Children's reasoning with schemes in the context of science education: Studies of exemplification, analogy and transformation

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ABSTRACT

It is clear from common experiences that abstract ideas are often difficult to understand, and that the use of concrete examples is often useful, perhaps always necessary. The research investigates some aspects of the relation between abstraction and examples: how 11-12 year old children move in their thinking between more and less generic levels; between greater and lesser degrees of abstraction; from example to generalization and vice versa, in the context of science education. The central interest is in how children use and modify concrete reasoning schemes. Its significance is in eliciting deep and implicit ideas which affect how children learn science. The empirical work consists of four related studies. The analysis is both qualitative and quantitative, in both cases looking for patterns in response.

The first study explores the limitations of the boundaries of ontological categories in children's transformations of entities. Results provide evidence that ontological categories such as natural kinds and artefacts exist in thinking and that schemes are the "bridges" which can make possible even cross-ontological transformations.

The second study explores the way that dimensions organise various entities and suggests a novel analysis of analogies. Results show that schemes appear in children's reasoning as packages. The presence of one scheme may predict the presence of another. Children use schemes such as “flow” and “path”, which interact and modify one another.

The use of examples in science teaching varies. The focus of the third study is on the analysis of examples of ideas in terms of objects which can be seen schematically. Results show that children are able to give consistent examples, in many cases different from the examples in their text books. Schemes that are used by children in the description of objects appear together across the various examples. Examples constrain the schemes children use to describe entities that take part in them. Examples work rather like metaphors.

The fourth study shows that children are able to establish connections between concrete examples and generalizations. They think of some instances as better examples of ideas than others. The fit between examples and ideas is good when schemes such as ‘support’, ‘border’, ‘autonomous action’ or better when several such anticipated schemes, are satisfied and poor when some are and some not.

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Chapter 1:

CHILDREN'S REASONING IN SCIENCE

1.1 Introduction to the thesis

This research describes children's commonsense reasoning about entities in science, and particularly, the way that children use concrete physical schemes in order to reason about entities. Its significance is in eliciting deep and implicit ideas which affect how children learn science. The research investigates how children move in their thinking between more and less generic levels; between greater and lesser degrees of abstraction; from example to generalisation and vice versa.

The theoretical basis draws on Piagetian ideas on the meaning of objects (Piaget & Garcia, 1987), on Rosch's work on prototypical classifications (Rosch, 1978); and generally on work on analogy and metaphor such as that of Lakoff (1987) and Johnson

(Lakoff & Johnson, 1981) amongst others. My central interest concerns how children use and modify concrete reasoning schemes.

The focus of the theoretical discussion and the empirical work in this study, is:

a) on describing children's commonsense reasoning about entities in science in terms of various levels of abstraction in their mental representations, and
b) on relating these levels of abstraction to some fundamental categories of thought as described by Johnson (1987, 1988), diSessa (1993), Johnson- Laird (1983), and Ogborn & Bliss (1990).

1.2 An example

It may help the reader to have an example of the kind of reasoning I am interested in, to bring to life necessarily abstract notions of "schemes", etc.

One child, whom I asked what a battery is like, said (to my surprise) that it is like an orange. Why? I asked. He replied that an orange has juice inside, as a battery has electricity inside, both ready to come out. Squeezing the orange is like connecting the battery to a lamp -what is inside comes out. Also, juice provides energy as a battery does. What is interesting about this is two-fold: the analogy is very abstract, or at least generalised at the level of 'container', 'fluid', 'flow', 'energy'. Yet the reasoning can be very concrete and straightforward - fluids are kept in containers and can provide a resource (energy). Finally, the analogy is a pure product of the child's concrete imagination.

It is exactly this interplay between imagination, concrete reasoning and abstraction through generalised schemes which motivates the whole thesis. Nor is this early use of a specific example an accident. I shall try to show how essential examples are to abstract thinking.

1.3 The structure of the thesis

The thesis consists of three parts: a theoretical discussion, an analysis of the data drawn from four empirical studies and a discussion of these results. The first part is divided into two Chapters:
Chapter 2: Schematic Representations, and
Chapter 3: Rationale for the research.

Relevant theories about mental representations, analogies and examples share a common assumption: considering the levels of abstraction they describe we can characterise them as “multilevel-systems”. Cognitive scientists and psychologists have approached this issue by asking an important question: To what extent is there a prototypical-basic level which is used by humans and particularly by children in their reasoning?

In Chapter 2, a theoretical framework about the nature of mental representations is described (i.e. image schemata, mental models, p-prims, primitive schemes) giving the most emphasis to their level of abstraction. So, representational studies in cognitive science are chosen to provide the fundamental theoretical background for the research, because they focus specifically on representing knowledge. The focus is on the description of schemes as the mental representations that children use in their thinking.

The research attempts to identify variation and change in children's use of concrete schemes and the way that they produce, manipulate and modify these schemes, when they make imaginative transformations at three levels: a. an object into another, b. an event into another (analogies), c. an example into a generalization.

Chapter 3 presents the rationale of the thesis, providing at the same time a theoretical analysis of transformations, analogies and examples that justify the use of schemes as tool of their analysis. So, the theoretical part of Chapter 3 deals with three issues: the role of imagination, analogy and examples.

First, the role of imagination of concrete objects in the process of conceptualization of a scientific entity is explored. If the reasoning of children transforming one object into another is based on schemes, then the boundaries of ontological categories (such as artifacts versus natural kinds) have to be more flexible than other researchers have suggested. This should be the case because the boundaries of ontological categories can not here just be defined by 'what their members are' but also by schemes which describe 'what they can do'.

Second, transformations of events involving analogical thinking, have a fundamental role in thinking and reasoning. Keane, Ledgeway, & Duff (1994) claim that "work on analogy is in advanced state and has the potential to be an exemplar for cognitive science theory and methodology". In this part of the research, work on the use of concrete examples and analogies by children that has been done in psychology and in problem solving is reviewed. This review suggests an analysis that stays close to the content (viewing it through schemes) rather than, as is common, just to the form of analogies.

Third, schemes seem useful as tools in the exploration of a little explored area which is nevertheless important to science education, the nature of examples of ideas and the way children match an abstract structure (generalization) to a concrete example, and the other way round.

The second part of the thesis presents the analysis and discussion of results of four studies carried out in Greece with 11-12 year-old children. The various studies suggest appropriate ways of looking at children's concrete schemes: schemes such as containment, passive and active objects, actions as causes, etc. The identification of these schemes uses diSessa's (1993) ideas about the existence of p-prims, Johnson's (1987, 1988) work on image schemata, and Ogborn & Bliss's (1990) work on primitive schemes.

The first study (Chapter 4) consists of transformation tasks between objects. Children were asked to imagine changing one object into another e.g. to turn an eagle into an aeroplane. Results show how children distinguish essential features of a scheme, e.g.

flying without obvious support, which they preserve during transformation, from "accidental" features, which they change e.g. nature of material.

The second study (Chapter 5) consists of analogy tasks. Children were asked to think of things which are alike, for example, an electric circuit. Result show that children use schemes such as "flow" and "path", and that these interact and modify one another, in agreement with Black's (1979) interactive view of metaphor.

In the third study (Chapter 6) children described examples of various ideas using schemes. The results show the way that examples constrain the schemes that are used in the description of the objects that take part in them, and how examples of the same idea differ from each other.

In the fourth study (Chapter 7), children were asked to choose "good" examples of a generalisation, to form generalisations from examples, and to deal with counter examples. I look for fundamental dimensions such as time, decision making, necessity, interaction support etc., which are responsible for 'a good fit' between example and generalisation, and how they lead children to extend or restrict their generalisations.

The analysis of these studies is both qualitative, looking for categories to describe the reasoning, and quantitative, looking for patterns in responses (e.g. by cluster methods). In general terms, the outcome of these studies - which are presented in the third part of the thesis (Chapter 8)- is the powerful role that schemes have in children's imaginative transformations of objects, analogies or examples. Schemes are useful tools in the description of children's thinking and can be used by science educators for the analysis of the movement between concrete and abstract forms of knowledge

Chapter 2:

SCHEMATIC REPRESENTATIONS

2.1 Introduction

Children (and adults) find it difficult, and often fail, to give a "good" definition for many concepts in science. According to Mariani (1992), there is a structural sort of knowledge about entities in science, with its ultimate origin in "sensorimotor experience" of children (seeing, feeling, etc.) and their activity (destroying or moving things for example). So, children attempt to explain entities using some of the characteristics that come from their concrete knowledge (examples, sensorimotor experience, activity). For that reason concrete thinking and reasoning have always been regarded as crucial topics in psychology and artificial intelligence (A.I.).

The focus of the theoretical discussion and of the empirical work in this study will be on describing children's commonsense thinking about entities in science, in terms of various levels of abstraction in their mental representations, and to relate these levels of abstraction to some fundamental categories of thought as described by Johnson (1987, 1988), diSessa (1988, 1993), Johnson-Laird (1983), Ogborn & Bliss (1990).

Bliss (1994), exploring the differences that appeared in various attempts to describe the ways in which knowledge is represented in the human mind, refers to the existence of two different approaches in that area. The differences between these two approaches arise because of their attempts to give an answer to the following two different questions: (a)What does someone use to think? and (b)What does someone think?

The first approach attempts to discover and describe the tools for thought. In this respect, the Piagetian (1970) description of schemes and the Johnson-Laird (1983) approach of mental models are similar. On the other hand, the second approach explores the content of thinking. Gentner and Stevens (1983) can be considered as representatives of this field.

In this research, both these questions will be considered, in order to investigate the role of children's mental representations in their reasoning about the real world. Thus, both the tools that children use in their reasoning and its content are investigated.

In the theoretical discussion, mental representations are regarded as a "multilevel - system" varying from concrete to more abstract forms. It is suggested that a middle level of abstraction plays a fundamental role in children's commonsense reasoning. Particularly, this Chapter reviews various approaches to describing this basic level (i.e. Johnson, diSessa, Johnson-Laird, Ogborn & Bliss) showing the similarities between these approaches.

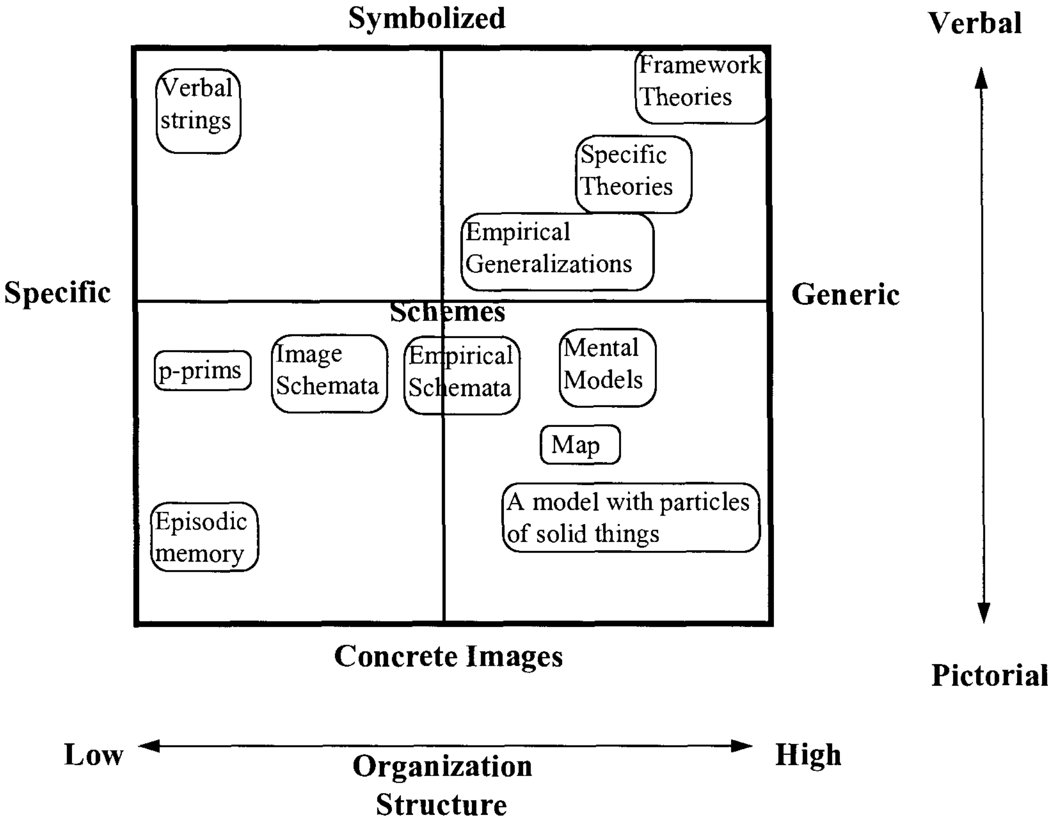
The exploration of the nature of this basic level could contribute to a deeper understanding of children's ideas about the natural world and then could provide us with answers to the question, “How could we help them to change their ideas, and make them more scientific?”

