting their energy from the air they breathe, usual instruction led to an increase in the numbers of students who believed these statements to be correct. These results assist in the answering of research question two. It can be stated that the instructional approach brought about more significant changes in students' beliefs than usual instruction. Consequently it can be stated that the constructivist learning approach has affected students' personal knowledge about energy with changes in the students knowledge being towards more scientifically acceptable ideas.

This approach has brought about significant construct change in the students undergoing the implementation. The process of making explicit their constructs, testing those constructs against others' constructed reality and elaborating those constructs has led to the construction of reality that accords with the scientifically accepted picture of situations to do with energy which confirms results from previous chapters.

CHAPTER ELEVEN

Energy Knowledge Test

Introduction

A school science test comprising 20 multiple choice questions was constructed, based upon objectives for the unit Energy. The test was used to assess the effect upon students' school science knowledge of the constructivist approach compared to traditional instruction and results are used to answer research question one. Identical forms of the test were administered as pre and post tests. Identical forms were used as the time between administrations was 10 weeks, limiting test effects. The maximum possible mark for the test was 20.

Class Results Pre Implementation

Table 28

Summary statistics of students' performance on science pre test for each class.

	Rob's class (n = 31)	Sean's class (n = 30)	Rick's class (n = 24)
Minimum	4	4	4
Maximum	15	17	14
Mean	9.3	9.8	8.6
Std. Dev.	2.6	2.7	2.4

Table 29
ANOVA results from comparison of mean numbers of items correct, from all classes, pre and post implementation.

Source	SS	df	ms	F	P
Total	2119.60	171			
Between groups	1094.30	5	218.90	35.44	0.00
Within Groups	125.30	166	6.19		

Table 30

Scheffé test of significant differences between mean numbers of items correct per student, from all classes, pre implementation.

	Rick		Sean		Rob	
	Scheffé F	p	Scheffé F	p	Scheffé F	p
Rick			0.16	0.99	0.20	0.97
Sean	0.16	0.99			0.68	0.65
Rob	0.20	0.97	0.68	0.65		

Tables 28, 29 and 30 indicate that students in these classes already have some knowledge about energy as indicated by class mean scores of about nine out of 20. The tables also indicate that there is very little difference between the classes, as measured by this test. The mean for Rick's class is slightly less than the mean for the other two classes but the difference is not significant at the 0.01 level.

Class Results Post Implementation

Table 31

Summary statistics of students' performance on science post test for each class.

	Rob's class (n = 30)	Sean's class (n = 30)	Rick's class (n = 27)
Minimum	10	10	8
Maximum	19	18	17
Mean	14.5	14.6	13.6
Std. Dev.	2.3	2.1	2.8

Table 32
Scheffé test of significant differences between mean numbers of items correct per student, pre and post implementation for each class.

	Rick Pre		Sean Pre		Rob Pre	
	Scheffé F	p	Scheffé F	p	Scheffé F	p
Rick Post	13.39	0.00				
Sean Post			10.88	0.00		
Rob Post					10.32	0.00

Table 33
Scheffé test of significant differences between mean numbers of items correct per student, from all classes, post implementation.

	Rick		Sean		Rob	
	Scheffé F	p	Scheffé	p	Scheffé F	p
Rick			0.005	1.00	0.35	0.88
Sean	0.005	1.00			0.68	0.65
Rob	0.35	0.88	0.44	0.82		

Table 32 indicates that all classes have learnt about energy as shown by the significant differences. For all classes the increase was statistically significant ($p < 0.000$). Again there is very little difference between the classes' mean scores on the posttest with Rick's class having a slightly lower mean. However, as shown in Table 33, the difference is not significant.

The multiple choice format was chosen because of the potential of achieving high reliability for the test. The reliability of the post test was 0.62 using Cronbach's alpha calculated across all classes, pre and post test. This is an adequate figure given the low number of items in the test. If other items, such as completion or short answer items had been included then it is possible that the test could go some way towards assessing a wider range of students' constructions, however this would be at the cost of reliability.

Conclusion to the Chapter

These results indicate that students who learnt using the constructivist approach learnt the school science as well as students who underwent traditional instruction. There is no significant difference in the mean scores from the two approaches as measured by a normal school science test. The second conclusion that can be reached is that this standard school test is not capable of determining changes in other aspects of a student's knowledge of energy. In previous chapters, significant change was identified through the use of other probes. Accordingly, it can be stated that standard school multiple choice tests are insensitive instruments for determining the breadth and depth of students' knowledge.

It can be postulated that much of the learning that occurs in constructivist (and possibly usual) classrooms is not adequately assessed by instruments such as usual school science tests. This point is elaborated using Hilary, a student from Rob's class as an example.

Hilary scored seven on her pretest and 10 on her posttest, out of total marks of 20, which would lead to her being classified by most teachers as a student who is not good at science. Yet this student could recognise, kinetic, potential, sound, heat, chemical, electrical, solar and stored as examples of energies. She could list many uses for these energies and knew that energy could be converted from heat to kinetic, coal to kinetic, coal to electricity, chemical to heat and from electricity to light. Constructs elicited post implementation showed that she knew that energy could be stored, was renewable and has the ability to do work. Her knowledge about energy was displayed in her explanation about energy in an electric circuit - "electricity is passing through the wires and is kinetic energy...and the globe gives off light and there's light energy...the globe and there's stored energy in the battery" and again displayed in her answer to the cartoon representation of ice melting - "heat is causing the ice to melt so the water moves to produce kinetic energy". With the representation of a ball rolling, she wrote "kinetic energy was used to roll the ball, potential is when the ball is going to roll off the table and sound is when the ball hits the ground". Simple assessment methods such as essays or a task like "Write down all you know about energy" would all allow her to reveal more of her science learning, in her own words.

Clearly this student knew more about energy than could be revealed by a school assessment item. Reasons for this need to be investigated and a possible beginning is the investigation of the relationship between the language used on the assessment instrument and the student's language. Hilary could express her own understandings in her own language but may have had trouble translating these meanings into formal, school science language. Hilary had a rich understanding of the topic and the question is raised of how best to assess this personal knowledge. A further question relates to the equity of current assessment practices and the relationship between these practices and the kind of student who succeeds at school with these current practices.

In conclusion to the chapter, research question one can be answered. Students undergoing the constructivist approach learnt the school science as well as students taught with the traditional methods. Results from Chapter Seven led to a similar conclusion.

CHAPTER TWELVE

The Individual Students

Introduction

In all previous chapters dealing with results, the class has been the unit of study. In this chapter, the individual views about energy from four students from each of the three classes, gathered before and after the implementation of the different learning approaches, are summarised. The views from two boys and two girls selected at random from each class at the commencement of the study are collated in this chapter. The results from this chapter are used to answer research question two on an individual student basis rather than on a class basis.

Data came from three sources; the students' own energy grids, questions-about-events (QAE) data, and individual interviews-about-events (IAE). Data sources were restricted to these qualitative probes and responses to standardised instruments such as questionnaires and normative grids were omitted because of the lack of individual meaning inherent in such instruments and because these data are reported in previous chapters.

The data from completed repertory grids were treated in two ways. Firstly, the number of constructs elicited from each of the students was counted, before and after implementation and is reported in a table. Secondly, one student's grid from each class, chosen as typical of the four students, is analysed in detail to exemplify the learning that has occurred. The students chosen for analysis were Sharon from Rob's class, Nigel from Sean's class and Tom from Rick's class. Each student's repertory grid will be displayed, followed by a principal components map of their constructs, followed in turn by a discussion of any groupings of elements and constructs displayed. Principal components maps are used as they convey the most information about the relationships between elements and constructs in the least space.

The QAE data were examined so that the number of forms and uses of energy stated by each student could be listed. These data give a guide to each student's knowledge about energy and are reported in

Table 34. These data are also reported separately for Tom, Sharon and Nigel.

Four students from each of the three classes were interviewed before and after implementation. This resulted in eight interviews being analysed from students who learnt using the constructivist approach and four interviews being analysed from students taught in the traditional manner. All 12 interviews were coded. Categories of data were identified by the use of open coding based on sentences as units of text. The procedure was similar to the procedure which might be applied in a grounded theory (Glaser & Strauss, 1967) study. The rationale for the determination of categories was detailed in memos which enabled another researcher to confirm the categorisation procedure. Inter-rater reliability was not required, because of the very broad categories established, and because no difficulty was encountered in assigning text units to a category. This assumes that any other researcher with the same background as this researcher would assign text units to the same categories.

Codes were mapped using NUDIST (Richards, 1987) computer software. NUDIST (Richards, 1987) is a specialist built data base designed to handle data such as interviews and their associated codes. The systematic processes dictated by the use of this software resulted in the emergence of several themes from the pre and post interviews and these are reported. This method of analysis helped to identify similarities and differences between the responses from students who learnt using the constructivist approach and those students who underwent instruction in the traditional way.

It was possible, using NUDIST (Richards, 1987) to obtain a numerical measure of the number of responses coded into each category. This is expressed as the percentage of text units in the category of the total number of text units in the document being coded. In this study, sentences were used as text units and so percentages reported in each category refer directly to the number of sentences placed in that category. This percentage is not an accurate measure because of variability in sentence length and the number of sentences which could be included in a particular code. However it does provide some estimate of frequency of responses.

This chapter begins with a summary of the data for all students from repertory grids, QAE and IAE. This is followed with a detailed description of the data from these sources for Tom, Sharon and Nigel to exemplify the effect of the different approaches in the separate classes. The chapter concludes with results from the analysis of interviews.

Summary of Data from Repertory Grids, QAE and IAE.

Table 34
Individual student scores from each class, pre and post implementation.

Category	Class	Pre implementation	Post implementation
Number of elicited constructs	Rob	5, 5, 3, 5	20, 20, 14, 31
	Sean	8, 8, 6, 4	20, 19, 12, 11
	Rick	11, 7, 7, 5	14, 6, 10, 6
Number of forms of energy listed in QAE	Rob	3, 2, 1, 4	8, 9, 11, 7
	Sean	3, 4, 3, 2	14, 9, 10, 12
	Rick	3, 4, 3, 3	7, 10, 4, 9
Listed uses of energy from QAE	Rob	4, 4, 3, 7	15, 16, 7, 6
	Sean	8, 4, 5, 0	11, 19, 7, 9
	Rick	7, 6, 4, 4	6, 7, 4, 4
Listed conversions of energy from interviews	Rob	1, 1, 0, 2	12, 11, 5, 10
	Sean	1, 0, 1, 2	19, 10, 10, 12
	Rick	1, 2, 1, 1	5, 5, 2, 2

Note: In the columns titled pre implementation and post implementation, the student's individual results are listed, in the same consecutive order in each class.

Table 35

Means of student scores from each class, pre and post implementation.

Category	Class	Pre implementation	Post implementation
Number of elicited constructs	Rob	4.5	21.2
	Sean	6.5	15.5
	Rick	7.5	9
Number of forms of energy listed in QAE	Rob	2.5	8.8
	Sean	3.0	11.3
	Rick	3.3	7.5
Listed uses of energy from QAE	Rob	4.5	11
	Sean	4.3	11.5
	Rick	5.3	5.3
Listed conversions of energy from interviews	Rob	1	9.5
	Sean	1	12.8
	Rick	1.3	3.5

From Table 35 it can be seen that there is a large increase in the mean number of elicited constructs from the four students in Rob and Sean's classes and a small increase in Rick's class. With forms of energy the increase is also larger in Rob and Sean's classes but the difference is not as marked. With uses of energy and conversions of energy the difference between Rob and Sean's classes and Rick's class is very marked.