2.2 Hierarchical Structures of Representation

Mental representations play a central role in thinking and reasoning. The degree to which such representational systems correspond to the real world is in debate. A reasonable answer to this debate might be the assumption that the representational system operates at multiple levels. That is, there are different levels of abstraction and of organization of mental representations which people use in their reasoning.

Researchers have studied mental representations at a variety of levels. Figure 2.1 summarizes the multiple levels of representations. The vertical axis represents possible variation from concrete images to abstract propositional forms of mental representation. The schematic level is between these poles. Piaget (1970) has defined as "schemes", "whatever is repeatable and generalizable in an action" (Piaget, 1970, p.42). The horizontal axis represents possible variation from isolated fragments of knowledge to highly organized systems such as theories.

Figure 2.1: Mental representation system



The horizontal axis has at the right hand edge the organization of knowledge in theories. McCloskey, Caramazza and Green (1980) proposed that people develop through their everyday experience well articulated naive theories. They argue that intuitive ideas are theoretical structures. So, for them, everyday reasoning is theory - like, in the sense that people make use of abstract, causal-explanatory constructs (see also McCloskey et.al, 1983; Carey, 1985; Gopnik & Wellman, 1994).

According to Gopnik and Wellman (1994) children can develop theories of mind; in their terms the "theory theory". They distinguish between framework theories and specific theories. Framework theories define domains of inquiry, providing an ontology which specifies the types of fundamental phenomena to be explained. For example Behaviourism provides an ontology for behaviour, external stimuli, overt responses etc. In contrast, specific theories (such as the Rescorla-Wagner theory of classical conditioning within Behaviourism) accounts for specific phenomena by reducing them within the ontology and explanatory structures of the framework theory. A framework theory is both general - it includes a large number of phenomena - and specific - it defines a domain and it is different from other framework theories from other domains (Gopnik and Wellman, 1994).

Gopnik and Wellman (1994) argue that analogously to framework theories, the "theory theory" predicts a combination of specificity and generality in children's thinking. So, it is neither so general as "stage theories" - such as that of Piaget - (children construct different theories for different domains such as biological, mathematical, etc.) nor so specific as accounts of development in terms of skills, empirical generalizations, scripts and some modularity theories suggest.

In contrast with the account given by the "theory theory" account, diSessa (1989, 1993) argues that human knowledge cannot be characterized by organized structures. His account of fragmentary knowledge structures (he calls them phenomenological-primitives or p-prims) tends to be at the left hand end of the horizontal dimension of Figure 2.1 while Johnson's (1987) account, that the knowledge consists of patterns (he calls them "image schemata") is less close to the left hand end.

I am more sympathetic with the view of Ogborn and Bliss (1990) who unlike diSessa, regard the minimum knowledge structures in reasoning (primitive schemes) "as forming a system and as having a developmental history" (Ogborn & Bliss, 1990, p.380). This systematicity of schemes leads me to explore groups or packages of schemes because the schemes seem to function as systems or clusters and not as isolated pieces.

The similarity between diSessa's p-prims, Johnson's image schemata and Ogborn & Bliss primitive schemata (at least in their nature - all of them have their origins in the Piagetian notion of schemes -), forces me to use one term, "empirical schemes" which will cover all the above variations in the description of schemes (the variation mainly concerns the different degree of organization).

The hierarchical structure of the vertical axis of the mental representation systems that researchers describe, can be seen as an analogical projection of what has been proposed by "prototype theory" about the categorization of concepts. According to Rosch, (1975, 1978) the majority of everyday concepts can be organized into hierarchical classification schemes. She suggests that there are three levels of categorization: superordinate, basic and subordinate level. The superordinate level is more abstract than the basic, whereas the basic is more abstract than the subordinate.

Consider for example the superordinate category "furniture", which might have a "chair" as basic level and a "kitchen chair" as subordinate level. The general idea is that concepts are organized around these basic-level prototypes. One of the crucial effects of this prototypical structure is that we are able to classify a case into a category without being able to define why. It is extremely difficult to find a definition appropriate for all the members of a category. According to the "family resemblance" idea proposed by Wittgenstein (1953) and Rosch (1975) a classification of a member to a category can be done through the comparison of this member with other members of the category but mainly with a basic-level member.

In an analogous way children can reason about a phenomenon "comparing" it with a basic level item of knowledge. That is, they can reason through the use of schemes without using propositions or theories. I will call this middle or basic level of the vertical axis (in other words the middle- horizontal line) the “empirical level”.

The exploration of the nature of levels of representation systems could provide us with descriptions of the ways that children can use information from their background knowledge, in order to construct explanations for a phenomenon. According to Johnson (1987) a rich store of concrete images, which is based on our bodily experiences, provides a valuable and necessary “background” for the construction of cognitive structures. He regards the background as part of the meaning.

Since there are some transformations that take place during the process of going from the background to an explanation, the hypothesis of this research is that there is a level of concreteness which facilitates transformations from one concrete example to another, induction from an example to a generalization, or deduction from a generalization to a concrete example. That is, children use in their reasoning cognitive structures - empirical schemes - which are stored at a basic level - empirical level.

Let us see in greater detail how diSessa’s, Johnson’s, Johnson-Laird’s and Ogborn & Bliss’s views are related with the dimensions of Fig.1. diSessa (1993) has been influenced by the Prototype theory of categorization and he describes the nature of his "cognitive structures", that is - p-prims, in a way similar to the way that concepts which are members of a category may be related with other members of the same category. He regards p-prims as primitive-prototypical forms of knowledge, and holds that representations based merely on words cannot play such a crucial role as prototypical forms of knowledge are required to play in human reasoning.

diSessa argues that the human knowledge system consists of a large number of simple elements which are minimal abstractions of phenomena. If we provide someone with a range of experience within a domain, we can observe a developmental change in these elements. This developmental change in the nature of these existing elements is their change from relatively isolated, self-explanatory entities into pieces of a larger system.

He describes as the most drastic change of these elements a change in their function. "They can no longer be self-explanatory but must defer to much more complex knowledge structures, such as physics laws, for justification" (diSessa, 1993, p.115). Consider for example an element called "Resistance". This element can be a common abstraction from several phenomena. It is more abstract than a specific phenomenon (subordinate level e.g. a string becomes taut when used to pull an object: the object resists motion), but is less abstract than "complex knowledge structures" (superordinate level) such as laws. For example, Newton's definition-law of inertia is: "... innate force of matter, is a power of resisting by which every body, as much as it lies, continues in its present state, whether it be of rest or of moving uniformly forwards in a right line" (Cohen & Westfall eds., 1995).

There are many commonalities between diSessa's and Johnson's thoughts. Johnson (1987) argues that image schemata differ from images and propositions. Image schemata organize our mental representations at a more general and abstract level than that which we use to form mental images, while at the same time being more concrete than propositions.

To understand Johnson's idea, consider for example a man moving into a room. We can think about this using one of the following levels in our representation system:
a. Propositional level ("John is in the room")
b. Image-schematic level (e.g. The "in" image schema. This arises from the abstraction of our bodily experience such as: we move into and out of rooms, we manipulate objects placing them in containers (cups, boxes, can etc.). In each of these cases there are repeatable spatial and temporal organizations)
c. Mental image level (e.g. a picture image of a man in a room).
Image schemata are not propositional because they are not abstract subject-predicate structures. Propositional representations can capture some of the important features of any given image schema but they cannot capture the analogue nature of images and the crucial role of image-schematic transformations. By transformations, Johnson means "such cognitive operations as scanning an image, tracing out the probable trajectory of a force vector, superimposing one schema upon another, and taking a

multiplex cluster of entities and contracting it into a homogenous mass" (Johnson, 1987, p.3).

On the other hand, image schemata are different from mental images. This is because mental pictures represent one particular thing, which differs from another because they do not share all the same features. In contrast, image schemata contain structural features that are common to many different objects, events etc.

Johnson regards image schemata as being at a basic level (they contain structural features that are common to many different objects or events), mental images as being at a subordinate level, and literal meaning as being at a superordinate level.

Johnson-Laird (1983) discusses similar issues but in different terms. His central notion is that of "mental models". These are more generic than p-prims (see Fig.1). In general, he proposes the existence of three types of mental representations: "propositional representations which are strings of symbols that correspond to natural language, 'mental models' which are structural analogues of the world, and images, which are the perceptual correlates of models from a particular point of view". So in this case, the representational system can operate at different levels, from the more concrete images to the more abstract forms. The intermediate step between the propositional form and the images could be mental models. Johnson-Laird argues that the process of understanding yields a mental model. His focus is on the crucial role that mental models play in reasoning.

A view with a narrow focus is provided by Ogborn and Bliss (1990) who suggest that commonsense reasoning happens through the use of prototypes. The theory that they propose about a psychologic of motion, relies on the development of prototypes of motion. For example, support and effort are identified by their theory as basic categories for thinking about motion. Thus according to them, we organize our prototypical thinking, according to some primitive schemes, rules, actions etc. that constitute the basic level of thinking.

Summarizing, mental representations are described by various researchers as a hierarchical structure. These researchers recognize that a basic level ("empirical level") for mental representations can be used by a child in order to classify a case into an "empirical scheme" and this scheme can be used in his/her reasoning without defining it with propositional statements. This level is basic, because it contains features that are common to many phenomena. That is, they are common abstractions.

2.3 Elements of the "Empirical Level" and their Structure

In the previous section, mental representations were discussed in relation to levels of abstraction (exploring mainly the vertical axis of the Figure 2.1). In this section the organization (structure) will be considered (exploring the horizontal axis of the Figure 2.1). The exploration of the "empirical level" could be done through the identification and analysis of hypothetical cognitive structures that subjects use when they attempt to think and reason at this level of abstraction.

diSessa (1993) in his program for exploring the human sense of mechanism, puts the emphasis on identifying and analyzing specific elements of knowledge. His focus is on a hypothetical knowledge structure. He calls it a phenomenological primitive - p-prim. The genesis of a p-prim is often the abstraction of a phenomenon.

An example of a p-prim, he proposes, is what he calls "Ohm's p-prim". It consists of the following subentities: "an agent that is the locus of an impetus that acts against a resistance to produce some sort of result"(diSessa, 1993, p.126)

diSessa (1993) argues that the knowledge system consists of a large number of fragments rather than one or any small number of integrated structures (theories). He mentions that although light, radio waves, and even forces like pushes and pulls by which objects are moved around, are consequences of Maxwell's equations, these phenomena are in some degree understood independently.

In contrast with diSessa, there are a great number of recent discussions denying that children's conceptual system consists of a number of fragments. The "knowledge-based" approach suggests that children's early conceptions of the mind are implicit theories (Carey, 1985; Wellman, 1990; Gopnik and Wellman, 1994). However, in my opinion diSessa is not absolute about the existence of fragments.

Both "small fragments" and "theories" may well be true for certain sorts of knowledge at different levels of abstraction (empirical and propositional level respectively). It appears to me that it might be possible that through fragmentary knowledge and schemes we can describe an empirical level of reasoning, while for the analysis of propositional forms of knowledge we need to use more structural forms such as theories.

This research will focus mainly on the empirical level which appears to be the level that can explain children's thoughts about phenomena better than propositional level theories do. It is notable that the "empirical level" of abstraction refers to a large number of different versions of empirical schemes. That happens because of their dynamic form. In the empirical work the way that the "content" of an empirical scheme depends on, interacts with and is modified by other empirical schemes that take part in the same phenomenon, - in agreement with Black's (1979) interactive view of metaphor - will be presented. For example, in the specific case of an electric circuit children gave analogical examples using the mixed schema 'source-container' for the battery. In these analogical examples, the entity which played the role of battery was not just a 'container'. It was also the 'source' for another entity which played the role of the current. Consider for example, a child who used an analogy where an orange was used as an analogy for a battery. The orange was a 'container' and at the same time was a 'source' which could provide us with another entity (juice) such as the current.

Furthermore, these mixed schemes are very powerful. Consider a 'container' such as a cup. It can be "full" or "empty". These two schemes (container, full/empty) are strongly related. So the "sea" is not an obvious example of a container because the sea does not fulfill the second scheme (it cannot be empty or full). That is, the nature of an empirical scheme depends on the form of the whole "package of elements" which constitute a phenomenon. These empirical schemes are like dynamic patterns that we use in order to organize our knowledge.

Johnson (1987) makes clear the dynamic character of these cognitive structures. He claims that in order to understand and reason about our experience, we need some patterns for organizing our actions, perceptions, and conceptions. He calls these patterns "image schemata", and these constitute our background knowledge. "A schema is a recurrent pattern, shape and regularity in, or of, these ongoing ordering activities". He emphasizes the crucial role of background knowledge and explores the way that non-propositional structures (which are there in the background) such as image schemata, contribute to the elaboration of meaning.

These cognitive structures have parts and relations. The parts consist of a set of entities such as objects, events, goals etc. The relations include causal relations, part-whole patterns, relative locations etc. A meaning cannot exist without some form of structure which establishes relations. A schema usually contains a small number of parts which have simple relations between them (Johnson, 1987).

Also, image schemata have an internal structure. Because of their definite internal structure, they influence the ways according to which we make sense of things and they constrain inferences about them. For example, the internal structure of the schema “in-out” can have consequences such as “protection from” or “resistance to” external forces, limitations on the forces or actions that the contained object can produce etc. Lakoff and Johnson (1981) called the consequences of the internal structure of image schemata "entailments". They argue that "patterns such as these which exist preconceptually in our experience, can give rise to rational entailments (which we describe propositionally)" (Johnson, 1987, p.22)

2.4 Common Abstractions

Several phenomena may be related by having a common abstraction. If we provide someone with a range of experiences within a domain, it may lead him/her to a systematic organization of those experiences. In this case the specific reasoning structures may develop a kind of integration. So, a coherent organization of "cognitive structures" appears to develop subsystems, that are both relatively integrated within themselves and also relatively independent of other subsystems (diSessa, 1993).

diSessa gives as an example Ohm's p-prim which may be a common abstraction from a great range of already competent sensorimotor schemes. That is, it can be a common abstraction of a broad number of physical experiences, such as pushing objects. diSessa (1993) mentions that Ohm's p-prim may be used to interpret intellectual as well as interpersonal relations, such as trying harder and influencing.

Furthermore, Johnson (1987) claims that we can find the same "cognitive structure" in many domains, because the parts that constitute its internal structure can be metaphorically understood. The relations which exist between several senses of schemata like "balance", "in" etc. can be explained by a metaphorical projection from the bodily domain - in which the schema emerges - to the mental epistemic domain. Johnson therefore places great emphasis on the material, experiential, action basis of metaphor.

According to this experiential sense of metaphor, understanding is a process in which we structure one domain of experience in terms of another one. Metaphors do not merely help in understanding, they are part of this process and its structure. Metaphorical interpretations, "can properly be called structures of understanding" because they are patterns in terms of which we "have a world" which is what is meant by "understanding" in its broader sense" (Johnson, 1987, p.83).

Metaphorical-analogical projections of various phenomena (which are related to common abstractions) lead to the production of empirical schemes. Through analogical projections we construct a "package of elements" with a new form different from existing patterns since we make some possible connections between elements and when/where they are active. That is, "empirical schemes" are dynamic structures.

So, what is happening in an electric circuit can be analogically projected to what is happening to our body. In this case we have another package of elements (heart, blood, body) and processes (beat, send). To some extent the empirical schemes in a new case could be different, e.g. the 'source-container' schema which was "perfect" for the battery in an electric circuit, in the case of the heart - and its role in circulation of the blood - may have to be enriched with the notion of 'duration'. In the case of the heart, the "life" of the source-container scheme is notably bigger. The aspect of 'living' attributed to the source-container scheme is notably more important.

2.5 Interaction with the Physical World - Embodied Reasoning

Piaget (1974) distinguished two different aspects of knowing: the "figurative" and the "operative". Using figurative activity we merely represent environmental sensory inputs while through operative activity we transform these representations into "objects of knowing". The operative aspect is based on actions. Thoughts are for Piaget internalized actions (see also Bliss, 1994).

Piaget (1974) argues for the primacy of the operative aspect. He views mental operations both as a logico-mathematical activity (reflective abstraction) and as physical abstraction, giving primacy to "reflective abstraction". "It is clear that, if causality favors the functional exercise of intelligence, the operational construction of that intelligence still proceeds by "reflective" and not by physical or simple abstractions" (Piaget, 1974, p.21). So, children's operational structure is attributed to objects and is not drawn directly from them. These operations seem to derive from children's reflection on the nature of general types of actions.

Although Piaget (1974) mentions the importance of children's physical activity, he has paid little attention to physical abstraction, or what Ogborn and Bliss termed "empirical abstraction". In this case, children through their acting on objects and physical situations, learn about the size, shape, color etc. of objects. Through empirical abstraction, children abstract information from objects. So, empirical abstraction leads to knowledge about particulars; children think about particular instances-examples. In this research, I try to cast some light on thinking about particular instances-examples through empirical abstraction, something that was neglected in Piaget's work (see Bliss, 1994).

Ogborn & Bliss (1990) using their work on commonsense reasoning about motion proposed a psycho-logic of motion. In this case prototypical thinking (through the development of prototypes of motion) has its origins in very early infancy with actions and perceptions of movement.

Furthermore, action plays a crucial role in the perspective that has been described by diSessa (1988) as a Knowledge-in-pieces view, which portrays intuitive knowledge as a set of context-dependent schemes. According to diSessa (1993) humans interacting with the physical world, gradually acquire a sense of mechanism. At this point diSessa relates the sense of mechanism with the ways that things work, and with the sorts of events that are necessary, possible, or impossible. His major claim is that the intuitive sense of mechanism involves a large number of p-prims.

P-prims have their roots in human experience. diSessa (1993) gives a great weight to direct experience. Particularly he points out the "principle of the body". According to this principle "p-prims are likely to be abstracted in internally evident terms, especially early in development. Thus, agency, (muscle) tension and so on, are likely to be represented in important base vocabulary for p-prims"(diSessa, 1993, p.123).

Although diSessa describes a very similar representational system and its origins (i.e body, action) with schemes, he did not refer to Piaget. It is also notable that nowhere in his book does Johnson (1987) refer to Piaget, who also adopted the word "scheme" (as Johnson did) from Kant. However, internalization of bodily action is a central aspect in the Piagetian theory as in Johnson's. Johnson, in order to illustrate the notion of embodied, imaginative structure, mainly considers two types of imaginative structure: image schemata, and metaphorical projections. Through metaphorical projections the emergent schemata move from the bodily sense to the mental domain. He suggests that thinking may be arranged on a continuum from concrete to more abstract forms, and it seems arbitrary where one draws the cut-off line beyond which mental constructs are no longer called images.

2.6 Self Explanatory phenomena- Obviousness

diSessa (1993) argues that some special phenomena are sometimes treated as self explanatory. Reasoning at a basic level through the use of empirical schemes may lead to the accumulation of a phenomenology of events rather than the reduction of events to fundamental principles. For example, although the phenomenon of balls bouncing, can be explained by basic laws such as those of energy and momentum conservation, one might not reduce a complex event such as a billiards collision, to basic principles. Instead one could accumulate a phenomenology of events like bouncing, which do not demand detailed justification at each occurrence. It seems that there is a relation between the nature of empirical schemes and the level of what is 'obvious' in an explanation.

Ogborn (1994) mentions the crucial role of the "obviousness" principle in scientific explanations. According to him, a scientific explanation is a "story" which attempts to make the occurrence of a phenomenon seem "obvious". It can be made by arguments of natural necessity, not mainly of logical necessity. "It rests in the end on the virtuous circle of saying. That happens because that is what those things do... 'Obviousness' is where explaining stops" (Ogborn, 1994). So a level must exist (probably it is the empirical level) in which the story stops going further because the story seems to be obvious at all the remaining levels.

2.7 Imagination

Imagination can help us to modify existing patterns in order to generate novel meanings. According to Johnson (1987) imagination does not merely play a role in discovery, invention and creativity, it is also "essential to the structure of rationality".

He explores the important role of human imagination - as basic to the structure of rationality - in the areas of meaning, understanding and reasoning. Image schemata and metaphorical projections are matters of imagination. We use imagination in order to achieve new structure in our experience through the process of metaphorical projection. So, imagination can help us to modify existing patterns in order to generate novel meanings.

Johnson argues that "the schematizing activity of the imagination, then, mediates between images or objects of sensation, on the one hand, and abstract concepts on the other"(Johnson, 1987, p.155). So, he sees the imagination as an activity meditating between sensation and abstract forms of thought.

Furthermore, according to Ogborn (1994) the conceptualization of an entity requires people to imagine the entity and manipulate it mentally in order to generate meanings.

Whenever we attempt to imagine an entity, we put it in a "package of elements". Suppose we try to imagine water. We have to imagine it in a glass or in a river, flowing. That is, we imagine what this entity “does”.

Then, when we try to imagine water in an example of a phenomenon, the exploration of the nature of the other things come along with it. For instance, when we try to explain the way that a lamp lights because of the electric current in an electric circuit we can imagine the current as water. Also, we have to imagine the other parts of the “package” that will come along with the water (e.g. a barrier). In this case we have also to imagine what another entity “can do”.

2.8 Are schemes non Propositional?

Empirical schemes are described as non-propositional cognitive structures. According to diSessa p-prims have about the "size" and complexity of words, but in many cases they are even smaller and simpler than words. Although lexical items such as words often have clusters of meanings (polysemy), p-prims are more comparable to a single sense of a word. diSessa compares the meaning of the word "force" with a variety of p-prims about force, such as force as a mover, continuous force, force as reflector etc.

Johnson-Laird argues that inductive reasoning takes place through the processing of mental models rather than through the processing of sentences or other linguistic elements.

Johnson (1987, 1988) disagrees with the traditional theories in linguistics which in order to answer the question "How can anything (an event, object, word, etc.) be meaningful to a person?" exclusively focus on the role of the words in a sentence that influence their meaning. He explores how nonpropositional structures like image schemata influence meaning.

Johnson is clear that we cannot treat all meaning as conceptual and propositional. He mentions two reasons for this: "1) meaning in natural language begins in figurative, multivalent patterns that cannot typically be reduced to a set of literal concepts and propositions; and 2) the patterns and their connections are embodied and cannot be reduced to a set of literal concepts and propositions. In other words, meaning typically involves nonliteral (figurative) cognitive structures." (Johnson, 1987, p.5)

diSessa claims that p-prims cannot be analyzed through mappings that are judged by purely structural criteria, as Gentner (1983) did in analogical reasoning. He uses the principle of content over form. That is, p-prims are content-based analyses. “Thus, p-prims cannot be removed from an analysis in favor of general processes such as analogical reasoning” (diSessa, 1993, p.125)

The argument that image schemata are not propositional forms does not mean that these embodied patterns remain private only to the person that has the relevant experience. Image schemata are based on a shared world of bodily experiences. It is the shared nature of this experienced world, facilitated by communication, which makes shared meanings possible (Johnson, 1987). As Johnson says "They become shared cultural modes of experience and help to determine the nature of our meaningful, coherent understanding of our world. Moreover, they are conventionally encoded in language and are immediately understood by hundreds of millions of other people" (Johnson, 1987, p.14). It seems that in this way they can be partly learned by talking.

2.9 A Variety of Reasoning Levels

The empirical level is neither the same for all people, nor for all contexts. For example, according to diSessa, to a physicist, in contrast with intuitive physics, phenomena like bouncing must be reduced to the actions of forces. A physicist cannot use those phenomena as primitive explanations. We can observe different levels of reasoning. So, what is basic level for novices might not be the same for experts. In this case the development of these elements is a result of a greater systematicity, or more knowledge, or more questions. Furthermore we have to consider the influence of action, culture, and imagination.