Data From Three Individual Students

		1	2	3	4	5	6	7	8	9		
Regular	1	5	1	1	1	5	5	1	5	1	1	Irregular
Seen often	2	5	1	1	1	5	5	1	5	1	2	Seen unoften
Dangerous	3	5	2	4	2	1	1	2	2	2	3	Not dangerous
Made in huge factories	4	4	1	3	1	1	5	3	4	4	4	Not made in huge factories
Good for environment	5	1	4	1	5	5	2	4	4	4	5	Bad for environment
Not luxury energy	6	5	5	1	4	3	1	4	1	5	6	Luxury energies
Mechanical energy	7	1	1	5	1	1	1	1	5	3	7	Not mechanical energy
Does not involve burning	8	1	1	1	5	3	5	2	2	3	8	Involves burning
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 46. Tom's repertory grid (traditional instruction) about energy pre implementation

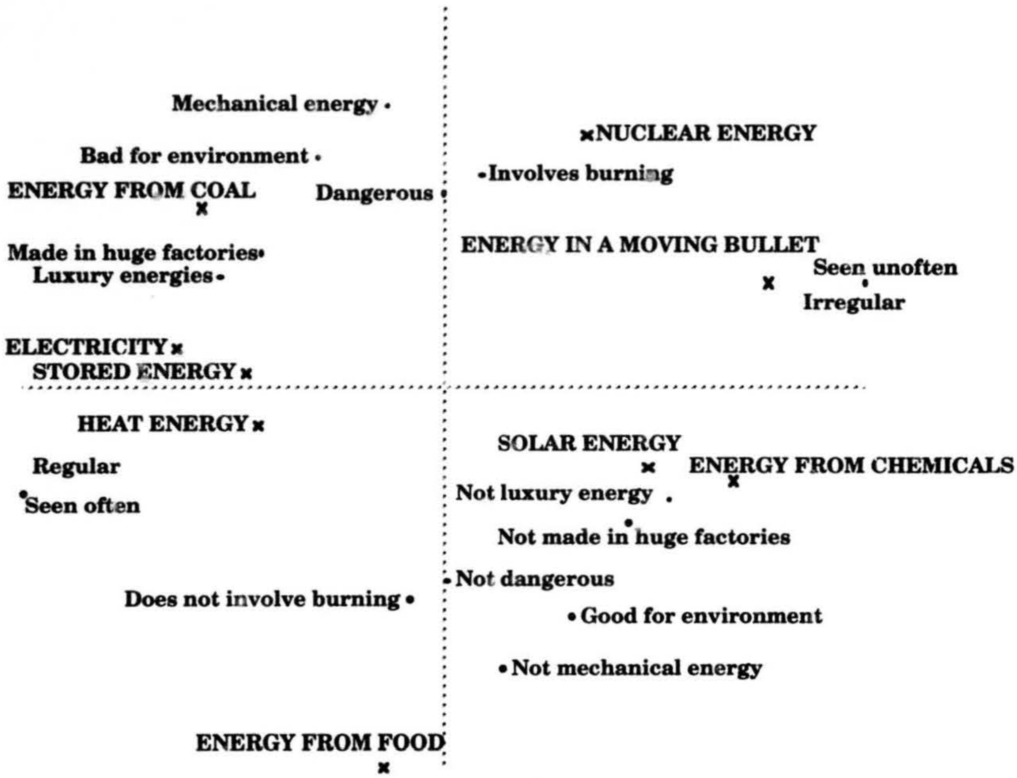


Figure 47. Principal components display of Tom's repertory grid about energy, pre implementation

Tom was taught with usual methods and was from Rick's class. Eight constructs were elicited from Tom, pre implementation. Figure 46 displays his grid and the ratings he applied to the various elements. There are constructs related to how he feels about energy, which was expected as repertory grids elicit constructs from all three domains. For example, Tom regards *Energy from coal* and *Nuclear energy* as *Bad for the environment*. Some constructs, like *Regular* and *Mechanical energy*, would probably need explanation before we could understand Tom's meaning for these constructs.

Figure 47 displays several groupings. *Electricity, Stored energy* and *Heat energy* are very close together indicating that they are regarded in a similar fashion by Tom. *Solar energy* and *Energy from chemicals* are close to *Not luxury energy* and *Not made in huge factories*. *Energy in a moving bullet* is close to *Seen unoften* and *Irregular*. *Nuclear energy* is close to *Involves burning.*

		1	2	3	4	5	6	7	8	9		
Natural forms	1	1	3	1	4	4	5	5	5	1	1	Unnatural
Not kinetic energy	2	1	1	1	3	1	5	1	3	3	2	Kinetic energy
Safe energy	3	1	5	1	4	5	5	1	4	5	3	Dangerous energy
Not from the sun	4	5	1	3	1	5	1	3	2	5	4	From the sun
Uses burning	5	1	3	2	1	1	5	4	4	1	5	Doesn't use burning
Always man made	6	5	3	3	1	5	1	1	1	5	6	Not always man made
Needed for human life	7	1	5	1	5	1	5	5	3	1	7	Not needed for human life
Produced by sun	8	1	5	5	5	1	5	5	3	1	8	Not produced by sun
Dangerous energy	9	5	1	4	1	1	1	5	5	1	9	Safe energy
Non kinetic energy	10	1	1	1	1	1	5	1	5	1	10	Kinetic energy
Heat energy	11	1	2	5	1	1	5	5	5	1	11	Not heat energy
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 48. Tom's repertory grid (traditional instruction) about energy, post implementation.

The number of Tom's elicited constructs has increased from eight to 11 following traditional instruction. However two constructs about burning and dangerous energy are identical to constructs pre implementation. Also three constructs to do with safe, the sun and kinetic energy are repeated. This means that after nine weeks instruction to do with energy, the only new constructs incorporated into Tom's construct system are *Natural forms, Not from the sun, Always man made, Needed for human life, Not kinetic energy and Heat energy*. Perhaps only one construct, *Not kinetic energy* could be classified as a science construct. These are the constructs that Tom will bring to bear upon situations to do with energy and there is little evidence that usual instruction has resulted in the translation of school science into Tom's personal domain.

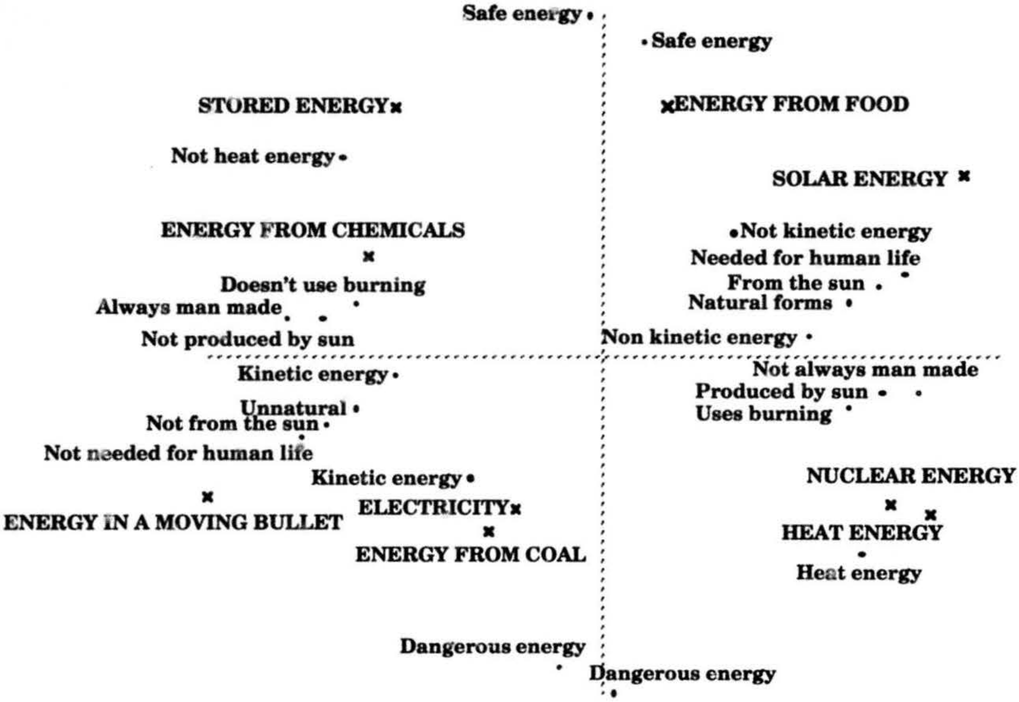


Figure 49. Principal components display of Tom's repertory grid about energy, post implementation.

The principal components map of Tom's constructs shows some groupings. *Electricity* is associated with *Energy from coal. Kinetic energy* is close to *Unnatural* (sic), *Not from the sun* and *Not needed for human life. Natural forms* is close to *Needed for human life, From the sun* and *Natural* forms. *Natural* and *Man made* are highly loaded on factor one and *Safe / Dangerous* highly loaded on factor two indicating that Tom can construe most forms of energy along these dimensions and they may well be the most important ways in which he construes energy. In time, these may come to be the only way in which he construes energy.

Pre implementation, from the QAE sheets, Tom could recognise chemical, heat, electrical, nuclear and light as forms of energy. These energies could be used for movement, melting the ice, for appliances, to move the generator, to change a substance and to give the body energy. In an electrical circuit "electrical energy is replaced by light energy". We cannot create or destroy energy just "replace types of energy with other types".

Post implementation, Tom could recognise chemical, heat, electrical, light and gravitational potential energy. The uses for this energy were to move things, make electricity, make bubbles, make light, digest food, survive. In an electric circuit electricity, heat and light were present. "Electricity turns into heat and light in the globe". Energy could not be created or destroyed just "transformed or transferred".

There is very little difference in Tom's responses pre and post QAE. He could recognise one additional form of energy and his uses for energy were increased by one additional use. His response to the question regarding an electric circuit was reasonably similar to his response pre test but involved a conversion of energy.

Table 36

Forms, uses and conversions of energy from Tom's IAE, pre and post implementation.

Situation	Pre implementation	Post implementation
Forms of energy recog.	Gravity, body energy, friction, pushing, heat, electrical, light and food.	Kinetic, potential, heat, electrical, chemical, sound and light
Uses of forms of energy	Push, movement, for light, melting, to keep you alive, to keep plants alive, and heating.	Movement, melting, to make electricity, to make heat, to make light, and to make food
Conv.	Electricity to light, light to food, and food to human energy.	Kinetic to electricity, chemical to heat, electricity to light and heat, chemical energy to electricity, food to kinetic, and light to food

Table 37

Quotes from Tom's interviews, pre and post implementation, regarding selected energy situations.

Situation	Pre implementation	Post implementation
Electric circuit	It's going through the cord into the wire and then back around to the battery and around again	Electric energy is coming from the battery and it's going into the light globe which is making heat and light in there and then going back to the battery and that's it
Create/ destroy energy	Yes by moving around and pushing or... if lit up something or made something hot or dropped something. Maybe if you ate some food it would be destroying it and if you didn't do anything with it. If you cut an electrical wire, because it couldn't do anything.	No. You can just change it from one form to the other.

Tom's interviews show little difference pre and post instruction in terms of forms and uses of energy. However he is able to state a reasonable number of conversions of energy. There is not a large difference between his stated ideas about energy in an electric circuit, pre and post instruction. In general it can be stated that there is little evidence of the translation of science ideas about energy into his own understandings. What evidence that exists is present in the form of stated conversions of energies. Tom's score on the school science pretest was 9 and posttest 14.

		1	2	3	4	5	6	7	8	9		
Doesn't come from a star	1	5	3	1	1	1	3	1	1	5	1	Does come from a star
Made from an element	2	5	1	5	1	3	5	3	3	3	2	Not made from an element
Comes from an object	3	1	1	1	1	1	5	1	1	5	3	Didn't come from an object
Come from a liquid	4	5	5	1	5	5	3	3	1	5	4	Didn't come from a liquid
Types of energy	5	1	3	5	5	1	5	3	5	1	5	Not types of energy
Get energy from things	6	3	1	1	1	1	1	5	1	5	6	Don't get energy from things
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 50. Sharon's repertory grid (constructivist approach) about energy, pre implementation.

Sharon was in Rob's class and underwent the constructivist approach. Sharon's six constructs indicate how individual a student's views of energy can be. No other student used a construct, to do with stars, to distinguish between types of energy.

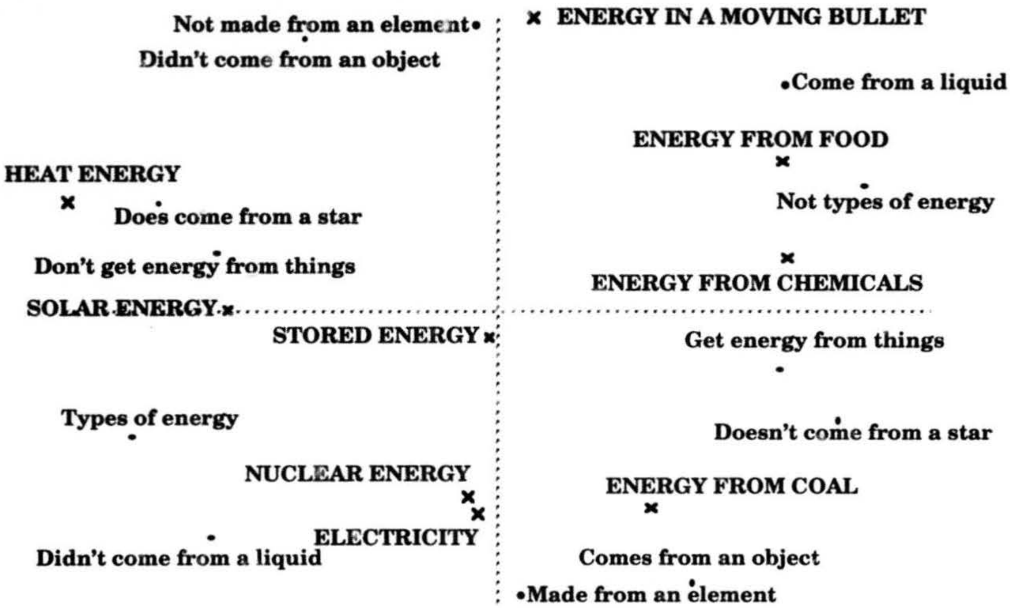


Figure 51. Principal components display of Sharon's repertory grid about energy, pre implementation

Sharon's principal components map shows that *Heat energy* is close to *Does come from a star*, *Don't get energy from things* and *Solar energy*. *Electricity* and *Nuclear energy* are close and most other constructs and elements are evenly spread through the space.

Construct	#	1	2	3	4	5	6	7	8	9	#	Contrast
Used in photosynthesis	1	1	5	1	5	5	5	5	5	4	1	Not used photosynthesis
Man made	2	5	1	3	1	1	1	1	3	1	2	Natural
Common in Australia	3	1	1	1	3	5	5	5	4	3	3	Not common in Australia
Used a lot in the house	4	3	1	1	5	5	5	5	5	1	4	Not used a lot in the house
Not from splitting uranium atoms	5	1	1	1	1	5	1	1	1	1	5	From splitting uranium atoms
Can be converted to other forms	6	1	1	1	1	1	2	5	1	1	6	Cannot be converted to other forms of energy
Used in respiration	7	1	5	1	5	5	5	5	5	4	7	Not used in respiration
Used by humans	8	1	1	1	5	5	5	5	1	1	8	Not used by humans
Has the ability to do work	9	1	3	1	3	1	1	5	1	3	9	Does not have the ability to do work
Expensive source	10	5	1	1	3	3	3	5	3	2	10	Cheap source
Produces light	11	1	1	5	1	1	5	5	5	3	11	Does not produce light
Common around the world	12	1	1	1	3	5	5	5	3	1	12	Not common around the world
Not very useful	13	5	5	5	1	1	1	1	1	3	13	Extremely useful
Can produce sound	14	5	1	5	3	1	1	5	1	5	14	Does not produce sound
Originated from the sun	15	1	1	1	1	1	1	1	1	1	15	Did not originate from the sun
Is measured in joules	16	1	1	1	3	1	1	1	1	1	16	Not measured in joules
Can cause an explosion	17	3	3	5	1	1	3	5	1	3	17	Cannot cause an explosion
Can produce kinetic energy	18	1	1	1	3	1	5	5	1	1	18	Cannot produce kinetic energy
A source to make things hot	19	1	1	5	1	1	1	5	1	1	19	Can not make things hot
Type of potential energy	20	1	3	2	5	5	5	1	1	3	20	Not a type of potential energy

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 52. Sharon's repertory grid (constructivist approach) about energy, post implementation

Post implementation, the number of constructs elicited from Sharon has increased from six to 20. Of these constructs *Used in photosynthesis, Not from splitting uranium atoms, Can be converted to other forms, Used in respiration, Has ability to do work, Can produce sound, Originated from sun, Is measured in joules, Can produce kinetic energy and Type of potential energy* could all be classified as science constructs. These constructs provide good evidence of the construction of science ideas by Sharon and the incorporation of these ideas into her personal knowledge.

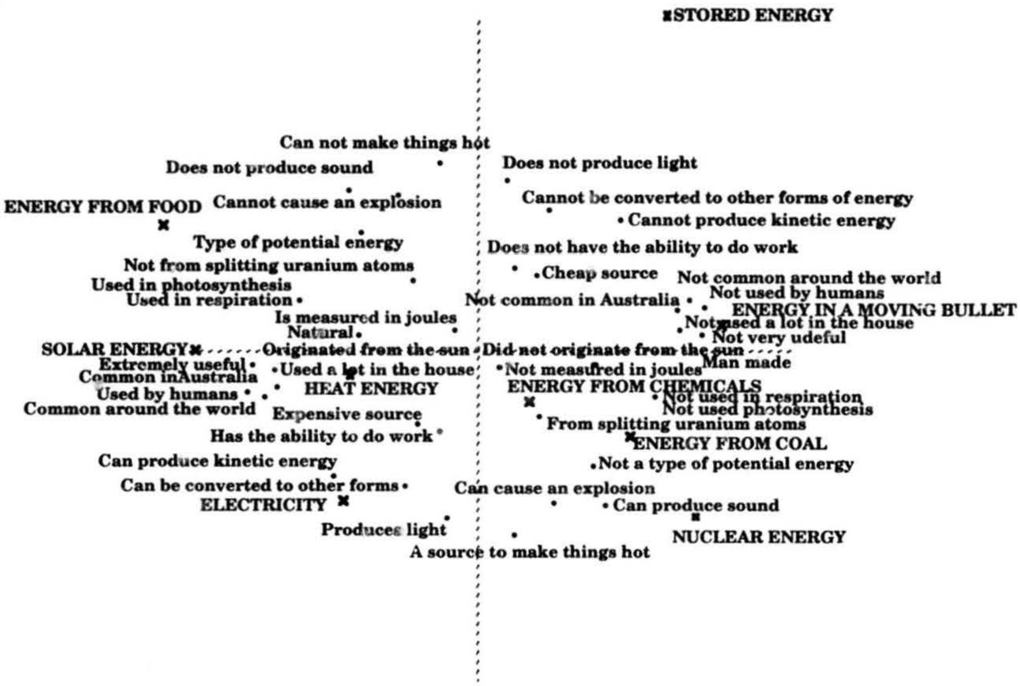


Figure 53. Principal components display of Sharon's repertory grid about energy, post implementation.

Many groupings are apparent from Sharon's crowded principal components map. *Solar energy* and *Heat energy* are close to *Natural, Extremely useful, Common in Australia, Used by humans and Common around the world. Electricity* is close to *Can be converted to other forms* and *produces light. Energy from food* is associated with *Type of potential energy, Not from splitting uranium atoms, Used in photosynthesis* and *Used in respiration. Energy from coal* is close to *Not used in respiration, Not used in photosynthesis* and *Not a type of potential energy. Is measured in joules, Natural* and *Originated from the sun* are not highly loaded on either factor indicating that these constructs are not useful in distinguishing between types of energy. Most groupings evident indicate scientifically correct ideas. It can be concluded from the above that the implementation of the learning approach has resulted in the translation of science ideas into Sharon's domain in a mostly scientifically correct fashion.

From the QAE, Sharon could recognise kinetic, heat, electrical and solar as forms of energy, pre implementation. The uses for energy included to do tasks, to melt ice, to produce a gas, to make the battery and globe, eat, photosynthesis and grow. In an electrical circuit electrical energy was present and it was used "to make the battery and the globe". Humans had energy " we get from the food we eat. Solar energy helps us to grow". We could make energy" from elements such as coal. We can destroy energy by "wasting it".

After implementation from the QAE, Sharon could recognise gravitational potential, kinetic, heat, sound, electricity, potential, light, chemical and food energy. There were many uses for these forms of energy including movement, melt ice, transform from solid to liquid, move current, chewing, photosynthesis, producing friction and to produce all of the mentioned forms of energy.

In an electrical circuit "potential, light, heat and electrical energy" were present. "The potential energy stored in the battery can produce light from the globe which will then give off heat. Kinetic and electrical energy are involved as the currents move through the circuit". We can't make or destroy energy as " the law of conservation of energy says so".

Table 38

Forms, uses and conversions of energy from Sharon's interviews, pre and post implementation.

Situation	Pre implementation	Post implementation
Forms of energy recog.	Electricity, light, solar.	Kinetic, heat, sound, electricity, potential, chemical, light, solar,
Uses of forms of energy	Pushing, melting, eat food, and movement.	Movement, friction make all above energies, force, melt, spread ice, and make food.
Conv. of energies	Food to body, light to electrical, and food to movement	Kinetic to heat, kinetic to sound, heat to kinetic, heat to electrical, heat to sound, fuel to kinetic, potential to kinetic and reverse, potential to light, food to heat, food to kinetic, and solar to food.

Table 39

Quotes from Sharon's interviews, pre and post implementation, regarding selected energy situations.

Situation	Pre implementation	Post implementation
Electric circuit	Well when you turn the globe on that's electricity so the globe's putting electric energy on to the battery. And the globe is acting like a huge light like the sun, solar energy....	I don't really know what's happening but maybe light and heat and sound and kinetic and electrical and potential energy could be involved. The battery has stored potential energy.
Create energy	Yes, I think so. I can't think of an example.	No
Destroy energy	Yes I think so but I don't really know how or why.	No

The QAE results show an increase in the number of science ideas that were stated by Sharon. These results also showed evidence of the use of science ideas in explanations such as her explanation of energy transfers involved in an electric circuit. Post implementation her explanation contained many types of energies with precise explanations of the energy transfers involved.

These results are confirmed by results from Sharon's interviews which show an increase in the types of energy recognised, in the uses of energy and the conversions of energy in various situations. Additionally her verbal explanations showed a corresponding increase in the use of science terms and ideas. Interestingly Sharon could give a much better explanation, in science terms, of energy and electric circuits in written form on the QAE than she could verbally. Sharon now believes that energy cannot be created or destroyed. Her scores on the pretest was nine and on the posttest 14.

		1	2	3	4	5	6	7	8	9		
Direct from a source	1	1	5	4	2	1	3	5	3	1	1	Not direct from a source
Converted to a form humans can use	2	4	1	3	5	4	5	1	4	1	2	Primary form and can't be used
Stored	3	4	5	5	5	4	1	5	1	1	3	Not stored
Chemical reaction necessary	4	4	5	1	1	1	5	5	1	2	4	No chemical reaction necessary
Natural form of energy	5	1	4	1	4	5	5	3	5	3	5	Man made
Physical form of energy	6	1	3	2	2	2	1	2	2	1	6	Non physical
		1	2	3	4	5	6	7	8	9		
		SOLAR ENERGY	ELECTRICITY	ENERGY FROM FOOD	ENERGY FROM COAL	NUCLEAR ENERGY	ENERGY IN A MOVING BULLET	STORED ENERGY	ENERGY FROM CHEMICALS	HEAT ENERGY		

Figure 54. Nigel's repertory grid (constructivist approach) about energy, pre implementation

Nigel was in Sean's class and was taught using the constructivist approach. Nigel's grid, pre implementation, shows six constructs which can probably classified into groups to do with conversion and source of the energy.

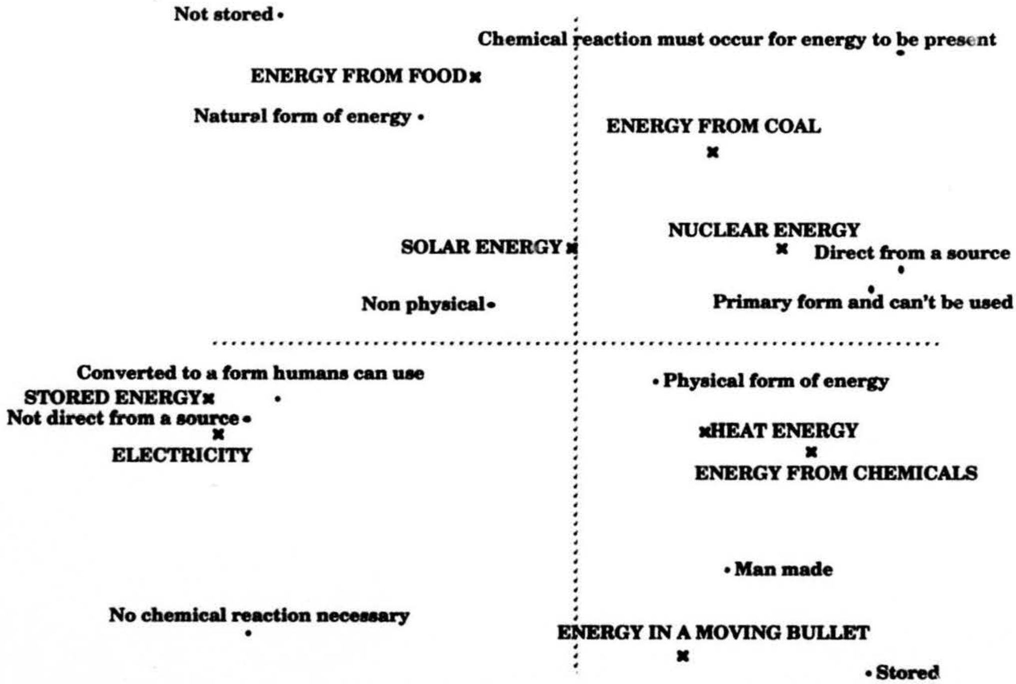


Figure 55. Principal components display of Nigel's repertory grid about energy, pre implementation

Some groupings are evident in the above principal components map. *Stored energy* and *Electricity* are close and close to *Not direct from a source* and *Converted to a form humans can use*. *Heat energy* is close to *Energy from chemicals* and *Physical form of energy*. *Nuclear energy* is close to *Direct from a source* and *Energy from food* is close to *Not stored* and a *Natural form of energy*. *Solar energy* is close to *Non physical*. most groupings could be regarded as scientifically correct.