Johnson (1987) mentions that what constitutes a basic level in our thoughts depends on background knowledge, interests, motivation and previous experience. He gives as an example, the case concerning interactions with physical objects, in which what is a basic gestalt for a layperson may differ from that of a physicist, who has different background knowledge about the nature of the physical world and understands differently the interaction with it. "Experiential basicness is a relative matter" (Johnson, 1987, p.62)

Also Johnson recognizes image schemata as dynamic structures that organize our experience and comprehension. Even though they have definite internal structures, they are dynamic patterns rather than fixed and static images, and they can lead to different levels of reasoning.

2.10 Problems with the identification of Empirical schemes

diSessa (1993) mentions as a difficulty in his empirical investigation of p-prims, their weak relation to the dictionary lexicon. P-prims have not an explicit propositional form. One can make predictions using p-prims, but the prediction is not the p-prim. Even in the case where one accepts a form as "In circumstances x, y happens" under which we might subsume many p-prims, "the inexplicitness of circumstances and lack of other reliability checks makes such attributes as universality, truth value, and participation in general reasoning patterns (approximating to logical reasoning) highly dubious." (diSessa, 1993, p.197)

This research attempts to identify these kinds of hypothetical structures in children's explanations about phenomena. That is, to find whether there are hidden common patterns in their explanations and what are the origins of these patterns. Having in mind that these empirical schemes have a weak relation to the dictionary lexicon, I attempt to describe what they could be like without it being possible to present an accurate picture of them. The description of these entities is as if one wanted to present a bridge without a picture. He might describe how it is, but the receiver (and the sender) will lose a lot of information. We know that it is impossible to translate with absolute success from one mode into another, for example an image into verbal form. To translate and describe schemes into a verbal form presents the same difficulty.

2.11 Ontological Dimensions in Concrete Thinking

Tyson, Venville, Harrison, Treagust (1997) outline a multidimensional framework for considering conceptual change events in the classroom and they synthesize a number of researches by proposing that children's conceptual change can be viewed from several perspectives: the epistemological (the way that a student perceives his or her own knowledge about the thing being studied), the ontological (the way that a student perceives the nature of the thing being studied), and the social (examines the social/affective conditions such as interest, motivation necessary for conceptual change to occur).

There is a movement in the tradition of the description of thinking in the field of mental models. Bliss (1994) exploring different descriptions of thinking from Piaget to "mental models tradition" mentions that much of the past work on thinking and learning is related closely with epistemology (the study of the grounds of knowledge) whereas the mental models view leads to a new direction, since there is now an ontological focus on studying "what people take to be the nature of the things around them. What *is* comes before what *is the case*" (Bliss, 1994, p.30)

Researchers such as Chi and her colleagues (1992, 1995) have attempted to explore the difficulties in the conceptual change of children in science, considering the notion of ontologically distinct categories. They argue that conceptual change is difficult since naive concepts and scientific ones belong to different ontological categories. But what makes the boundaries between different ontological categories so strong, and is there any way that we can make possible transformations across ontological categories? It seems possible that ‘empirical schemes’ which in many cases are common abstractions from members who belong to different ontological categories can make possible such difficult transformations.

Ogborn and Mariani (1991) propose the existence of a fundamental "ontological space". They attempt to find a small number of ontological dimensions along which objects and events can be placed, for example, dynamic vs static, cause vs effect, place-like vs localized and discrete vs continuous. In an analogous way, this research explores fundamental dimensions of thought which children seem to use in their attempt to understand the nature of processes in the physical world, and how children use them in order to give an analogical example. It is suggested, that the identification of empirical schemes of elements can be done only by exploring their interaction in "packages". So, finding "groups" of elements and putting them onto an ontological space, at a later stage we can interpret the fundamental dimensions (e.g. cause-effect, dynamic-static etc.) that underlie children's reasoning.

2.12 Empirical Investigation of children's schemes

In the previous sections of this Chapter, the discussion shows that the idea of "schemes" has been used frequently by researchers. However, most of them identified schemes in texts (e.g. Johnson) or analyzing interviews of adults (e.g. diSessa). A recent study with young children which attempted to explore schemes and made a great contribution to this thesis was conducted in London by Joan Bliss, Jon Ogborn, Orla Cronin and Will Reader during the last two years. I followed the work of this project very closely from the beginning and towards the end I joined the project team (see report in Appendix 2.1).

The project aimed to investigate empirical abstraction and concrete physical schemes. The idea was to construct novel tasks which would show whether schemes exist in children's thinking, and if so, how they are used. The project team developed a methodological framework for investigating schemes as tools of thinking, and constructed a range of novel tasks for the investigation of the schemes.

The various tasks used can be classified into four mainly generic forms:

- imaginative transformations. (children were asked to transform objects or events into others using their imagination)
- thinking of something as ... (children tried to think of instances as like a given scheme, going from instances to schemes)
- instances of something like ... (children created or identified instances of schemes, going from schemes to instances)
- thinking metaphorically with physical schemes (children used physical schemes as the basis of metaphors to reason about non-physical situations

This research project gave precise pictures of the nature of schemes. In the various tasks it appeared possible that schemes can be shown to exist (e.g. schemes which identified by example and name could be reliably and easily identified by children in a variety of physical contexts). Schemes developed with age (and might be used in a metaphoric way by children 13-14 years old) and many schemes (particularly those which have to do with physical movement) were available and produced even by very young children(around 5 years old).

Summarizing, schemes such as "support", "flow", "container", "rigidity" etc. appeared as re-usable building blocks, neither too specific nor too generic. They are generic enough to be used in many situations but not so generic to be used everywhere. Schemes are used in packages to make models. So, schemes appeared with a small set of "potentials" (e.g. the scheme 'support' includes 'something underneath', 'above the ground etc.) which provide 'entailments' (e.g. removing support will make something fall).

2.13 An overview of Chapter 2

A central aspect of the thesis concerns the idea of 'abstraction', which is involved in all theories of mental representation, of analogy, and of the role of examples. It will be important to regard abstraction not merely in terms of 'more' or 'less' abstract, but as involving a middle level - the level of prototypes - which is fundamental. Much of the work is addressed to elucidating this notion. In the present research, I treat 'empirical schemes' as the basic level of mental representations. The term 'empirical schemes' is used to cover a wide variety of schemes described by other researchers: Piagetian's schemes, diSessa's p-prims, Johnson's image schemata and Johnson-Laird's mental models. All these schemes appeared to me to be located at the same level of abstraction (basic level) but having different location in the axis which represent their specifity. Thus, 'empirical schemes' -which are very close to schemes as they described by Piaget and earlier by Kant- are less specific than p-prims but more specific than mental models. 'Empirical schemes' have their origins in physical activity and are common abstractions of various phenomena. That makes them very powerful tools in the imaginative transformations that children attempt to make between very different objects or events.

Chapter 3:

RATIONALE FOR THE RESEARCH

3.1 Introduction

During the last two decades, work on children's ideas has shown how difficult it is to change them (Osborne and Freyberg, 1985; Driver, Guesne and Tiberghien 1985). The difficulties in changing children's ideas might exist because of the way that researchers describe them. It appears to me possible that this happens because we try to make this change just at a propositional level (usually adults expect a child to understand and make use of sentence meaning in the same way as they do) and not at a level closer to children's mental representations which can bring to the surface children's deep reasoning patterns about natural phenomena and in particular make clear children's basic-prototypical level of schematic representations. So, this research suggests a way of looking at children's reasoning from an ontological point of view.

The ontological view of concepts can refer either to changes in concepts within or across ontological categories, or at a more abstract level to the ontological dimensions which organise schemes. As already mentioned in the previous Chapter, Ogborn and Mariani (1991) argue that scientific concepts can be placed along dimensions: for example, dynamic vs. static, place-like vs. localised, cause vs. effect and discrete vs. continuous. 'Empirical schemes' are used in this research as tools to analyze the way that children make transformations of objects, construct analogies, and create examples from generalizations and vice versa.

This Chapter includes a literature review of the areas of transformations, analogies and examples, and also provides a rationale for the research questions chosen.

3.2 Transformations of objects

Keil (1989) argues that when young children attempt to transform an entity of one kind into an entity of a different ontological category by manipulating characteristic features, they "maintain that the type of kind is not changed even though they readily judge type of kind to be changed for entities within the same ontological category" (p.209). Chinn and Brewer (1993) describe ontological beliefs as "beliefs about the fundamental categories and properties of the world" (p.17). It is very hard to change them because they are used to support ideas across domains or subdomains and because the beliefs are remote from experience.

Chi and her colleagues (1992, 1994, 1995) apply the notion of ontologically different concepts to the issue of conceptual change in science learning. They argue that learning in science involves conceptual change across ontological categories since the scientific meaning of many science concepts belongs to different ontological categories than those to which their naive intuitive meanings belong. They propose that some science concepts are more difficult to learn than others because they require a conceptual transition between different ontological categories.

Chi et al (1994) argue that concepts belong to different ontological categories such as "matter", "process" and "mental states". Students have to stop thinking of concepts like heat, light, force and current as material substances since it is very difficult for a student to achieve a transformation of an entity which belongs to a "matter" category into a "process" category. They refer to this difficult process as radical conceptual change. Chi et.al., (1994) document evidence from three experiments in which students were presented with physics problems about the scientific entities light, heat and electric current. They base their analysis of transcripts on the identification of predicates such as contain, move, block etc. which might be regarded as schemes. Results show that novices do not use the process predicates for these concepts whereas experts do.

However, the term "ontological categories" seems to me quite arbitrary because the ontological categories do not have such precise homogeneity as Keil argued. Consider for example Keil's ontological categories such as "animals" and "artifacts." At a different level it can be argued that birds and fish constitute also two different ontological categories, since, although they have clusters of similarities, they have also different clusters of properties. So, the categories of animals and artifacts are not themselves homogenous groups.

Also, perhaps nowadays (about ten years after Keil's studies), the boundaries between the categories which Keil called ontologically distinct are more flexible. In the most popular children's TV films, creatures similar to the monster of Frankenstein appear very frequently. Machine-robots have the same characteristics as humans. Do the children believe that the artifacts they see on television (i.e. Mr. "Data" in star trek, dinosaurs with machines inside, etc.) belong to living things? It seems at least possible. The cultural (i.e. TV) influence is great.

Furthermore, in Keil's studies children were judging the result of a transformation process that he had already given to them and it is possible that the changes he suggested to the children were not enough for them to accept that the object has been transformed into another, changing its identity. So, the question is whether children (who receive a great cultural impact about flexible ontological categories) can themselves make transformations of objects within and across ontological categories. I decided to ask children to make transformations of objects - about ten years after Keil's studies - and to give them the opportunity to make their own changes. I was hoping that if the children had any difficulty in accepting the change of the identity of objects which belong to different ontological categories, I would be able to observe what those changes that make it difficult are.

In the present research, the hypothesis is that in the transformation tasks, children make changes related to their empirical schemes. For example, in transforming a bus into an aeroplane they might need to change the shape of the bus, (e.g. putting wings, a tail, smaller wheels, screws etc.) but they will not change essential schematic features (e.g. seats for the passengers - both are containers -, the need for power, both can move etc.). But what are these empirical schemes, how we can detect invariances between them, and can they make possible difficult transformations across ontological categories?

Gelman (1979) claims that children might think about the insides of animals in terms of the functions that they serve. On the other hand Simons and Keil (1995) in one of their studies concluded that "emphasising the functional role of the insides for each animal or artifact had little if any effect on children's patterns of responding"(p157). How important is the role of 'functional schemes' (what things can do) in the transformation of one object into another?

In the previous Chapter there is a discussion of the prototypicality of examples or members of categories. It appears interesting to me to explore questions such as, given two objects A and B, is it easier for a child to transform A -> B, or B -> A, and why? If children prefer one specific direction, this might be evidence for an asymmetry between the two examples. This asymmetry can be explained as the result of the existence of some parts in one thing that are more prototypical than the respective parts in the other. That is, this asymmetry could be evidence for the existence of prototypes. So, it is expected that children will find it easier to transform a non-prototypical thing into a prototypical one.

Summarising, schemes by their nature are common abstractions which are cross-categorical. Schemes such as 'flying' can describe things that belong to different ontological categories, for example an aeroplane (artifact) and a bird (natural kind). So, I asked children to make transformations using their imagination, of objects that belong to same ontological category and of objects that belong to different ontological categories, to see whether these ontological categories exist and constrain the success of transformations. In the case with the objects from different ontological categories I chose some pairs which have common schemes (i.e. an aeroplane into an eagle, both have common schemes such as they fly), and some which have not (i.e. an eagle into a toy car). I was interested to identify the schemes that would be used by children and to see whether the existence of common schemes can make possible cross-ontological category transformations. Also, I decided to ask half of the children in each group to make the opposite transformation (i.e a toy car into a bird) to see whether there is evidence about any asymmetric character of prototypes.