		1	2	3	4	5	6	7	8	9		
Stored forms of energy	1	5	5	1	1	5	5	1	1	5	1	Not stored forms of energy
Natural forms	2	1	3	1	1	5	1	3	3	1	2	Non natural forms
Needed for survival	3	1	5	1	5	5	1	1	1	1	3	Not needed for survival
Originates from coal	4	5	1	5	1	5	5	5	5	5	4	Doesn't originate from coal
Used widely	5	2	1	1	1	4	1	1	2	1	5	Not used widely
Expensive to extract	6	3	1	1	1	4	2	1	3	1	6	Cheap to extract
Originated from sun	7	1	2	1	2	4	3	3	3	1	7	Doesn't come from sun
Dangerous	8	4	2	5	5	1	3	4	2	4	8	Safe
Old	9	1	3	1	2	5	1	2	4	1	9	New
Able to be used to make electrity	10	1	1	5	1	1	1	2	1	1	10	Not able to be used to make electrcity
Needed by plants	11	1	5	2	5	5	5	1	3	1	11	Not needed by palnts
Hot	12	1	5	5	5	5	5	5	5	1	12	Cold
Moving	13	5	5	5	5	5	1	5	5	5	13	Non moving
Used a lot in Australia	14	3	1	1	1	4	1	1	2	1	14	Not used alot in Australia
Produces heat	15	1	2	5	2	2	2	3	3	3	15	Doesn't produce heat
Has potential	16	5	5	1	1	5	1	1	2	5	16	No potential
Fossil fuel	17	5	3	5	1	5	5	5	5	5	17	Non fossil fuel
Found in a battery	18	5	5	5	5	5	5	1	1	1	18	Not found in a battery
In this room	19	1	1	5	1	5	1	1	1	2	19	Not in this room
		1	2	3	4	5	6	7	8	9		

9 HEAT ENERGY
8 ENERGY FROM CHEMICALS
7 STORED ENERGY
6 ENERGY IN A MOVING BULLET
5 NUCLEAR ENERGY
4 ENERGY FROM COAL
3 ENERGY FROM FOOD
2 ELECTRICITY
1 SOLAR ENERGY

Figure 56. Nigel's repertory grid (constructivist approach) about energy, post implementation

The number of constructs elicited from Nigel, post implementation, has increased from six to 19. Many of these constructs such as *Stored forms of energy, Needed for survival, Has potential, Produces heat , Able to make electricity, Originated from sun, Needed by plants* and *Expensive to extract* could be regarded as science constructs.

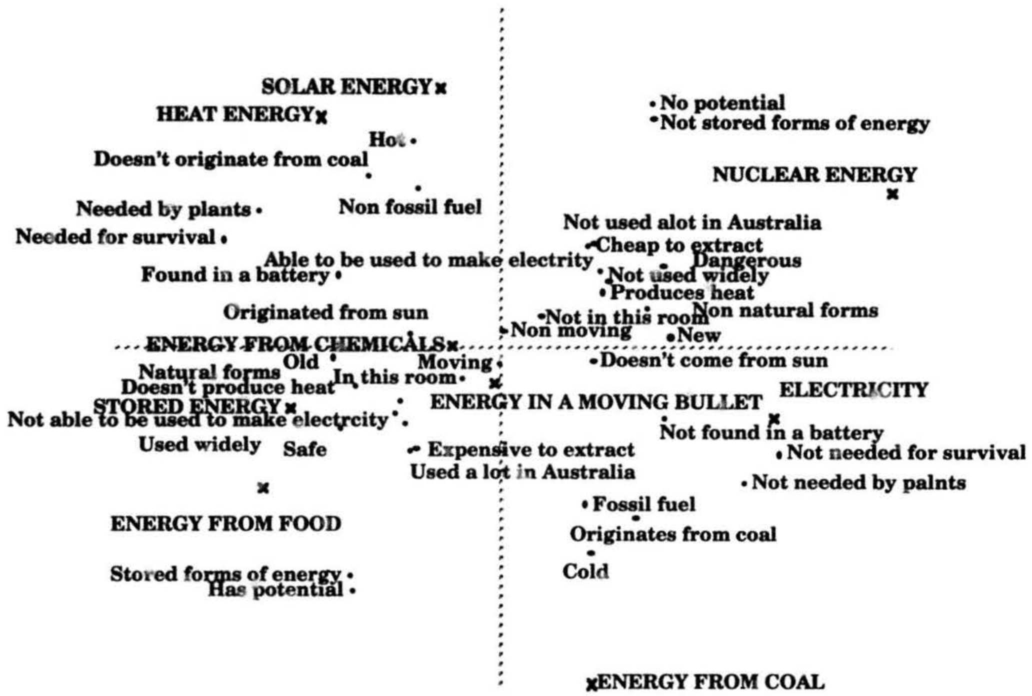


Figure 57. Principal components display of Nigel's repertory grid about energy, post implementation

Many groupings are evident in the above map. Some examples follow. *Heat energy, Solar energy, Hot, Doesn't originate from coal* and *Non fossil fuel* are all close together. *Nuclear energy* is closed to *No potential, Not stored forms of energy* and *Not used a lot in Australia. Fossil fuel* is close to *Originates from coal* and *Cold.* Interestingly, *Expensive to extract* is very close to *Used a lot in Australia.* Other groupings are evident and interviewing of Nigel would be needed to verify some of the associations. As in all of the principal components map, the truth rests with the individual and not the mapping.

QAE responses indicated that Nigel could recognise the following forms of energy, prior to instruction; heat, gravity, kinetic and light. He described the following uses for energy: melting, for homes and industry, produce heat, for respiration and for rolling a ball. A "battery provides energy and produces light and heat energy" and humans had energy in the form of "Mechanical energy allowing us to run and work". Energy could not be "made or destroyed. It can be transformed from one type to another".

Post implementation Nigel could recognise these forms of energy; chemical potential, kinetic, gravitational potential, heat, potential, solar, mechanical, light, sound and electrical. The uses he described for the energy include to push, to create friction, movement, make atoms move faster, spread water, produce steam, turn turbines, make magnetic field, move food, body processes, survive, grow, move ball and thinking. In an electrical circuit:

> "Chemical potential energy in the battery, also a small amount of heat energy. When the wires are connected to the battery, light energy (sparks) may occur. The chemical potential energy is converted to electrical energy and this passes through the wires, causing a slight magnetic field. The electrical energy may encounter resistance - this causing heat. When the electricity reaches the globes, heat light and sound energy are produced. This is the basic principle on which home lighting works".

His thoughts on thinking and energy are worth quoting: "Thinking is the worst offender wasting many times the amount for resting, leading to RMI - repetitive mental injury Ha Ha. Mr (*Sean*) said that was an ailment - yeah, sure !"

He still believed it was not possible to create or destroy energy but expanded upon this:

> "If someone was to say energy is made at a power plant, it would be incorrect as the energy for coal was used to make electricity. Destroy ? No way, energy can only go from one form to another. Even though energy is wasted it is not destroyed".

The above results from the QAE sheets demonstrate an increase in the form, uses and conversions of energy that Nigel could recognise post implementation. In addition the quotes demonstrate a richness of ideas being bought to bear in different contexts.

Table 40

Forms, uses and conversions of energy from Nigel's interviews, pre and post implementation.

Situation	Pre implementation	Post implementation
Forms of energy recog.	Heat, coal, electricity, light, battery, meals, sugars, solar.	Heat, kinetic, GPE, chemical potential, mechanical, sound, light, electrical.
Uses of forms of energy	Separating atoms, effervescence, making heat and light.	Pushing, making heat, movement, making kinetic energy, separating particles, slowing particles, eating and digesting food, photosynthesis, making remaining forms of energy.
Conversions of energies	Coal to electricity, battery to heat, food to sugars, heat and light to sugars.	Conversion of kinetic to potential and reverse, kinetic to heat, heat to kinetic, chemical to kinetic, mechanical to electrical, chemical to heat, light and sound, electrical to mechanical and heat.

Table 41

Quotes from Nigel's interviews, pre and post implementation, regarding selected energy situations.

Situation	Pre implementation	Post implementation
Electric Circuit	Yes from the battery and heat energy might be produced by the globe. Light energy. The battery or the power supply or whatever.	The battery has chemical, potential energy and when this is connected the battery makes it have a little bit of heat in it and when the wires are connected there could be a spark creating light energy. When it's travelling through the wires it's got heat energy and then maybe resistance through the wires and that causes heat energy again. Once it reaches the globe it could-as soon as it reaches it could have sound and...heat and light.
Create energy	Yes. It's present but you just have to capture it. The sun. Solar collector - the solar collector converts it from another form.	No.
Destroy energy	I don't think so. I think it will always be present.	It only can be converted to different forms and while you're converting you can lose some but that will only go to a different form.

From his interviews there is an increase in the number of forms, uses and conversions of energy that Nigel could recognise and state which agrees with data from his QAE sheets. His quote regarding an electric circuit and creating and destroying energy demonstrate a qualitative difference, pre and post implementation, in the type and application of his ideas to these situations. His ideas, as stated in the above quotes, are scientifically correct post implementation. Nigel's score on the school science pretest was 13 and on the posttest, 14.

Summary of Data from the Three Individual Students.

It is clear from the above data that students from the constructivist classes have become more cognitively complex individuals. They have a much wider range of ideas that they can draw upon in attempts to make meaning of external events to do with energy. There is ample evidence of the incorporation of school science ideas into their domain more so than the student who was taught with traditional methods.

Analysis of All Student Interviews-About-Events.

Student interview responses, prior to implementation, were much the same in all three classes. Consequently frequency of codes is reported for all 12 students from the three classes in Table 42.

Table 42

Percentage of text units in each category, all classes, pre implementation.

Category	Percentage of text units coded in category
1. Recognised the presence of energy.	46
(a) Energy residing	27
(b) Energy having an affect	16
(c) Energy needed	9
2. Energy created	23
(a) Manifested as heat, light or electricity	11
3. School science idea applied to event.	14
4. Energy is created by burning	11
5. Energy not destroyed - omnipresent	10
6. Using energy destroys energy	4

Responses could be grouped into two large categories. Firstly, a category based upon students recognising the presence of energy in the event with most stating the form recognised (46%), and secondly a category based upon the idea that energy was being created in the event (23%). Percentages in brackets indicate the mean number of responses coded into that category from all 12 participants.

Some of the responses that could be coded as recognition of the presence of energy could be further coded into a category that contained statements about the idea that the energy just resided in an object as in the following examples.

"Yes in the electricity. ...It comes from the switch...there is energy in the globe, it lights up. *Is energy to do with the globe ?* ...Yes there is something there" (Adam);

"(*Where does the heat come from ?*) ...From energy. *Where is this energy ?* In the sun" (Bill).

Often the fundamental idea of transformation of energy or the flow of energy from one object to another was absent, when the energy was viewed as resident:

"The energy is being used for the globe to light up. *How does the energy get to the globe ?* Through the wires. *What form is it in ?* ...No answer (Hilary).

Created energy manifested itself in various common forms such as heat, light, electricity (11%) according to the students:

"Energy is produced inside the power station in the form of electric energy" (Adam);

"*Is there anything in the house that makes energy?* Only things like heaters, light globes...(Alex);

The idea that burning creates energy was common (11%):

"To make electricity...it could be burning something (Bill);

"When it's burnt it makes the energy" (David).

Sometimes when the energy was present, it was not residing nor converted but still had an affect. Students who felt this way did not have a complete explanation, involving transformations, of how energy could display its effects (16%).

"Well, heat often comes off light" (Bill);

"The heat is making the atoms move slower and further apart... The temperature is warmer in the air than in the original situation...Heat is energy. *How does the heat get to the ice block ?* I don't know" (Nigel);

"Yes you would need your strength to push it up otherwise it will just fall. *So energy has something to do with strength ?* Yes (Tom).

Occasionally energy was present just because it was needed and not present if it was not needed (9%):

"Energy is present cause you need energy to pick up a knife and fork" (Hilary);

"*When the person let the ball go down the slope, is there energy present then ?* No, because there is no energy needed (Nigel).

Coding of responses to direct questions about destroying energy revealed that the omnipresence of energy was not an uncommon idea amongst students prior to implementation (10%):

"I don't think so. It will always be there" (Bill);

"I don't think so. I think it will always be present" (Nigel).

Some students believed that using energy also tended to destroy it:

"I think we are destroying energy all the time. ...Well we are using it, therefore we destroy it" (Shirley);

"If you ate some food it would be destroying it" (Tom).

School science ideas were recalled and applied to the instances presented with varying degrees of scientific correctness (14%):

"Gravity is the force of the planet pulling you in because of its size...It's like a force, it's a type of energy" (David);

"You need the sun for the tree to photosynthesise, when it photosynthesises it produces energy. *In what form is that energy ?* I don't know" (Hilary);

"Our muscles make us have energy. Our muscle cells, respiration and oxygen (Lyn).

Watts (1983) found some similar frameworks of ideas about energy in his study. For example students he interviewed also thought energy resided in objects. The framework described in his study as "energy as an ingredient" (Watts, 1983, p. 214) is very similar to the above category of Energy created/manifested as heat, light or electricity. His category of "energy as an obvious activity" (Watts, 1983, p. 214) also is similar to the above category of Recognition of presence of energy.

In summary of responses pre implementation it can be said that, in general, responses were not extended, lacked precise detail and were generally not linked to other ideas. Additionally students ideas were frequently scientifically incorrect. Using the SOLO taxonomy (Biggs & Collis, 1981), responses could be termed prestructural or unistructural.

Initially, categories established from pre interviews were used to code student responses but it was soon realised that not all the responses could be squeezed into the existing categories. Consequently, very different categories were established to code student responses after implementation. As all students could now recognise the presence of energy and also knew that energy was not created in most situations, these categories were not useful in determining differences between classes. Two new large categories were established. These were to do with the students' ability to give a detailed explanation and to expand upon their answer when prompted. Table 43 summarises the main categories established from coding.

Table 43
Percentage of text units in each category, from post interviews.

Category	Constructivist approach	Traditional
Not particularly detailed	10	83
Expressing science in own words	36	5
Detailed response	47	10
Elaboration of a previous response	58	6

All of the students who learnt using the constructivist approach were able to give detailed explanations and were all capable of elaborating upon their answers when prompted. As coding progressed, it was obvious that in almost all instances presented, students who underwent implementation could give detailed explanations. Responses coded this way from students in the constructivist class could be termed relational or extended abstract, using the SOLO taxonomy (Biggs & Collis, 1981).

In contrast students who were taught using traditional methods could only occasionally give a detailed answer or elaborate upon their answer. A response was coded as detailed if it identified many forms of energy and related these forms to transformations or to some detail of the instance presented. A response was coded as being elaborated upon if the interviewee could expand upon detail presented in the initial responses.

Some examples, below, convey the essence of the differences in responses between the two classes. The examples are presented as pairs with the first quote from a student who underwent the constructivist approach (C) and the second quote from a student who was taught in the traditional manner (T). Typical quotes are used.

C. "And they heat it and the steam from that is then, well it rises and it spins turbines which then convert this moving energy from the air into mechanical energy which is then turned into electricity. And then it goes through the wires and it's stored whenever it's stored" (Nigel)

T. "Well it's taking energy to move the coal, the coal is burned and the heat sort of makes turbines move...and then it's just producing electricity" (Kym)

C. "Pushing energy into the box so it goes up the hill. The person has kinetic energy, potential energy, heat, sound, electric and chemical...he or she is moving the box up the hill which is creating more potential energy as it moves up the hill and it has kinetic energy. There may be some heat involved between the box and the ground and there is also gravity acting against the box moving. The person might be perspiring because of the sun, it might be hot, so producing more heat, I think" (Shirley)

T. "Well there's kinetic energy because the man is moving and there's potential energy because the higher he gets the more potential he gets" (Tom)

C. "There would be chemical in the battery which would be changed to electric and there would be kinetic between the electrons and so there would be potential as well as they move around. There would be light and heat in there, heat coming off the light" (David)

T. "The light globe with...heat is also caused by the light... and chemical from the battery and electrical energy" (Lois)

Generally, responses from students taught the traditional way lacked direct references to the transformation of energy into a variety of forms and students were not able to elaborate their responses when prompted. Fifty-eight percent of text units from students in the traditional group could be coded this way. In the constructivist group, only three students had responses that could be coded this way and of those three, a mean of 6% of their responses could be coded as not being able to be elaborated.

A category, labelled "Expressing science in own words", which is perhaps the reverse of the category used in the preinterviews labelled "School science idea applied to instance", was established. It became apparent that some students were using substantially their own language in response to interview items rather than simply repeating learnt school science.

Students in the constructivist classes had a mean of 36% of their responses coded as expressed in their own words and scientifically correct. Students from the traditional class had a mean of 5% of their responses coded similarly. Examples of responses included in these categories follow.

C. "In this situation the ice particles, the cold ice particles, are moving from their solid state to a liquid state in which all the particles are separating. There may be heat of solar or electric or something like that making the particles become liquid. The gravity in this situation pulls the water as low as possible, that's why it all spread out" (Shirley)

This was coded as use of own language.

T. "Heat energy is being applied which is making the molecules move faster which is causing it to melt" (Kym)

This was coded as use of school language.

The use of the students' own language to explain science ideas by students from the two classes involved in the implementation was particularly noticeable in response to questions about creating and destroying energy. Students from the traditional class tended to just recall the law of conservation of energy or answer just "yes" or "no" and did not elaborate upon their answers:

"You can't..it's called the law of conservation of energy" (Bill);

"Because the law of conservation states that you can't make or destroy energy but it can only be transformed from one form to another" (Kym).

Conclusion to the Chapter

The four students from the traditional class each showed only a very small increase in the numbers of constructs they held regarding energy, post implementation, compared to the students in the constructivist classes who all showed bigger increases and in some cases, very large increases. Students in all classes all showed evidence of school science in their constructs post implementation.

Results from the QAE and interviews showed similar trends. Although in some cases students in Rick's class could recognise a similar number of forms of energy and uses for that energy as the other students, generally students in the other class could recognise and state more uses. In terms of conversions of energy, students who underwent the constructivist learning approach could state more conversions of energy and this difference was more marked than differences in recognition of forms and stating of uses.

The conclusion that can be reached from the analysis of interviews is that this particular constructivist approach has resulted in students who can express abstract science ideas in their own words with the explanations being mostly scientifically correct. This ability of students to express the science ideas in their own words is evidence of students successfully incorporating science ideas into their personal knowledge system and this occured in the majority of cases.

Students who were taught the traditional way often just gave rote learnt responses or tried to recall science facts which may have been relevant to the particular instance. In a lot of cases, on the spot construction took place in response to the instance presented.

Students in the traditional class did not have a range of previously constructed ideas upon which to draw and apply to QAE interview events. They had not had the opportunity to test their personal constructions in a wide variety of situations during instruction and when interviewed were forced to apply untested constructions or recall rote learnt science facts. This is probably what occurs when, students taught the traditional way, apply their knowledge in situations away from the classroom. When viewed in this light it is not surprising that probes that attempt to reveal students' own ideas such as IAE, consistently demonstrate that usual instruction has little affect on students own ideas.

These results support findings from previous chapters which were used to answer research question two. There are differences in students' personal knowledge concerning energy between students taught with traditional methods and students undergoing the constructivist approach. It can be stated that the constructivist approach is much more successful in allowing students to incorporate formal, abstract science ideas into their own domain and much more successful in allowing students to construct their own meanings for these ideas. The approach has led to a students generating a rich set of ideas and being adept in applying these ideas in a variety of situations as depicted in the QAE and interviews.

Students in Rick's class who learnt in the traditional manner did not appear to construct meanings and understanding in a personally meaningful way. It appears that they have a range of loosely held ideas prior to instruction which have been supplanted by a range of equally loosely held ideas during instruction.

CHAPTER THIRTEEN

Classroom Observations

Introduction

This chapter presents the results of observations conducted in the two constructivist classrooms. Observations were conducted in a phenomenological sense with the aim of producing empirical generalisations that described the meaning of events to participants. Because of the holistic nature of the constructivist learning approach, the thoughts feelings, attitudes and conduct of the teachers during the implementation are recognised as having potentially important effects upon the learning of the students in their classroom. Additionally, the holistic nature of the approach implies that the teachers will be involved in some personal learning as well as the students. This process of learning and change in the teacher was encouraged by the particular role they were asked to fulfil during the implementation. This chapter attempts to answer the final research question: "Does the manner of implementation of the constructivist approach, by each of the two teachers, influence the quality of learning outcomes in their respective classes ?"

All observations were collected by the author and hence the orientation is that of a pedagogue with a science education background. Observations were gathered by talking to individual students, to individual teachers, groups of students and observation of classroom discussion. All observations took place in the students' normal science classroom and observations were recorded in a journal. This journal was then transcribed to computer disk immediately following the observation periods. These observations are supplemented by pre and post interviews of the two teachers involved in the implementation.

Throughout the chapters dealing with the results, a consistent difference has been noted between the results from Rob and Sean's classes. Both classes used identical workbooks in an attempt to get some consistency of implementation. However this chapter will show that the actual classroom behaviour of the teacher, despite being to some extent dictated by the learning materials, was a significant variable in the implementation.

If this was an implementation of a traditional curriculum, as both classes used identical work books, we could be tempted to say that both classes covered the same content. In this implementation this is only partially true. All three classes involved in the study used much the same kind of activities. The activities for the work book used by students in the constructivist classes were much the same as the activities that were performed by the students in the traditional class. However because the emphasis in the constructivist classes was always upon the students own ideas, the content could never be the same in the two constructivist classes, even if all students were doing the same activity. This point is addressed further in the final chapter. The teacher's own ideas about the phenomena being addressed by students are important and represent a source of variation in content addressed in the two classes. It is postulated in this chapter that it is the difference between the two teachers, in terms of their own ideas and the way they interacted with the students, that resulted in the difference in learning outcomes between the two classes. Observations are now presented to support this.

The Teachers

The implementation of the learning approach had markedly different effects upon the two teachers involved. Although both teachers tried hard to implement the approach in the manner suggested, the differences in the way the teachers approached the implementation led to differences in the learning that occurred in their respective classrooms.

No personal criticism of any individual teacher is intended in the following pages. The author is extremely grateful for the cooperation he received from the individual teachers and the school. Both teachers tried very hard, within the constraints of the real world of the school and within the constraints of their personal beliefs about teaching and learning, to implement a package, about which they knew little before implementation. This cooperation is further appreciated as this implementation fundamentally altered the power relationships in the two classrooms involved. What follows is a description of the teachers and their approaches, before, during and after the implementation. This assists in further understanding results reported in previous chapters.

Before Implementation

Rob was in his twentieth year of teaching and had spent the last 12 years at this school teaching lower secondary science and upper secondary Physics and Chemistry. I regarded him as a traditional science teacher. In his interview prior to the implementation he said that "I'm more used to taking the approach where subject matter is organised according to Chemistry, Physics in a rather old fashioned traditional way". He was "teacher centered" and this traditional approach was illustrated further when he stated that "this is the only teaching aid you need", holding up a stick of chalk. I believe he was reluctant to change and seemed resentful of the change forced upon him by recent curriculum changes occurring statewide, stating "before hand I totally knew the old subjects off by heart and I...not have to rethink and rework everything" and "I would still like to go back to the old fashioned way of organising things according to disciplines...drawn in from all over the place . It's not organised the way I would like it".

In responses to the question "How do students learn" it emerged that motivation "stick and carrot", "a fair few notes", questions and practical activities formed the basis of his usual teaching approach. Group work was used for practical activities. He was aware that students often had their own ideas which were different to the scientist and embraced a basically constructivist position stating "I don't think there is any objective reality. I tend to think it is more a matter of us building models to explain the world around us". It appeared that this model building was basically an activity restricted to scientists but after further discussion he stated that "I guess everytime somebody learns a model, they are actually constructing their own model of that model in their heads".

In summary, prior to implementation, Rob could be described as traditional, conservative, experienced, opposed to change and with some theoretical constructivist ideas which were not necessarily translated into daily classroom life.

Sean was in his fourteenth year of teaching and had spent the last five years at the school. Like Rob, he was dedicated to his job but unlike Rob, he was involved in further study towards a Masters degree in Education. Sean taught lower secondary science and upper secondary Physics and Chemistry. He was reasonably happy with recent curriculum changes liking "the large amount of experimental work" but disliking the lack of "hierarchical buildup of factual material and process skills as well" involved with the changes. It was important to him that students found out for themselves in a "kind of guided discovery" but was trying to reconcile this approach with the "four or five students who don't really like being there". His general approach was "as practical as possible...involved with materials" and liked students to work "independently on their own in groups". Working along professed Piagetian lines ("...you have to assimilate and accommodate") he "get(s) them involved in process learning and then I come along and summarise results and draw conclusions, look at the data and maybe emphasise extra work". He distributed worksheets and "... don't spend an enormous amount of time writing notes on the blackboard". Discussion occurred in his class at the beginning of lessons, at the end of lessons and in groups of students. His view of science was that "the universe and nature is out there and to make some sort of sense out of nature we research, experiment and come up with hypotheses and laws". He was sensitive to the idea that students can construct differing ideas from the same activity but thought that the teacher still had control over the ideas constructed:

> "It depends on how much leeway you give them in terms of the material they are working on. If the experiment you give them is fairly directed and narrow and all follow the same path then they will see...but if you give them a more open situation then they will come up with the different ideas that they construct".

According to Sean, everything "was fairly prescriptive" and he was always working within a "time constraint" leading to the situation where "We are bound to work in that particular way, the best we can" because of the "system...we have to finish a unit within...".

Sean was not a lot different to Rob in his approaches and attitudes prior to implementation. He was little less traditional and conservative in his approach and seemed to use discussion more than Rob in his classes. Because of this he was potentially more able to encompass the approach involved in the implementation.

During the Implementation

Rob

Initially, Rob had some problems. I noted "the class seems to need some help in getting organised in their groups - they are not in a sensible arrangement for group discussion". Rob was moving around groups but seemed to be acting as a policeman pointing out what the task was and generally the students did not seemed too interested. Rob intervened frequently on a whole class basis early in the implementation, and I thought "maybe he still wants to be the dominant figure in the classroom". I felt uncomfortable in the room and I thought it was because Rob was wanting to approach the learning in a teacher dominated way yet the materials did not allow for this.