In contrast to Keil, who believed that the boundaries of these ontological categories might be innate, the hypothesis of this study is that schemes cross the boundaries of ontological categories, and that "ontological categories" are context dependent. It does not mean that humans represent 'things' merely as a sum of parts, making categories according to clusters (at a superficial level) of these parts. The present research is intended to show that function - what things or their parts can do -, plays an important role in the construction of weak or strong boundaries between categories.

Venville & Treagust (1996) document evidence for transformations across ontological categories with the help of analogies. They describe an analogy as a "transformer" in the process of conceptual change since analogy might play a role of transforming the ontological category of a concept from the erroneous ontological category to the preferred category. They describe how the fluid mosaic model for cell membranes (a membrane consists of a double layer of lipids with proteins embedded in it like mosaic tiles) was used by a teacher with the purpose of changing students' view from static to dynamic entities. The purpose of the analogy was to draw students ideas away from that of a cell membrane as a barrier with holes in it, and to emphasise the process attributes such as the 'fluid' nature of membranes and the associated functions such as the ability of proteins to move. In the particular study the teacher used the analogy as a transformer to change students view of cell membranes from a "matter" category to a "process" category.

3.3 Analogies can be described at a schematic level

3.3.1 Analogical reasoning

A recent special issue of the Journal of Research in Science Teaching (1993), is dedicated to the role of analogy in science education. It is the result of the great interest in the role of analogy in science and science education during the last decade.

Lawson (1993) introducing this special issue categorised scientific concepts into two types: (a) descriptive concepts, and (b) theoretical concepts. In the first category belong concepts such as the concept of solid, liquid and gas states of matter, for which perceptual exemplars exist in the environment. So, a teacher can help pupils understanding by pointing out several examples of these. In contrast, there are concepts such as atom, gene, phlogiston that do not have perceptual exemplars. In this case, the meaning of such concepts cannot be derived from our perceptions, and a teacher might help children's understanding using analogies.

However, analogy is a difficult term to define. DeJong (1989) calls it a "fuzzy concept that means different things to different people". Goswami (1991) gives a review of the research that has been done in the area of analogy. She particularly focuses on research that has set out to measure the development of analogical ability and points out that relevant theories share a common assumption: "the ability to reason about relational similarity". This assumption is common both in classical analogies (Piaget's structural theory and Stenberg's information processing theory), and in problem solving analogies (Gentner's structure mapping theory etc.).

Classical analogy, taken from IQ tests, is the a:b::c:d task. An example might be car:fuel::person:?. Fuel is to car as "what" is to person? In this type of analogy the child has first to determine the causal relationship between the B and A entities and then to identify the D entity that has a similar causal relationship to the C entity (Pierce & Gholson, 1994).

Research on analogical reasoning has demonstrated that novices who try to solve problems in a new domain often think back to an earlier analogous problem that the current problem reminds them of. Success depends to a large extent on whether they are reminded of an appropriate problem that has the same principle as the test problem (Ross, 1984).

Gick and Holyoak (1983) emphasize the important role of analogical thinking in the transfer of knowledge from one situation to another by a process of mapping which is the "finding a set of one-to-one correspondence (often incomplete) between aspects of one body of information and aspects of another".

In the last decade researchers have investigated children's (mainly students') ability to reason by analogy in problem solving tasks. Gentner's (1988, 1989) structure-mapping theory of analogical reasoning is based on children's solution of problem analogies rather than classical analogies (a:b::c:d). The analogy depends on a similarity of relational structure between a problem that has already been solved (the base) and a new problem (the target). Goswani (1991), recognizing the crucial role of relational structure, claims that young children can reason analogically in both classical and problem analogy tasks as long as they have knowledge of the relations used in analogies.

Gentner & Gentner (1983) defined an analogy as a mapping from one structure, the base or the source, to another, the target. The source domain is the part that is already known, whereas the target is the part that has to be inferred. Structure-mapping defines as the essential elements that constitute an analogy, objects (with their attributes) and relations between them. The goodness of an analogy mainly depends on the correspondences between relations, rather than on source and target objects having similar attributes (see also Gentner and Toupin, 1986).

Consider for example the well known analogy between the solar system and an atom. In this case the sun corresponds to the nucleus, the planets to the electrons. The size, shape, weight etc. of these couples of entities differ greatly. Despite these differences, what makes this analogy “good” is the correspondence between relations. The relation of attraction and centrifugal force that causes the planets to orbit the sun and the electrons to orbit the nucleus are common to both (Gentner 1983).

Children use their memory to allow novel experiences to bring to mind relevant prior knowledge, even though the constituents of the new situation have never been directly associated with those involved in the remembered ones. For example, a child who sees a drawing of a simple electric circuit for first time might be reminded of the circulation of blood. This example illustrates analogical reminding. Both phenomena are analogically connected because they systematically correspond in the relationships between their objects, entities and processes. It is this structural consistency of the phenomena that makes them analogous, rather than simply that both involve some similar objects, entities and processes.

However, I think that the structure-mapping view has some weakness. It has been criticized, mainly, for two reasons:

a. It does not show the way that objects of the target domain are identified; they are simply placed in correspondence.
b. In a similar way, Gentner (1983) does not point out how and which relations in the source domain are selected for mapping onto the target domain.

Probably, in order to solve the first problem we have to look at the role that object attributes play (Keane, 1991). Furthermore, because of the second problem Holyoak (1985) proposes that the goals of the person who constructs the analogy constrain what is mapped from the base domain.

The proposed "solutions" by Holyoak and Keane help to account for the way that an analogy works. However it seems to me that the main problem with structure mapping (Gentner), the pragmatistic (Holyoak), and Keane's view is that they attempt to analyze the phenomenon of analogy, while seeing it only at a propositional level.

In contrast Johnson (1988) makes clear that there is a nonpropositional level that we have to consider if we want to explore the way that analogies work. He claims that "we don't yet have a fully adequate theory of analogical reasoning, because we haven't given sufficient attention to these preconceptual and non-propositional levels of cognition" (Johnson, 1988, p.26).

Particularly in analogical thinking, the core subprocess is the analogical mapping. It is the process that has received the most attention in the literature (Keane, et. al 1994). Researchers such as Gentner & Gentner (1983) who have explored this process have focused on relational similarity. However, in an analysis of the way that an analogy works, there is a stage after the identification of relational similarities. Relational similarities might describe the "form" of the analogical projection, while the identification of the "empirical schemes" that take part in a specific analogy could give a description of the “content” of the analogy. But, what are the common empirical schemes that can be identified in the source and target domain?

Most of the studies mentioned so far investigated the role of well known analogies in problem solving contexts. These studies do contribute to a better understanding of children’s use of given analogies. However, I decided to ask children to give their own analogies since in the case of learning science, it seems more important to understand how pupils can productively generate their own analogies to advance their conceptual understanding of scientific phenomena (see also Kaufman et.al 1996). Kaufman et.al. (1996) explore students’ and physicians’ use of spontaneous analogies in reasoning about concepts related to biology. The results show that participants produced analogies which facilitated explanations in various ways such as bridging gaps in understanding, illustrating and expanding on their explanations. The authors suggest that through the analysis of these spontaneous analogies it is possible to identify students’ misconceptions.

The investigation of the production of self-generated analogies might give evidence of the methods that children use to produce their analogies. Clement (1988) evaluated experts’ methods of generating their own analogies in scientific problem-solving (exploring the stretch in two springs). He documented evidence for three different methods of analogy generation:

a. generation via a principle (1 case)
b. generation via an association (8 cases) and
c. generation via transformation (16 cases).

The most common method was the last one. Tranformation occurs when participants create an analogous situation B by modifying the original situation A. In the case of generation via an association, participants are reminded of an analogous case B in memory, rather than transforming A into B. Associative analogies tend to be more "distant" from the original situation conceptually than those produced by transformations. But, what is the method that novices (young children) follow? Do they generate novel analogous cases rather than analogous cases which already exist in their memory? Do children follow a method based on schemes which lies between the second and the third method described by Clement?

3.3.2 Analogies in the domain of electric circuits

In the tasks developed in this research for the exploration of analogies, a simple electric circuit was used as the target domain of an analogy. The selection of the particular domain was not random. The difficulties with its introduction in the early stages of the science curriculum (last two years of the primary school in Greece), have led teachers to use analogies frequently as a helpful tool in the teaching of this domain.

Furthermore, research shows that children find it hard to understand scientific ideas about electric circuits (Shepardson & Moje, 1994). Osborne (1983) describes what children have in their minds and suggests that they think mainly using four mental models about the circulation of flow in a simple electric circuit. Also Duit et al. (1985) argue that many school students have great problems with the ideas that describe an electric circuit.

Many researchers have proposed as an important way of resolving this difficulty, the use of analogical reasoning in the development of children's ideas (Gosgrove 1995, Duit 1990, Gentner and Gentner 1983). Furthermore, children seem to accept analogies as useful tools in the understanding of this topic. For instance in a classroom with 11-year-olds, many children identified their teacher's analogy for electricity, as the main way of making sense of this topic (Gosgrove 1989).

Thus the electric circuit is a domain that has been used frequently by many researchers to explore the ways that various analogies can contribute to children's learning. Various analogies have been proposed as suitable. Stocklmayer and Treagust (1994) describe many analogies of electric flows used in textbooks in the last 100 years and mention that the water-circuit analogy has received considerable attention (see also Gentner and Gentner 1983). It is clear that each of the analogies that are used in textbooks - water, gravitational and anthropomorphic analogies - have a different focus and their goal was to represent various aspects of the electric flow (see also Dagher, 1995, for a discussion of the effectiveness of text-based or teacher-based analogies in learning science concepts).

Goswani (1991) argues that the answer to the question how good children are at reasoning by analogy seems to depend on the measure used. In the case of "problem solving analogies" the degree of success depends on what a researcher has as a standard of a "good" analogy. So, it is notable that researchers in this field have a preference to suggest ways for the analysis of analogies in their papers, that are based on "good" analogies.

However, I decided to explore children's own analogies in this research because many researchers have pointed out that children's "imperfect" analogies could be very useful in the learning processes. Gosgrove (1995) explores ways that students generated their own analogies in a series of sessions about electric circuits, and argues that it is useful in their understanding. Self-generated analogies are tools by which students can generate, evaluate, and modify their own explanations (Wong 1993). I decided to ask children to produce their own analogies to see what analogies they could give for simple electric circuits and how they could be analysed in terms of schemes.

3.4 *Examples of ideas*

3.4.1 Introduction

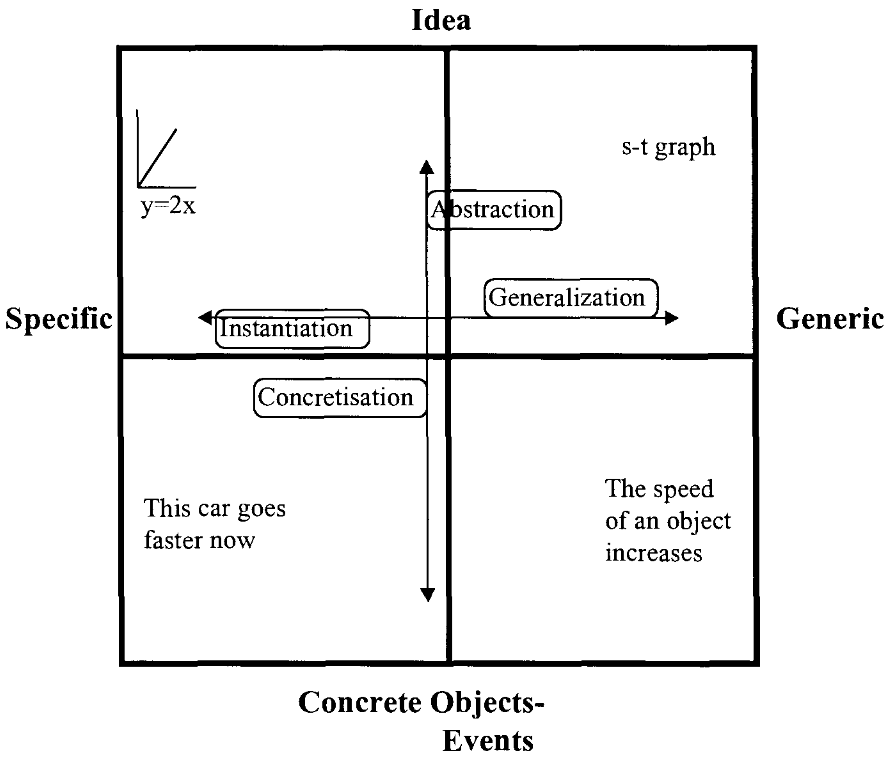
Examples are concrete instances. They are specific instances of something. There are different levels of specification-concreteness. So we can imagine a Table (see Figure 3.1) with:

a. a vertical axis in which the top end is the abstract-idea pole and the bottom one is the concrete (object/event) pole and,

b. a horizontal axis which goes from specific (left) to generic (right) pole.