At the conclusion of one lesson, Rob expressed the idea that he felt uncomfortable about not giving the students the correct ideas and telling them that this idea was what they had to know. At the start of the next period, Rob mentioned that some students felt insecure about not getting a summary or notes and being seemingly unsure about "what to know". They are not yet in touch with the way this works, he thought, and was going to give it a week or two to see how they felt. Despite these misgivings he still proceeded but he was beginning to feel unsure about how ideas he would present in summaries or notes would be interpreted by the students. This meant to me that he was starting to accept that it is the students' ideas that are important and their ideas are main focus of the approach.

After about one week, I felt that Rob still seemed a little anxious about how things were progressing and perhaps was worried about how much and what the students were learning. I noted that on one occasion, he followed me from group to group as I talked to the students checking that the students were actually working. I think he did not quite believe students could be trusted to work on their own, on material of their own choosing, without coercion (carrot and the stick).

At the start of the implementation I had asked both teachers to complete the same pretest materials as the students, hoping to measure changes in their construing as the implementation proceeded. After two weeks, Rob had still not finished some of the pre test material I had given thus rendering any subsequent conclusions invalid. This was despite constant reminding.

As time progressed, Rob slowly settled into the routine and generally followed the implementation as planned. He seemed to relax more with the students and to adopt a role different to his usual. He conducted the classroom profile episodes in the manner detailed in the workbooks but still could not quite surrender his previous role in the classroom. I noted that during one classroom profile episode that the students were not sitting in their groups but in rows and the focus was the teacher and that Rob was generally expounding the scientist's view and looked enthusiastic and comfortable in that role. I noted that Rob gave a good summary of the scientist's view.

The above discussion was the third period on what I had planned in the workbook as a 20 to 25 minute discussion. The students were contributing. Rob stated after the lesson that the discussion revealed many student ideas, generated a lot of discussion and revealed to him a lot about what students thought about energy.

After four weeks, Rob expressed a feeling about a "slackening in motivation" in two particular groups. I mentioned that I thought it would occur about this time as the novelty of the different approach wore off and suggested that it might be to do with the fact that the motivation of learning for a test had been removed. Rob agreed with this and also agreed with the fact that students might be floundering with the idea of "why are we learning this if not for a test". I suggested one solution might be give back some of the elaboration sheets which students had completed as these were good indicators to the students' of their understanding. Rob had not done this so far.

One day, during the fifth week, when I walked in the room Rob was on the desk at the front of the room and talking to the whole class enthusiastically about gravitational potential energy (GPE). He warned me that he "often did crazy things like jump on the desk" when I interviewed him at the start of the study. I interpreted this as him performing his usual role, doing the things with which he was most comfortable and being in control. Despite his 15 minute lecture on GPE students in his class used this term significantly less than students in Sean's class as measured by most of the instruments reported in previous chapters.

This occasional regression into a comfortable role was noticed on another occasion in the sixth week. Rob was discussing the energy involved in pushing a box up a hill. I noted that he was really enjoying playing this role of talking to the class as a whole, lined in rows at their desks. The idea of these discussion episodes was to allow a discussion and elicitation of children's ideas and a comparison with the scientists' ideas but in this session it lapsed into a teacher talk session with Rob's ideas dominating. Consequently it was quite boring to most students but allowed Rob the chance to fulfil his most comfortable role in the classroom. Talking with Rob later confirmed he had no particular feelings one way or the other about the discussion episode, it was just a normal part of the classroom, but students confirmed that they found it not very interesting and they could not remember much about it two days later.

Generally the implementation proceeded in this way with students and Rob mostly following the procedure but with Rob occasionally regressing into his more usual role.

The question of "motivation" in the same two groups mentioned above, arose in the seventh week. Rob felt that motivation was still lacking in two groups and was not quite sure what to do. I asked him how the students involved worked during normal science lessons and this produced the response that were doing more than they usually did. I talked to the students about their work and they said they did not need a test to confirm their progress (Rob's suggestion) but they wanted work returned from Rob and said to tell Rob to give it back. My feelings were that the students were unsure of their learning and wanted more validation and confirmation from Rob. This question of "motivation" did not arise in Sean's class and I noted in my journal that this could be because of the systematic way he moves around the class and the quality of the discussions he has with the students.

In summary, the implementation proceeded generally as planned in Rob's class. However the "reluctant participant" reinstated the status quo on several observed occasions generally for his own satisfaction and not necessarily congruent with the general feelings of the class. This occasional tension between the way the teacher wanted the class to run and the way in which the students and the implementation wanted the class to run had consequences for the learning outcomes.

Sean

From the beginning, it appeared easier for Sean to implement the approach as designed. I observed in an early lesson that Sean was moving around, talking with various groups who were well arranged in threes or fours for discussion purposes. I heard Sean actively encouraging discussion which seemed like he had accepted the point about the importance of discussion in this approach. But like Rob, early in the implementation, Sean would occasionally lapse into a previous role. I observed early in the second week that he started to "chalk and talk" about ideas about energy under the guise of scientists' ideas. He discussed things like where does energy come from, how is energy stored and the capacity of energy to do work. Interestingly the capacity of energy to do work does not appear frequently in students' ideas about energy from any of the previous results. At this stage I thought he was giving students lots of ideas but not checking the students' interpretations of those ideas. Students were listening without much discussion and Sean kept repeating the "doing work" definition. I wondered if he felt the need to tell students that this was what they needed to remember for some test, sometime. He seemed accepting of the students' ideas but I thought the message was something like "you've had a chance to talk about your ideas now here's the proper idea". This would be congruent with his approach expressed in his pre interview.

I noted, during the second and third weeks, that Sean interacted well with the groups. He was helpful and joined in the discussion and was sensitive to the students' ideas. I felt he liked the approach. The room felt comfortable to be in. I noted that he explained ideas effectively to groups and spent time with groups. His main role seemed to be to discuss and argue.

I did not notice Sean issuing any desists regarding behaviour, but he did issue a lot of positive comments. I noted during the third week that Sean's class was very active, in terms of discussion and practical work.

During the fourth week I observed one classroom profile discussion episode. After the lesson, I talked with Sean about the discussion. Sean said he was tired. He had spent three, seventy-minute periods on the discussion and still wasn't finished. He was impressed with the enthusiasm and ideas generated by the students and was going to finish discussion tomorrow. I asked why it took so much longer than planned and anticipated and he said because of the number of ideas the students had. I asked if anything like this discussion had occurred to the same extent before with this class and he said "nothing even close to it".

This seemed a significant learning event participated in enthusiastically by teacher and students. The success of these events is dependent upon students having good knowledge of their own ideas, which is the main thrust of this approach, and this metacognition seemed present as judged by the length and intensity of the discussion.

After about five weeks, during a lunchtime discussion, Sean suggested a wider range of activities to enhance interest. I thought this was a good idea and suggested that he do whatever he liked as long as students' ideas were the focus. I noted that it was "good to see a freeing up of approaches and see that he is thinking about what's going on". The result of this was that Sean showed a video on energy and used this for discussion purposes.

Sean was impressed with the discussion aspects of this approach. He felt that it elicited a rich set of ideas from students and felt that the students were starting to realise "other people could be a source of ideas". It broadened their base of ideas and helped them realise that their ideas were not necessarily unique. I thought this meant he was aware of this too. He felt that the students were becoming aware of the social aspects of ideas. They (Sean said) could identify many sources, knew about the conversion of energy into forms, knew about kinetic energy and potential energy due to position. He was very positive and a little surprised.

Sean made jokes with the class and generally, at about the seven week mark, there was a happy and positive atmosphere in the room. Sean was responding to individual student's needs. I noted that on one occasion he made a special effort to get a cathode ray oscilloscope to demonstrate sound waves (via microphone) to a group with which he had originally discussed sound. I wondered if that kind of special attention and response to needs could occur in his normal lessons.

After the Implementation

When asked about the implementation, Rob stated that he "was sceptical at first and then excited that the project was showing some interesting results". He felt he needed time at the beginning to be "inducted into this approach". He also felt that "I am less teacher centered and more aware that process skills in science are critical" Interestingly he did not mention the students' own ideas and the affect of the approach upon them but still viewed the classroom in terms of teacher centered and process skills stating that "the approach is an effective way of developing process skills". Formal notes would "have been useful" but he was "satisfied that students do not need as many notes as I normally provide". His role was seen as "facilitator, adviser with regards to materials and other resources. Someone to discuss ideas with".

Sean became "more comfortable with the approach" as implementation proceeded and this agrees with my observations. He accepted the "shift from a teacher centered to a student centered approach" and felt the students learnt as much with this approach as they would have normally. The students "came to understand the concept of energy/energy transformations and were able to actually analyse energy situations". The students were also "more responsible for their own learning". Being able to remember more was a reality for the students as "sharing, discussing, working with materials and teacher gave students many rich experiences".

The basically Piagetian approach held by Sean during the implementation was changing, he thought, though he could not clearly delineate his new philosophy. He felt that the students were constructing their knowledge from a "wide base of self/others experience/lab work" and that the student's own ideas were a basis for explaining new concepts. His role was to "talk to students about what they were doing, guiding, praising and asking probing questions".

At the conclusion of the implementation Sean thought students' ideas were "broader and more rich. They accept other peoples' experience as valuable experience". He thought the approach was "a very good and different experience for both students and teacher".

Conclusion to the Chapter

In summary, Sean's response to the implementation was generally very positive perhaps because it was easier for him. He had less ground to make up, in terms of personal beliefs and teaching philosophy than Rob, and this may have resulted in the more positive approach. Generally Sean spent more time with groups, spent longer with groups, conducted more whole class discussions and in general implemented the approach more faithfully than Rob. I believe it was this time spent with groups and the quality of the interactions between Sean and the groups which accounts for much of the difference in learning outcomes. It was clear that Sean was a source of ideas to many of the groups as well as a source of validation of those ideas.

It can be inferred that the implementation has had minimal impact on Rob's views of teaching and learning and I thought he was generally not as aware as Sean of the rich understandings built up by the students, expressible in their own terms, during the implementation. This is in contrast to Sean, whose ideas about teaching and learning underwent revision as a result of the implementation. Sean, additionally, seems well aware of the richness of the ideas built up by the students during the implementation, again perhaps because of his interaction with the groups.

The different effects of the implementation upon the two teachers were determined by their fundamental beliefs about how the classroom world should operate and the willingness of the teacher to encompass change. One teacher believed that the teacher should always have most of the power in a classroom and was generally resistant to change. This meant that the implementation, though still quite successful, was not quite as successful as it could have been. Students in Rob's class did not have as wide a range of ideas in some situations as students in Sean's class. Generally the difference was most noticeable in situations which needed the application of students' own ideas to new situations. It can be inferred that students' ideas were affected because a teacher was clinging to a comfortable and other role.

Just as important was the effect of the implementation upon the teacher. The teacher who was positive, open to change and willing to relinquish some power underwent changes. Sean's ideas about teaching and learning underwent substantial change and he was able to recognise the change in the students around him. For Rob such personal learning experience did not seemed to have occurred to the same extent and he seemed not to be as aware as Sean of the learning and change that had occurred in the students in his room.

CHAPTER FOURTEEN

Overall Conclusions, Implications for Science Teaching and Suggestions for Future Research

Introduction

This study has used a well articulated psychological base, constructivist in origin, to develop a learning approach which was grounded in the psychological theory. The developed approach was implemented in two science classrooms and evaluated by comparing data gathered from the two implementing classes with data from a class taught with traditional methods. In this final chapter, overall conclusions from the study are presented and implications from this study for science teachers and science students are discussed. This chapter concludes with some suggestions for future research directions which flow from the conclusions and implications from this study.

Conclusions from the Study

From the results presented in chapters seven to 13, the following conclusions, related to the research questions can be stated.

1. There is no difference between students taught with traditional methods and students undergoing the constructivist approach, in how well students learn school science.

2. There are differences between students taught with traditional methods and students undergoing the constructivist approach in students' personal knowledge concerning energy.

3. The teacher influenced learning outcomes significantly in classes implementing the constructivist approach, mainly through the quality of interaction with students.

It is clear that students who underwent the constructivist learning approach became more cognitively complex individuals. There was an increase in the number of constructs they held about energy and the students could recognise more uses, forms and conversions of energy and it can be reasonably inferred that this is due to the learning approach. These students were able to achieve the same results on a school science test as students who were taught using usual methods. It can be concluded that traditional methods involving all students covering the same content at the same time, reading text books, answering set questions, taking notes, learning notes, revising content, sitting in rows and only occasional talking does not result in students who know more school science. Results from this study show that traditional methods may actually inhibit the construction of science ideas and the translation of these ideas into the students own knowledge.