An example tends to be at the left-bottom corner. For instance when someone says "time-distance graph", it could be argued that this is a generic and abstract idea, that tends to belong to the upper-right hand quadrant. If we have a graph where y=2x it will tend to belong to the upper-left quadrant, being more specific. On the other hand a statement like "The speed of an object increases" tends to be in the bottom-right quarter when a more concrete-specific example, "this car goes faster now" tends to be in the left-bottom quarter.

Figure 3.1: Different levels of specification-concreteness of Examples



How concrete an example is depends not only on the nature of the example but also on the way that the person involved tries to think about it. That is, the level of concreteness of mental representations he/she uses to think about an example can vary. For example, someone who hears an example about a person that pulls a string, might shape in his mind immediately an analogous "real" example, when for example he himself pulled a specific string. In this case we have the person that pulls "the" string not "a string".

Furthermore, the concreteness depends on the context. It has to do with the focus that someone who gives an example in a particular situation has on that example, and the different ways that he/she can understand it. Findings in psychology have shown that context influences the role of examples, since varying contexts lead to a better overall memory. So, viewing an example in a variety of contexts has as a result a better memory of the example. Also, a better performance appears to occur when the context at test matches the learning context (Ross 1984).

It is notable that the majority of the research that has been done in the area of "examples", has considered the ways in which examples could be used in learning, while not much work has been done on the question "How are earlier examples retrieved and used" (Ross, 1984).

The last question is a key question for this research. It is suggested that children use an "empirical level" of their mental representations in order to retrieve examples and to give other examples. Working at a level like this, children manipulate and use in their reasoning “empirical schemes”, in order to construct and modify examples of an idea. They use their background, their empirical schemes, in order to construct examples, and to clarify abstract ideas. So, the variation of the examples and their degree of fit with generalizations depends on their constituents, which are empirical schemes.

The focus of this research is on how children reason about:

a) a phenomenon in science using a generalization

b) a generalization, giving an example of it, and how they describe an example using schemes, and

c) transformations of an example of a phenomenon into another example. The important question here is "Which structures and features do they hold constant, and which do they change?"

The description of the above three kinds of transformations in the present study includes the presentation of the products of these transformations (children's own analogies, examples and generalisations) and an analysis of such products based on the identification of their schemes. The purpose of the study is to clarify the process of exemplification, describing examples, both those produced by children and those provided in science textbooks.

So, the fundamental role of examples in children's reasoning in science, will be explored in this research. The hypothesis is that there is a level of concreteness which "allows" someone to construct, modify and in general transform examples easily. That is what in the first section was described as the "empirical level". This level is neither the same for all people, nor for all contexts.

Related work on reasoning about a phenomenon (target example), through the direct construction of a "connection" with another source example (because of their similarity) and so with the package of explanations which are known about the source example, can be found mainly in the research areas of analogical reasoning and problem solving. It is worthwhile to distinguish between the use of different types of examples in these two research areas. So, when I use research from the problem solving area I will call them exercises (worked-out examples) since the "examples" studied are typically end of Chapter exercises.

The work on analogies has been close to the present research aims. Interviews with science teachers suggest that most teachers used either examples or analogies in their teaching and that often they did not differentiate between examples and analogies. This lack of differentiation is not surprising given the similar purposes of analogies and examples in the learning process to make the unfamiliar familiar (Treagust, Duit, Joslin, Lindauer 1992). Through the construction of analogies humans can reason about a new target example using their background knowledge of a source example. The connection between source and target example is a result of their similarity which can become obvious through the transformation of one example into another one. The transformation process relies on noticing and making use of some kind of similarity between the empirical schemes that humans use in order to think about examples.

3.4.2 What are Examples?

Examples are parts of both commonsense and scientific thinking. The etymology of the word tells us that example is a part taken out of some whole. This part stands for the whole. Important questions arise from this etymological definition. "What whole?" and, "What makes an example so powerful to stand for or represent some other entity?"

The present research attempts to show that the "synthesis" of an example from specific empirical schemes is responsible for the fit with the whole, and the "power" (how good it is) of the example. For instance, we can have both "a child threw up a balloon" and "a child threw up a stone" as examples of the same idea "What goes up must come down". Both these examples have many common schemes (i.e. the balloon and the stone will "move" for a short period; they are not "decision-makers"- they do not have the "power for autonomous action") that makes them good examples of this generalization (they are better as an example than a bird flying or than a rocket). However, the "stone-example" might appear better for some people because its synthesis involves an empirical scheme, the time that the stone takes to come down, which is less than that of the balloon.

The production of examples is very similar to the production of metaphors and analogies. Using metaphors we can understand one kind of thing in terms of another. Metaphors subtract some features from one conception and focus on some other, in order to characterize something in a different way. Metaphors "provide coherent structure highlighting some things and hiding others" (Lakoff & Johnson, 1981, p.39)

In a similar way examples can be seen as a set of facts or features that are viewed through a certain type of lens. As such, examples are "filtered snapshots of the ‘world’ that emphasize some aspects and forget others, and the whole process is done on purpose" (Rissland, 1991). This description brings examples, metaphors and analogies close together. Thus, I decided to ask children (study 3) to describe objects in two different contexts - a non-exemplifying and later in an exemplifying context - to see whether examples will highlight or hide any schemes.

3.4.3 How do children understand and use examples of ideas?

There are many reasons why researchers need to focus on examples. An important reason is that examples seem to be an important tool for those who write textbooks. Also teachers when clarifying ideas, make extended use of their own examples and of textbook examples in the classroom. The simple idea “almost all solid things expand, when they are heated” can be exemplified by “the expansion of electric wires in summer” or “the expansion of railway lines in summer”. But what are their components and what makes the two examples that exemplify the above idea, different? In order to explore differences between examples of the same idea, I asked children to describe two examples (study 3) or more (study 4) of the same idea.

The traditional goal of exemplification is the role of an instance as a guide and stimulus to practice. Kant goes in a new direction, emphasizing the methodological status of reasoning through examples. Particularly he defines the reflective judgment as the “necessity of the agreement of all [men] in a judgment that can be considered as an example for a general rule that cannot be stated”. So, in this case, examples aid reason and judgment, and Kant characterizes them as wheelchairs or strollers for the judgment (Gelley, 1995).

“Good” examples, play an important role in learning. Also, one cannot ignore the special role of “bad” examples - that is, counter examples - in learning. Keenan (1995), argues that the “responsibility begins in the bad example.... there would be no experience of difference, no change, and no relation to the other without the adventure of the comparison and its failure - precisely because it is not always safe” (Keenan, 1995, p.121). This implies that teachers have to take into account not only the “good” examples but also the counter examples that children give. Through the analysis and comparison of counter examples with other examples, children can judge why, when and which examples of an idea are “good”. In the present research, I asked children to describe textbook counter examples and to produce their own counter examples (study 3) to see what schemes they use in this case in comparison with the description of “good” examples.

Lyons (1995) claims that example formation deals with two dimensions of integration: (a) between statement and instance that can be called vertical integration and (b) among instances that can be called horizontal integration. This study deals with both dimensions of integration. It aims through the description of: (a) children’s examples of ideas to identify the results of the radical changes of the transformation from abstract to concrete or general to specific, and (b) the constituents of examples to identify similarities and differences between examples of the same/different ideas.

3.4.4 How do children understand and use worked out examples (exercises)

There are findings showing that students often rely on exercises as a learning tool. VanLehn (1986) argues that arithmetic is learned by "the generalization and the integration of examples". His findings show that a large number (85%) of students’ errors in arithmetic, arose from some type of learning from exercises.

Reed and Bolstad (1991) distinguish two alternative approaches in order to teach people on a task: either presenting a detailed example or a set of procedures. When students attempt to solve problems and receive both procedures and examples they seem to prefer examples.

Also, there are studies in the area of learning computer programming that support the important role of recalling examples by students, who use them as an analogical basis. Pirolli and Anderson (1985) argued that students in order to write recursive functions rely on analogies to examples (see also Pirolli, 1991).

LeFevre and Dixon (1986) explored what happens when students attempt to solve inductive reasoning problems and these problems are accompanied by an example that conflicts with the instructions. The degree of effectiveness of example and instructions was measured by looking at which procedure subjects used. They found that most of the students used the example and disregarded the procedure described in the instructions.

However, there are limitations in the way that students can use worked-out examples and generalize what they learn from them. Frequently, a student who has studied exercises cannot solve problems that need a slightly different method of solution from that of the exercise. Reed, Dempster, & Ettinger, (1985) found that students often have difficulty in solving variations of exercises. They were able to solve only 6% of simple algebra word problems (such as mixture problems) that required the use of a slight transformation of the original equation.

Although the exercises have limitations (in the procedure of generalization), their frequent use in instructional procedure, makes the question "what do exercises offer to instructional procedure?" important.

In order to answer this question, we have to identify the limitations of exercises in the learning process. It seems that a factor which mainly gives learning from generalization of exercises a low level of success, is whether the statements that can be found in an exercise solution procedure are not explicit about the conditions under which the actions apply (VanLehn, 1986; Chi & Bassok 1989).

Chi and Bassok (1989) argue that students have difficulties in using in other contexts what they have already learned in an exercise. Particularly, these problems appear when they have learned from this example only a sequence of actions, or in other words have acquired only an algorithmic procedure or syntactic rules. In this case students have not understood "how the conditions of the rule can be derived from other variations of a given equation" (Chi and Bassok, p.263).

3.4.5 The movement between examples and generalisations

It is notable that already in ancient Greek thought examples are described in two different ways. In Plato, “paradeigma” means a model, a standard. It is related to the abstract theories of ideas, which are the source for the characteristics of objects. So, the Platonic model displays a vertical directionality, from primary exemplar down to multiple instantiations. This vertical directionality is a common phenomenon in science classrooms where teachers give an idea and then try clarify and explain it, through examples.

In contrast to Plato’s view, in Aristotle a rhetorically oriented conception of examples appears. In this case, “paradeigma” functions inductively: the instance serves as a vector pointing to a principle or conclusion. Aristotle describes examples as a movement with a horizontal dimension/direction “neither from part to whole nor from whole to part but from part to part, like to like, when two things fall under the same genus but one is better known than the other” (Gelley, 1995, quoting Aristotle).

If we apply the current terms in this definition then we can observe that Aristotle talks about:

- examples which are common abstractions and have common “empirical schemes” (same genus)
- examples which are best, prototypical examples (one is better known than the others)
- a kind of horizontal transformation of one example into another (from part to part, like to like).

In summary, two kinds of exemplification appeared in ancient Greek thought. Aristotle’s view is oriented towards a pragmatic function, to rhetoric, whereas Plato’s view is oriented towards a cognitive principle and to ontology. (Gelley, 1995)

An important use of examples in the learning-teaching process is arriving at a generalization through induction from examples. In the last two decades, there are mainly two different approaches that attempt to describe the way that generalizations are induced from examples: a) the similarity-based and b) the explanation-based approach.

The similarity-based approach claims that a generalization develops by inducing a principle (in other words a set of common features) from multiple examples. So, in this procedure of induction more than one example is necessary and there are essential features that will be shared by all these examples (Gick & Holyoak, 1983). The transfer between problems relies on making use of the similarity between the problems (Ross, 1984).

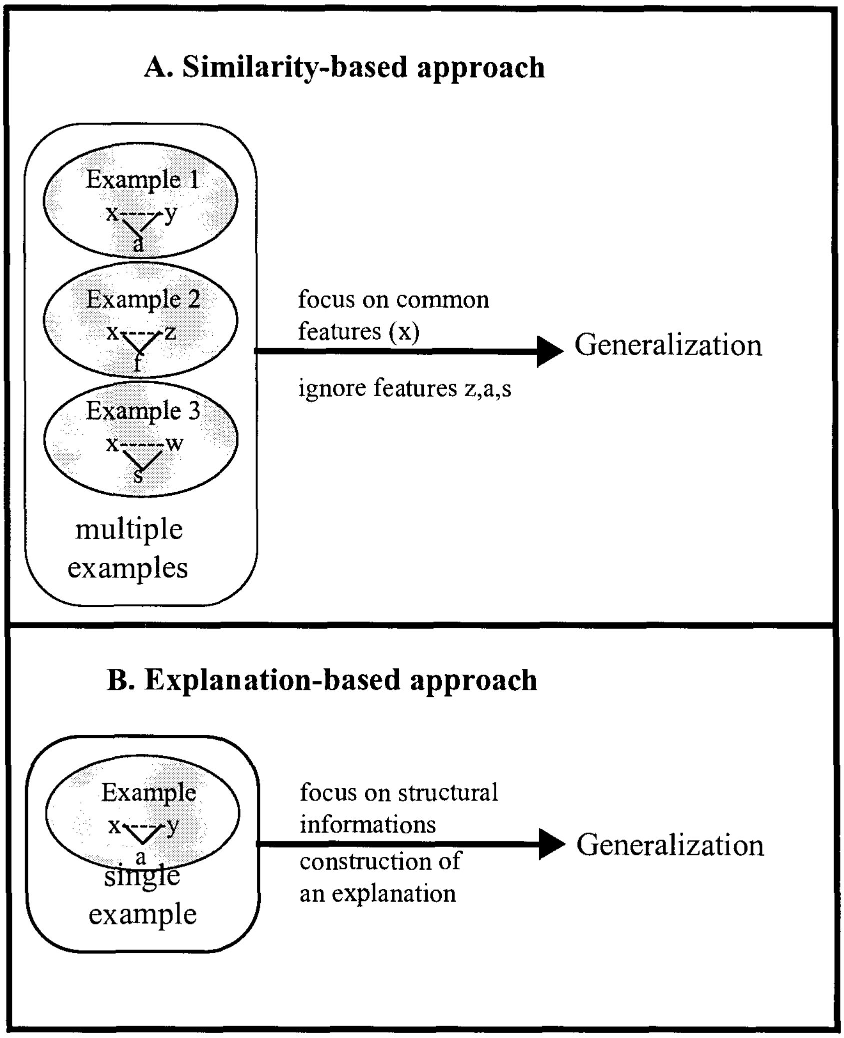
On the other hand the explanation-based approach proposes that generalizations can be induced from a single example. In this case the procedure of induction involves the construction of an explanation that justifies why the example is an instance of this generalization (Lewis, 1988). Figure 3.2 displays the differences between these two approaches.

Examples play an important role in the creation of abstract knowledge structures. That happens because the creation of abstract structures requires the comparison of examples of isomorphic problems in order to discover their common structure. (Catambone & Holyoak, 1989; Cummins, 1992).

Catambone & Holyoak (1989) found that when the source and the target analog share many salient surface properties, spontaneous transfer can occur even in the absence of an externally provided hint (for the application of the source analog). Usually multiple examples allow transfer even in the absence of a hint when the context is relatively constant, while a single source example typically would not suffice.

When students use multiple examples, they have the opportunity to induce a category based on the structural similarities among them. On the other hand, students who are required to analyze problems individually, or simply read the problems tend to categorize and describe them on the basis of surface feature similarity (Cummins, 1992)

Figure 3.2: The ways in which generalization can be induced from examples



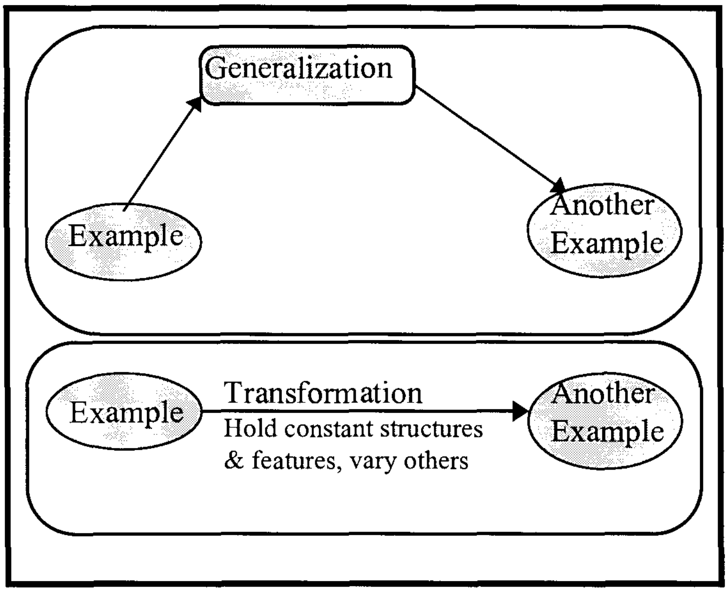
Gick and Holyoak (1983) in their research, found no evidence to support the view that subjects' ability to abstract from a problem schema can depend on just a single story analogue. In contrast, when two prior analogues were given, subjects induced successfully an abstract schema as a product of describing the similarities of analogues. This schema was "highly predictive of subsequent transfer performance" (p.31). These findings support the view that a mapping process cannot lead to a schema by operating on only a single prior analogue. On the other hand, a general schema can be a result of two analogues which can mapped together.

However, Ross & Kennedy (1990) suggest that the similarity-based approach needs to address two issues: a) what determines which instances are compared?, and b) what is the nature of this comparison?

According to their reminding view (a case of the explanation-based approach) the use of an earlier example to solve a current problem requires the novice to generalize some superficial features, and by doing so, the learning of a generalization includes more structural information about a problem of the same type. Also, the reminding, through these generalizations, affects later problem solving performance. So, in this case learning occurs from making the analogy, not from some separate processes (Ross & Kennedy, 1990).

Even though the majority of psychological theories support a similarity-based approach to learning, there are findings showing that students can generalize from single examples (Elio & Anderson, 1983; Kieras & Bovair, 1986). According to Chi & Bassok (1989) a combined similarity-based and explanation-based approach is necessary in order to learn from examples.

Figure 3.3: The induction and transformation of examples



According to these approaches, examples play an important role in the development of abstract knowledge structures. They focus on the way that induction from examples to generalizations takes place. This is one of the things that this research explores. Also, another interest of the research is the way that children use examples in order to clarify an idea and the alternative ways that children can use in order to go from one example to another through the use of their empirical schemes (see Fig. 3.3).

In human reasoning there is a continuous transformation from:

- concrete objects and events to abstract entities (generalizations),
- abstract entities to concrete objects and events (examples)
- one concrete example to another.

Humans can give an example for a generalization through the manipulation of some prototype schemes. When they produce an example, at the same time they check whether it fits or not, to their prototype schemes. Usually, they can say how good an example is by transforming it to a prototypical example (it depends on how easy and good this transformation is).

Consider for example:

> "If a leaden ball, projected from the top of a mountain by the force of gunpowder, with a given velocity, and in a direction parallel to the horizon, is carried in a curved line the distance of two miles before it falls to the ground ... And by increasing the velocity, we may at pleasure increase the distance to which it might projected, ... or even might go quite round the whole earth before it falls; or lastly, so that it might never fall to the earth, but go forwards into the celestial space ... And after the same manner that a projectile, by the force of gravity may be made to revolve in an orbit, and go round the whole earth, the moon also, either by the force of gravity, if it is endued with gravity, or by any other force, that impels towards the earth, out of the rectilinear way which by its innate force it would pursue; and would be made to revolve in the orbit which it now describes; nor could the moon without some such force be retained in its orbit (Cohen & Westfall ed. quoting Newton, p.229)

Newton seems to have a prototypical scheme of a centripetal force (bodies tend towards a point as to a centre). The moon can be a good example of a body which will go round the whole earth and the changes in the force of gravity can lead this body to orbit similar to the orbit of the prototypical body-ball. This is, of course, a deeper more complex transformation than most of those we make in everyday thinking.

The clarification of a generalization usually happens through the use of a variety of examples, but not all examples fit (to the same degree) equally well to a generalization. But what makes one example better than another? Thus, I decided (study 4) to ask children to compare examples (when is one example better than another and why?) because it can lead us to identify the prototypical concrete schemes that are required for a specific generalization. The basic questions that were explored in the present research are the following:

- How do children move from examples to ideas and vice versa, and
- What kind of examples work well and why?

3.5 A summary of the objectives & research questions

The overall goal of the research was to describe children's transformations of objects, events and examples of ideas using schemes as tools, in the context of their engagement with scientific ideas. Particularly, this research aims:

- to give some evidence for the existence of 'empirical schemes' and their structure in children's reasoning
- to contribute to knowledge of children's use of 'empirical schemes', with relevance to science education
- to develop novel tasks based on a methodological framework for investigated children's reasoning in the context of some domains in science education:
    - pupils' understanding of textbooks' example of ideas
    - pupils' construction of examples of ideas and of generalizations from various examples
    - pupils' generation of analogies
    - pupils' transformation of objects across ontological categories.

Summarizing the previous section, the following general research question were generated from the above objectives:

- Can the existence of empirical schemes make possible difficult transformations across ontological categories? What is the nature of these schemes?
- What is the structure of schemes? Do they appear together in groups?

- Can one document how young children produce spontaneous analogies in relation to a scientific concept?
- Are the analogous cases produced by children always retrieved or are they sometimes invented?
- How can children's self generated analogies be described in terms of schemes? Can the presence of one scheme in an analogical example predict the presence of another related scheme?
- How do children construct generalizations from examples and vice versa in terms of empirical schemes?
- What examples of ideas can children of this age construct?
- How do children describe various examples of different ideas in science using a set of empirical schemes?
- What empirical schemes can make one example of an idea better than another?

3.6 General Methodological approach

In the previous section, the research questions were presented. The idea of this research was to invent new tasks which could answer the new questions that had arisen from a theoretical discussion about the existence of schemes and about how we can use the idea of schemes in the analysis of children's reasoning in science.

This research supports the position that children base their reasoning on schemes, giving some more evidence of this, and proposes that schemes can be used as tools for the analysis of children's reasoning at various levels. Exploring different transformations at various levels (between objects, events, examples and generalizations) it was not possible to use the same type of task to explore the different levels, and to answer different questions that are relevant at the various levels. Thus, I decided to use different stimuli (pictures, written sentences, speech) and different elicitation methods (interviews, questionnaires with open and closed questions).

In order to describe ways that children use schemes, and how the idea of schemes can be useful tools in the analysis of these transformations, four groups of tasks were used:

- the imaginative transformation of one object into another (study 1)
- the imaginative transformation of one event into another, constructing analogies (study 2)
- the imaginative transformation of objects, contrasting contexts which do, and do not, use these objects to exemplify ideas (study 3)
- the imaginative transformation of an idea into examples and vice versa, looking at goodness of fit (study 4).

The tasks that were used in the various studies of this research were developed in a such a way as to fit (to have instances from the various categories) two dimensions described by the methodological framework of the research project 'Empirical Abstraction and concrete reasoning schemes': (a) the various generic categories of tasks and (b) the distinction between tasks which require the production and those which require the recognition of schemes (Bliss & Ogborn, 1997). I decided to use tasks which belong to the various categories because it helps research to give a whole picture of schemes.

The first and the second study, can be classified in a group of tasks called 'Imaginative transformations'. Another task of the category 'Imaginative transformations' which was used to investigate schematic reasoning in the 'Empirical Abstraction' project was the "Imaginative denial of rules" task. In this task children were asked to imagine carrying out a number of familiar actions (making tea, diving into a swimming pool from a spring board etc.) in a world where everything is the opposite so all is 'topsy turvy'. In these tasks, children were asked to transform one object or event into another, to see what sorts of transformations are possible, and then what is held constant and what is changed at each stage of the transformation.

The third study can be classified in the category of tasks called "thinking of something as ...". Tasks in this category asked children to think of instances as given schemes, going from the instance to the scheme. In the tasks of this thesis, children were asked to give descriptions of objects in contexts which differed by being related, or not, to providing an explanation of an idea.