It can also be stated that this learning approach is successful in facilitating the translation of formal, abstract science into students' own set of meanings. That is science laws ("energy cannot be created or destroyed") have not been rote learnt but meanings have been constructed in a social manner through comparison with the ideas of others and through discussion of ideas. This has resulted in students constructing their own personal meanings for science ideas, expressible in their own language, which are capable of being shared with others. This personally constructed knowledge, the researcher believes, is more likely to be enacted in real world situations involving energy and is more likely to remain as part of the student's knowledge system than rote learnt science. A delayed post test would highlight the differences in this regard between the students in the constructivist classes and the students taught the traditional way. Importantly, the constructed knowledge held by students from the constructivist classes is mostly scientifically correct.

As the learning approach used in this study is well grounded in PCP and because the learning approach is successful, then it can be inferred that Kelly's (1955) ideas regarding learning and meaning have some validity in this context.

The general propositions made in Chapter Two, designed to assist in the process of translating PCP into a practical classroom approach, can also be claimed to be validated. This is because of the success of the approach, the strong grounding of the approach in the theory and because of the demonstrable links between the theory, the propositions and the classroom approach.

At the beginning of this thesis, as a value position of PCP, that personal knowledge is the only knowledge worth knowing and that the intent of the learning approach was to increase students' personal knowledge. It can now be stated that this approach has achieved this valued outcome in that it did increase the personal knowledge of students about energy.

Implications for Science Teaching

The Teacher's Role

If teachers are to implement this approach successfully in the classroom, then teachers must be prepared to consider a different role in the classroom, within all the "contextual restraints that operate" (Fensham, 1989, p. 63). After seeing the results of this implementation, most teachers would consider a new role and would welcome help in adopting the different role. A model such as used in the PEEL (Baird & Mitchell, 1987) project could probably be used to good effect. The PEEL model used collaboration between researchers and practising teachers to improve the quality of learning amongst students over a two year period.

The teachers involved in this study volunteered to be involved and enthusiastically participated. In retrospect it is clear that the teachers involved needed much more help and support in adapting to this new approach than was provided and it is an implication of this study that such support be provided in future implementations. Initially a suggested role was outlined to the implementing teachers, consistent with the role described in Chapter 4 (p. 56), and both teachers acted mostly in a way consistent with this outlined role. It has been demonstrated in this thesis that the role of the teacher has significant learning outcomes. Consequently a further definition of the teacher's role may assist teachers with the implementation of the package and so maximise learning outcomes. Such a role definition is an attempt to establish a broad guide as to how a teacher might act in accordance with the constructivist learning approach and strict definitions of role are avoided as teachers must remain free to construct their own role based upon their perceptions of the approach, the students involved and all the other well recognised constraints that operate on teachers in classrooms.

According to Nussbaum and Novak (1981), any approach to teaching which takes into account students' ideas and the way in which they construct their ideas, will not reduce the number of roles of the teacher but will enhance the importance of some roles and may create new roles. Osborne and Freyberg (1985) identified the following roles for a science teacher in a constructivist setting; motivator, diagnostician, guide, innovator, experimenter and researcher. The above six roles could serve as a useful beginning framework upon which redefinition could be based. Each of these roles is now very briefly elaborated in the light of this particular constructivist approach.

The teacher, as motivator, would perform the role of assisting students to choose between the various options presented to them by the learning materials and the role of diagnostician can be redefined as making attempts wherever possible to know student's ideas in depth. A guide would provide students with examples and applications of ideas, present materials in different ways, encourage elaboration of the student's ideas and check predictions. Although Osborne and Freyberg (1985) point out that "no written instructional material can replace the teacher in this role" (p. 94), performing the role of guide in this implementation means interacting with students, with respect for their ideas and considering the utilisation of the techniques listed at the end Chapter 4. The remaining roles of teacher as innovator, experimenter and researcher would be mostly the same in this constructivist setting as, in the author's opinion, they would in most classroom settings.

The Meaning of Curriculum and Assessment in Constructivist Settings

Another major implication to arise from this study is a need to re-examine our meaning for curriculum when applied in constructivist settings. It is almost a cliché that during curriculum innovations teachers "domesticate" the curriculum. In this implementation, this has occurred but in a way which is not immediately obvious. To understand how the two teachers "domesticated" their perceived curriculum it is necessary to redefine the meaning of curriculum for constructivist settings. Such redefinition may lead to new understandings of the process of implementation of constructivist approaches.

Curriculum in science teaching and learning generally refers to the topic and the specific learning activities on which the students are engaged. These topics and activities are almost always related to behaviourally described aims and objectives which prescribe what a student should be able to do at the completion of the learning activities. In this constructivist setting, the particular learning activity was of secondary importance to the students' own ideas. Accordingly the curriculum can be redefined as the students and teachers' ideas which are brought to bear upon any particular learning activity. When the curriculum is viewed this way, it is clear that it is not possible to completely describe the curriculum in any constructivist setting unless the complete range of students' ideas and the teacher's ideas can be completely determined at any particular time.

Viewing curriculum this way means that the writing of objectives related to specified content and activities is not useful. This is because all students have a unique set of ideas initially and will construct unique ideas based on their individual beginning ideas. The curriculum, according to this definition, is a fluid entity, subject to continual change as students and teacher's ideas change and develop during the course of learning. In this sense the curriculum is socially constructed.

The role of specific activities becomes, not to assist students to accomplish previously described learning outcomes, but to serve to define the universe of discourse in which existing ideas can be brought to bear. The activities that students undergo may need revaluation as to their usefulness in bringing students' ideas into play. Many different activities may become repetitious if the activity always evokes the same sets of ideas from participants. It may be possible to identify very common ideas held by students and teachers as a beginning step to prevent this occurring.

With the above definition in mind, teachers could domesticate a constructivist curriculum in two ways. The first way is by bringing their own unique sets of ideas to bear upon learning activities which in this study they were encouraged to do. A study by Arzi, White and Fensham (1987) has shown that teachers' conceptions are influenced by the particular pedagogical situation in which they find themselves. This means that the implemented curricula in two different classes is different even if the same activity is being performed. The second way in which teachers domesticate the curriculum is by the extent to which they share their own ideas or encourage the sharing and discussing of other ideas amongst students. As demonstrated in this study, Rob did not discuss or share his ideas as much with the groups with which he interacted as Sean. This difference in implementation influenced the quality of learning outcomes.

Defining the curriculum as the set of ideas operating at any particular time in a classroom leads to the problem of assessment of those ideas and this is another implication to arise from this study. It is clear that assessment as traditionally occurs in science classrooms is mainly performed for the benefit of the institution. This is because, in a constructivist classroom, students are made well aware of their ideas as a result of the learning approach. This means that traditional assessment has little practical use for informing the student about his or her own ideas. A rationale needs to be developed which will guide the use of assessment in constructivist classrooms. If such a rationale is developed then it is also clear that constructivist learning approaches need constructivist assessment approaches and the methods used in this study such as repertory grids, IAE, QAE and questionnaires about beliefs may all be useful in this regard.

Usual assessment methods, apart from not measuring much of the learning that occurs, may be inherently unfair to students as the methods do not allow students to express all that they know about a particular topic. This point has been illustrated previously by using Hilary, one of the students in Rob's class, as an example. If new assessment practices are used in classrooms then different types of students may suddenly become recognised as good science students. This fundamentally alters the rules of the game and further research would be needed to determine whether such practices lead to more equitable participation from all groups in science classrooms.

A change in assessment practice could result in a fundamental shift in the power relationships in classrooms and teachers and students may need support in accepting such a change. Novak (1989) changed the classroom rules by concentrating on students' affective dimension to their learning. When the affective dimension was brought into play, test scores went down and this hurt some pupils and persuaded some teachers to abandon the strategy. The majority of students who persevered experienced a J curve of learning outcomes, with evidence of increased motivation. Such an effect would most likely occur in the implementation of this approach in classrooms requiring much support for students and understanding of their position.

Conceptual Change

This study has another implication relating to conceptual change research. Research in this area has its basis in the broad field of cognitive psychology (as opposed to constructivist psychology) and research has shifted from studies that describe the student's ideas, to studies examining ways of changing these ideas, to research which aims to inform the cognitive psychological base.

Considerable conceptual change occurred amongst students from the constructivist classrooms. This suggests that alternative frameworks and conceptual change could usefully be re-examined from a different psychological perspective. This re-examination may produce fruitful research directions that can help theorise this area of research more completely. From this study, it has been shown that students' constructed ideas were mostly scientifically correct and it appears that a more generative or evolutionary model of conceptual change occured in this study rather than the confronting approaches of conceptual change strategies. Cognitive respect was paramount in the implemented approach and change was not necessarily occurring in response to conflict but rather as an accommodating process. This is consistent with the previously mentioned idea of Kelly's (1955) that learning occurs continuously and involves evolutionary change and challenges the views of other constructivists. For example Yackel, Cobb and Wood (1991) believe that constructivism should be problem-centred. Steffe, a key proponent of constructivism in mathematics supports this view:"...learning involves accommodation of current mathematical concepts to neutralize perturbations..." (1990, p. 393). Duckworth, who according to Prawat (1993) bases her constructivist ideas upon Piagetian theory, also agrees with this idea: "...trying to solve practical problems, children spend time reorganising their levels of understanding" (1987, p. 49).

Alternative Frameworks

Alternative frameworks have a different meaning when viewed from a PCP perspective. According to PCP, everybody's perspective of a phenomenon is an alternative framework. There is no absolute, correct idea. Misconceptions then, in a PCP paradigm, would be recognised as just another set of alternative constructs and are held by the student only because they help the student run their life on a day to day basis, successfully predicting future events.

Some of these alternative constructions would be quite subordinate constructs which could be easily changed by students encountering and sharing constructions with others experiencing the same phenomenon. This evolutionary process could occur in a similar manner to that described by West and Pines (1985) who use the metaphor of the upward growing vine to describe the growth of the learner's intuitive knowledge. They extend their metaphor to describe learning outcomes that arise when this vine meets the downward growing vine of formal instruction. Their description of what occurs when these vines meet can inform us as to some of the outcomes possible when students personal constructions are compared to the abstract constructions of formal science.

Some students' constructs about science phenomena would be resistant to change. In PCP these constructs are considered to be core constructs and are linked to the essence of the person. These constructs would probably be closely linked to affective constructs which may be superordinate and are used all the time in the student's construction of the world. They are linked to his/her being as a person. An obvious example would be a Christian fundamentalist who holds creationist views, upon which ideas about natural selection would have little effect. An implication to arise from this study is that learning and hence conceptual change is just as much an affective decision as cognitive. PCP does not distinguish between different types of constructs.

Concepts

Conceptual change in a PCP context would be interpreted as construct change. Concept change is a very broad term and most times it is difficult to tell which particular feature of a student's concept has changed. By viewing concepts as a collection of constructs would allow a bridge to be built between PCP and cognitive psychology. By viewing concepts this way, it would be possible to obtain a very precise measure of conceptual change by assessing which particular construct belonging to a concept changes. Additionally, repertory grid methods could be used to reveal this fine structure of concepts.

Using repertory grid methods, constructs can be assessed as to whether they have disappeared or appeared and the relative importance of these constructs can be assessed using superordinancy measures. By using constructs, instead of broad concepts, more precision is bought to the measurement of change. The additional benefit is that it is possible to assess importance of constructs, by their position in the student's construct system, with more precision than is possible with the hierarchical arrangements resulting from concept maps. A final advantage of using constructs instead of concepts is the possibility of linking which construct, related to a concept, is related to which construct of another concept and this can be yet another measure of change. Such linking between concepts at this stage is restricted to lines drawn between concepts on a concept map and links revealed by word association.

Limitations and Generalisibility

The success of the approach could be used to claim validity for the propositions upon which the learning approach was based because of the explicit links between the theory and the practical classroom approach. It is accepted as a boundary to the study, and as a limitation of the study, that direct evidence is not provided in this thesis to support the validity of the fundamental postulate and eleven corollaries upon which PCP is based in this context. Further studies are necessary to assess the utility of the theory in a science education context.

The school in which this study was conducted is generally regarded as being of above average academic standing compared to most high schools. It has a high proportion of students who go on to tertiary study. This is a limitation of the study, in terms of generalisibility. However it is not a limitation in terms of initial development of the learning approach. From this initial trial, further studies would need to be conducted across a broad spectrum of student ability. Some measure of success, however can be predicted in other settings solely because this approach accepts students' ideas as the starting point. The approach may also need to be trialled in less controlled conditions where teachers have more freedom to interact with the approach.

Results from the constructivist classes in this study were constantly compared to results from a class taught with traditional methods. It is a limitation of the study and a limit to generalisibility that no data is presented to determine how representative Rick's teaching was of traditional methods.

This constructivist approach was implemented with experienced teachers who were well liked by their students and who had no control or management problems. It is a limitation of the study that the view of the students about the implementation is not formally reported. Copious data were obtained from students but a deliberate boundary was established to this study and consequently these data are not reported in depth. The reporting of the students' reaction to the implementation would be a major report in itself.

The students themselves were accepting of the different approach and in general enjoyed it. However, like Linda, the student who reported on the PEEL project (Baird & Mitchell, 1987) from a student's view, most students found the data gathering exercises boring and repetitive. Consequently, tnese tasks should be limited in any future implementation. Also like Linda some students became defensive about the change because of the fundamental shift in classroom practice and the uncertainty created. This means that students need much more explanation, support and control than was provided in this implementation and it can be postulated that a more supportive approach may result in even better learning outcomes.

Future Research

Research is needed into the function of repertory grids as metacognitive tools. From this research, grids appear to have the potential to be powerful metacognitive instruments but more research is needed to verify this. Research is needed into the conditions under which constructs change. It has been postulated above that some constructs are easier to change but others are less so.

Further analysis of existing data will be carried out to provide direct supporting evidence for propositions made in Chapter Two. Such data exists and much of it is reported in this study but further analysis is needed to explicitly provide support for the propositions. Such analysis will also explore the relationship between students' constructs, student learning in science and the fundamental postulate and eleven corollaries. Future research needs to assess the explanatory power of PCP in regard to student learning, which was beyond the scope of this particular study.

Computer programmes need to be developed to assist in the gathering and processing of grid data, especially in the processing of grids from all the members of a class. Coupled with this is the need to develop statistically sound methods of displaying grouped grid data. Some work has already progressed in this area (Fetherstonhaugh, In press).

Conclusion to the Study

In conclusion to this study it can be stated that this constructivist approach, which presents an alternative approach to the learning of science, has considerable benefits for students and teachers alike. Because of its emphasis on the unique ideas of the individual, this constructivist approach has the potential to considerably empower students and teachers who are involved in the learning process. This approach has respect for each individual's beliefs and even for this idea alone is worthy of consideration as a learning approach in science classrooms.

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LIST OF APPENDICES

APPENDIX ONE

Repertory Grid Sheet

Page 1

1	Solar energy	Electricity	Energy from food	Energy from coal	Nuclear energy	Energy in a moving bullet	Stored energy	Energy from chemicals	Heat energy	5
	●		●					●		
	●				●	●				
		●	●				●			
		●		●					●	
				●	●	●				
							●	●	●	
	●	●	●							
					●		●		●	
						●		●	●	

Page 2

1	Solar energy	Electricity	Energy from food	Energy from coal	Nuclear energy	Energy in a moving bullet	Stored energy	Energy from chemicals	Heat energy	5
	●				●		●			
		●	●	●						
	●			●	●					
		●				●	●			
		●					●		●	
			●	●	●					
			●		●			●		
	●					●		●		
	●						●		●	
				●			●	●		

APPENDIX TWO

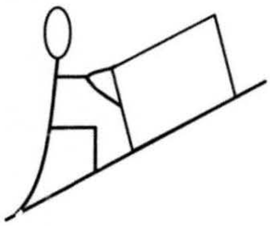
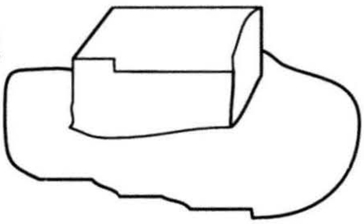
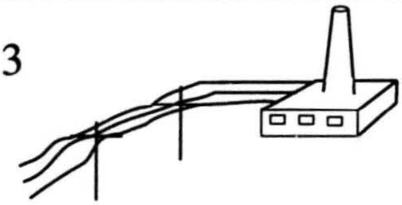
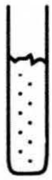
Repertory Grid Sheet With Supplied Constructs and Elements

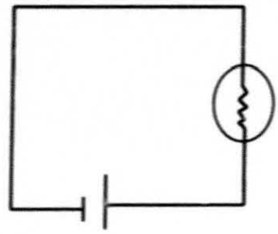
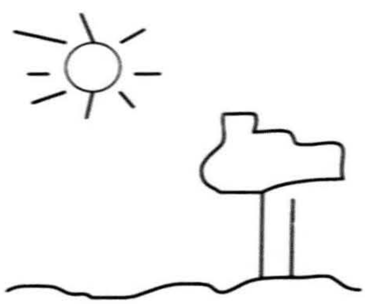
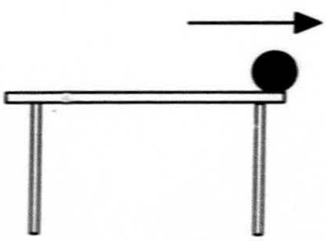
1	Solar energy	Electricity	Energy from food	Energy from coal	Nuclear energy	Energy in a moving bullet	Stored energy	Energy from chemicals	Heat energy	5
Natural										Man made
Involved in Photosynthesis										Not involved in Photosynthesis
Used as energy for our bodies										Not used as energy for our bodies
Causes pollution when it is made										Does not cause any pollution when it is made
Involved in Respiration										Not involved in Respiration
Can be used to do work										Can't be used to do work
Easily stored										Not easily stored
Can cause movement										Can't cause movement

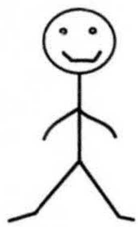
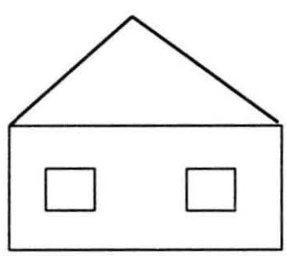
1	Solar energy	Electricity	Energy from food	Energy from coal	Nuclear energy	Energy in a moving bullet	Stored energy	Energy from chemicals	Heat energy	5
Can exert a force										Cannot exert a force
Easily converted to other forms										Not easily converted to other forms
Visible										Invisible
Used by machines										Not used by machines
A common source of energy in Australia										Not a common source of energy in Australia
Can occur as waste energy										Does not occur as waste energy
Originally came from the sun										Did not originally come from the sun

APPENDIX THREE

Events Used In Questions - About - Events

<table>
<tr><td>1

Pushing a heavy box up a hill</td><td>Is there energy here ? If so in what forms ?
Is it being used ? If so what for ?</td></tr>
<tr><td>2

Ice melting</td><td>Is there energy here ? If so in what forms ?
Is it being used ? If so what for ?</td></tr>
<tr><td>3

A power station</td><td>Is there energy here ? If so in what forms ?
Is it being used ? If so what for ?</td></tr>
<tr><td>4

A chemical reaction</td><td>Is there energy here ? If so in what forms ?
Is it being used ? If so what for ?</td></tr>
</table>

5  An electric circuit with battery and globe	Is there energy here ? If so in what forms ? Is it being used ? If so what for ?
6  Eating a meal	Is there energy here ? If so in what forms ? Is it being used ? If so what for ?
7 	Is there energy here ? If so in what forms ? Is it being used ? If so what for ?
8  A ball rolling on a table	Is there energy here ? If so in what forms ? Is it being used ? If so what for ?

9  Do we have energy ?	
10 Can we make energy ? Can we destroy energy ?	
11  Does a house have energy ?	

Note: The above events were also used in Interviews - About - Events.

APPENDIX FOUR

Energy Questionnaire

EDITH COWAN
UNIVERSITY
PERTH WESTERN AUSTRALIA
CHURCHLANDS CAMPUS

Name:________________

Age:________
School:__________
Date:_________

ENERGY

THIS IS NOT A TEST

Each of the statements over the page are about various aspects of energy and the use of energy. This is a survey to find out what you think about the various statements. There is no time limit; think about each statement and express your opinion by putting a number between 1 and 5 next to each statement.

Respond to each of the following statements by putting a number from 1 to 5 in each box:

1 *means I am sure this is right*

2 *means I think this is right*

3 *means I don't know if this is right or wrong*

4 *means I think this is wrong*

5 *means I am sure this is wrong*

Here are some practise statements:

	My Rating
It always rains in winter .	☐
We use more water in summer than in winter.	☐

1. Plants get their energy from the soil ☐

2. Plants get their energy from the air ☐

3. Plants get their energy from the sun ☐

4. Plants get their energy from the wind ☐

5. Plants get their energy from water ☐

6. Plants get their energy from animals ☐

7. Animals get their energy from sleeping ☐

8. Animals get their energy from water ☐

9. Animals get their energy from keeping water ☐

10. Animals get their energy from food ☐

11. Animals get their energy from the air they breathe ☐

12. Australia gets its energy mainly from nuclear fuel ☐

13.Australia gets its energy mainly from sea water ☐

14. Australia gets its energy mainly from the sun ☐

15. Australia gets its energy mainly from coal ☐

16. Australia gets its energy mainly from factories ☐

17. Australia gets its energy mainly from insulation ☐

18. Australia gets its energy mainly from oil ☐

19. Fridges take energy from food ☐

20. We sleep to get our energy back ☐

21. Pulling and pushing are examples of energy ☐

22. Energy is invisible ☐

23. Machines use up energy ☐

24. When you lift something you give it energy ☐

25. Without the sun we would have no energy ☐

26. Only living things can ever have energy ☐

27. Energy cannot be created or destroyed ☐

28. We can't live without energy ☐

29. Animals have energy ☐

30. People have energy ☐

31. Food gives you energy ☐

APPENDIX FIVE

Energy Test

1. Radiation is emitted from a nucleus when:

A. a stable nucleus is heated to a high temperature.
B. a stable nucleus becomes unstable.
C. there are more neutrons than protons in the nucleus.
D. two nuclei collide at high speed.

2. The metric unit of energy is the:

A. joule, if applied to electrical systems only.
B. watt, since electrical energy is most common.
C. joule in all systems.
D. watt, since energy is measured as work.
E. kilocalorie.

3. Most of the energy we use comes originally from:

A. oil and natural gases.
B. coal.
C. the sun.
D. the wind.

4. In which one of the following situations would your own body increase its total energy?

A. When you climb a tree.
B. When you run quickly along a flat road.
C. When you dive into a swimming pool.
D. When you eat a large meal.

5. The presence of some radiation in the environment at all times is the cause of:

A. changes in the gases of the atmosphere.
B. expansion of gases in the atmosphere.
C. nuclear explosions.
D. atomic evaporation.
E. background radiation.

6. The suns energy is produced as a result of:

A. fission reaction.
B. chemical reaction.
C. fusion reaction.
D. the fact that the surface is spinning.

7. Electrical energy is converted to mechanical energy in:

A. an electric lamp.
B. an electric iron.
C. a washing machine motor.
D. a generator.

8. What form of energy is used to produce electrical energy in a torch battery?

A. Light.
B. Chemical potential.
C. Kinetic.
D. Nuclear.

9. The greatest amount of energy used in a typical home is for:

A. lights.
B. cooking.
C. refrigeration.
D. heating

10. A food chain in a particular area include foxes, grasses, hawks and rabbits. Which of the following sequences represents the direction of energy flow in the food chain?

A. Grasses --> rabbits --> foxes --> hawks.
B. Hawks --> foxes --> grasses --> rabbits.
C. Foxes --> grasses --> hawks --> rabbits.
D. Grasses --> hawks --> rabbits --> foxes.

11. The energy possessed by an object because of its Motion is called:

A. Potential.
B. Electrical.
C. Kinetic.
D. Wave form.

12. A brick is lifted above the ground and then dropped. The main energy change while it is falling is:

A. gravitational potential to kinetic.
B. kinetic to heat energy.
C. chemical to gravitational potential energy.
D. gravitational potential to heat energy.

13. A radioisotope is:

A. a radioactive form of an element.
B. a radiation detector.
C. an isotope.
D. a unit of radioactivity.
E. fuel for a reactor.

14. Which of the body processes is designed to release energy?

A. Breathing.
B. Respiration.
C. Metabolism.
D. Perspiration.

15. The energy transfer in a nuclear power station may be shown as:

Nuclear energy --> Heat energy --> Mechanical energy --> Electrical energy.

If the nuclear reactor generates five million joules of heat when the output is two million joules, the overall efficiency of the station is:

A. 80%
B. 60%
C. 40%
D. 20%

16. Which situation wastes the MOST energy?

A. A man driving a large car lkm to buy a bottle of milk.
B. Using a two-piece pop up toaster for one slice of toast.
C. Using an electric toothbrush.
D. Using a jet plane for 50 people when it can carry 250 people.

17. A stationary ball on top of a hill is an example of:

A. potential energy.
B. kinetic energy.
C. kinetic and potential energy.
D. wave energy.
E. litter.

18. Which one of the following represents the flow of energy in a food chain?

A. Producer--> carnivore --> herbivore.
B. Herbivore --> carnivore --> producer.
C. Producer--> herbivore --> carnivore.
D. Carnivore --> producer --> herbivore.

19. Fission is the:

A. combining of two light nuclei to form heavy nuclei.
B. splitting of the nucleus to release large amounts of energy.
C. splitting of an atom so releasing alpha, beta, and gamma rays.
D. splitting of a light nucleus to release large quantities of energy.

20. When energy is transformed, the total energy is conserved. This means:

A. No energy is created but some is lost.
B. No energy is created or lost.
C. No energy is lost but some may be gained.
D. None of the above.