The fourth study attempts to see whether children are able to establish connections between concrete examples and generalizations, and to think that some instances are better examples of ideas than others. It can be classified in the category "instances of something like...". This category includes tasks in which children create or identify instances of a scheme, going now from the scheme to the instance.

In the research project 'Empirical abstraction and concrete reasoning schemes' the tasks distinguished whether they required the production (generation) or the recognition (selection) of a scheme (see Bliss & Ogborn, 1997). The transformations of objects tasks (study 1) and the tasks where children describe schematically the objects out and in the exemplifying contexts (study 3) are in these terms selective, since children just had to recognise and match schemes, not produce new instances of them. On the other hand, the tasks where children construct their own analogies (study 2), and most of the tasks where children transform an idea into an example (study 4) are generative, since they require participants to produce a scheme or an instance of one. In this case, schemes were not presented explicitly, although being partly implicit in goals settings of the task.

Children participating in this research were from 11 to 12 years old. They were pupils in the last two years of the primary school in Greece. It is notable that science in Greece is introduced as a separate subject in the last two years of the primary school. So, children of this age, could help us to understand: (a) how young children introduced to science construct and manipulate examples, analogies and objects, and (b) what these children who are nearly finishing the primary school are able to do in terms of transformations using schemes. The choice of this age had a practical reason since the distinction between ideas and examples (that used in studies 3 & 4), and also the notion of analogies (that used in study 2) are introduced in a systematic and explicit way (in school textbooks) in these last two classes.

Qualitative and quantitative methods were used in the analysis of the data. The most common position held by qualitative researchers about the relationship between 'qualitative' and 'quantitative' approaches is that these represent fundamentally different paradigms (considering the Kuhnian notion), which are founded on incommensurable philosophical presuppositions. Against this it is argued that qualitative and quantitative methods can be seen as complementary and the choice should be based on the focus, purposes and circumstances of our research. (Hammersley, 1996).

Douglas (1996) introducing a special issue of the journal 'Science Education' on qualitative research, argues that in the last fifteen years the idea that qualitative research has a place in science education became popular, and that the use of qualitative and quantitative research in science education has to be complementary rather than competitive. Quantitative research enables researchers in science education to "generate accounts that locate and explain events in terms of space, time, number and determinism" and the strength of such accounts is more on the side of precision than scope, while qualitative research "allow for explanations based on the qualities of events in terms of categories" and it is stronger on the side of scope rather than of precision (Douglas, 1996).

Hammersley (1996) suggests (a form of 'methodological eclecticism) the combination of qualitative and quantitative approaches, since that might cancel out the respective weaknesses of each method. Niaz (1997) documents the importance of integrating qualitative and quantitative research methodologies in science education. He is opposed to the view that the relationship between qualitative and quantitative research can be described in terms of the 'incommensurability' thesis. He argues that a review of the literature in science education research shows that there is a competition between divergent approaches (as described by Lakatos), and they are more productive than the appearance of only one paradigm.

Mason (1994) identifies as a key challenge in the case of the integration between qualitative and quantitative data, the development of the necessary approaches to deal with data that have different logical principles. So, using these two approaches in a research, one cannot say whether one method 'contradicts' the other, since they give answers to different questions. According to Hammersley (1996) it is preferable to use them in a complementary way, to give respectively answers to questions about 'what happens' and 'how often something happens'. The last formulation of Hammersley's is not, however, entirely adequate. It is quite possible for quantitative analysis, for example of clusters, to produce qualitative information. At several points I have used it in this way. Equally, it should be said, though I have not done this, that counts on a large scale of qualitative categories derived from data, can be useful.

In the present thesis, I used a 'complementarity' of methods mostly in the 2nd study. Qualitative research is regarded as being better able to produce information about the nature of schemes or packages of schemes children used giving their analogies, while quantitative research was used to give evidence of how often particular packages of schemes appeared in various analogies. Also, in the various studies, qualitative analysis is used to provide information and to generate accurate information about a small number of cases (pilot tasks), while quantitative methods are used mainly in bigger samples to make possible wider generalizations.

The fourth study mainly used another form of combination of qualitative and quantitative techniques, which Hammersley (1996) calls 'facilitation'. Qualitative interviewing about children's modification of examples was used as a preliminary method, both to generate hypotheses and to develop later a questionnaire which was analyzed mainly with quantitative techniques.

In most of the tasks (see the first and the third studies) open-ended questions are used. Thus I decided to carry out the qualitative data analysis using the 'systemic network analysis' (Bliss et.al 1983) because this method of analysis is particularly suitable for these data.

3.7 "Empirical Level" and Science Education

Science educators recognize that pupils bring to the classroom their own ideas about everyday phenomena of interest in science and that these ideas usually differ from scientists' current views. Pfund and Duit (1994) catalogued many hundreds of studies about the ways that children think about various phenomena of interest to science. According to Ogborn (1996), work about children's ideas "in Europe has often tended to focus on describing students' conceptions, whereas work in the USA has had a stronger focus on changing them".

This research investigates how the nature of the empirical level of thinking could be used in order to analyze the way that children construct their ideas about the physical world, and what implications this may have for science education. So, this research identifies some of these empirical schemes, and describes how children use them in their reasoning about science and considers what the implications are for science classrooms.

Adey (1995) produced a categorization of types (current themes in) science education research. His system used for the classification of all research papers appeared in the 1992 and 1993 volumes of the International Journal of Science Education and the Journal of Research in Science Teaching. One of the nine categories that were identified by this classification was 'Cognitive schemes as explanations'. That category, in which this thesis can be classified includes investigations into the influence on science concept formation of various cognitive schemes. Schemes include mental models, phenomenological primitives and schemes of concrete and formal operations. The research goal of the studies in this category is to provide an explanation for patterns of concept formation. Furthermore, they have an educational goal to provide a better understanding of deep structures which should help in the design of more effective instruction.

The focus of the present research is on the exploration of the ways that children think about particular instances-examples in science. An analysis which has as its tools the empirical schemes of children's reasoning is appropriate for the analysis of the value of examples and analogies in science classroom. It is possible that through the "good examples" and "analogies" children produce, one can explore their background knowledge at deeper level.

Also teachers, taking account of these spontaneous analogies of children, could better correct wrong analogies in order to correct the deeper "wrong-idea". Johnson (1987) pointed out: "Metaphors, or analogies, are not merely convenient economies for expressing our knowledge; rather they *are* our knowledge and understanding of the particular phenomenon in question."(p112). Also, Iding (1997) suggests that one of the possible future directions in research about analogies might involve research such as that of Wong (1993) on students' self generated analogies. The creation of guided exercises using self-generated analogies which will accompany science texts will be a very helpful tool in science teaching.

3.8 An overview of Chapter 3

Research on conceptual change has started to focus on describing ontological rather than epistemological issues. Relevant work investigates children's imaginative transformations of objects or events. They base their analysis more or less on the exploration of schemes. In this research it is suggested that if science educators aim to go further than a mere identification of children's ideas, for example if they aim to change them, they have to consider children's 'empirical schemes'. Science educators have to focus on children's thinking about particular instances-examples, viewing them through the form and the content of children's empirical schemes. They have to describe the appearance of "packages" of schemes, to identify the whole group-package of elements that constitute an example and then to investigate whether there is any relation between the specific package of the elements, and misunderstandings held by students. They have to recognise the powerful role of schemes - as common abstractions - in children's imaginative transformations of entities which belong to different ontological categories. In the thesis, qualitative and quantitative methods of analysis of data are used in a complementary way to show a possible way that researchers could approach the above issues.

Chapter 4:
TRANSFORMING AN OBJECT INTO ANOTHER

4.1 Introduction

Learning involves conceptual change and may include a change in the categorical status of concepts. Keil (1989) argues that entities of one ontological category cannot be transformed into entities which belong to different categories. The current study explores whether children can make transformations of objects within (exploratory study) and across (main study) ontological categories.

Both the exploratory and the main study attempt, through a group of transformation tasks, to identify prototypical empirical schemes and detect invariances between them. Children are asked to transform one object into another. The hypothesis is that in the transformation tasks, they will make changes related to their prototypical empirical schemes. For example, in transforming a bus into an aeroplane they might need to change the shape of the bus, (e.g. putting wings, a tail, smaller wheels, propellers etc.) but they will not change essential empirical scheme features (e.g. space for the passengers - both are containers -, the need for power -both need a "pilot" to give them the power for autonomous action- etc.). It also appears interesting to me to explore whether there is any asymmetry in the transformation of objects that might imply the existence of prototypical objects or parts of objects. Such asymmetry could present a greater difficulty for children to transform an object B into A, in relation to the transformation of A into B.

4.2 Exploratory study: Transformations within ontological categories

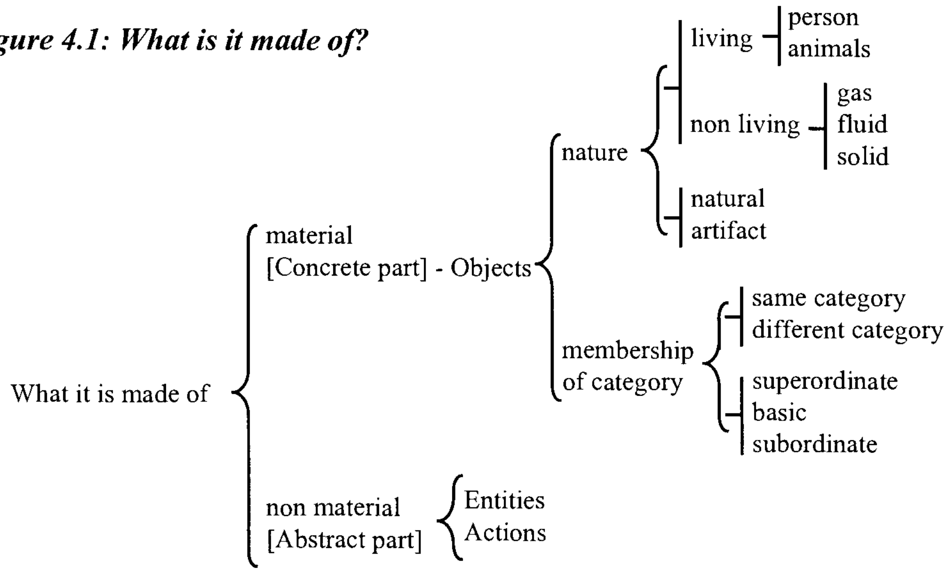
4.2.1 Methods

4.2.1.1 Design of the tasks and Aims

The tasks of the exploratory study are designed to examine the way that children make transformations, using a method related to Piaget's idea about how the development of meaning of physical entities occurs, through understanding of what can be done to them, what they can do and what parts they are made of.

For the design of the tasks the part "What is it made of" was considered (see Fig. 4.1), since the part of "what can be done to them" was expected to arise from the analysis of the results. The aim was to sample objects of very different categories.

Figure 4.1: What is it made of?



The final categories of this network were used in the selection of the objects for the tasks. Keeping stable the variation of category membership - same category and subordinate level - objects were chosen from the "possible" categories (Artifact-Natural, Living-non living, solid-fluid, person-animal) as shown in Table 4.1.

Table 4.1: Choosing objects from the "possible" categories

TASKS	ONTOLOGICAL	CATEG.
Bus -> Aeroplane (A)	non living - solid	Artifact
Duck -> Eagle (B)	living - animal	Natural
Girl -> Woman (C)	living - person	Natural
Orangina-> Lemonade (D)	non living - fluid	Artifact

The tasks explore whether there is any difference in the transformations when we have different categories of "material" things. The major dimensions were living versus non living, and artifact versus natural kind.

It was expected that transformation will involve groups of changes such as appearance (external change), internal characteristics, entities in science, actions etc. Furthermore, if there is a pattern in the order of appearance of specific transformations, this could be an indication of the existence of prototypical empirical schemes. It was expected that children in their transformations would give priority to features which they think of as important for the basic-prototype empirical schemes.

So, the aims of the exploratory study were mainly to find out how children transform an object into another which belongs to the same ontological category and the identification of the empirical schemes that children use in their transformations. It also tested the methods that were to be used in the main study.

4.2.1.2 Participants

The participants were 10 children with an average age of 11 years and 5 months old, who volunteered to participate in the study. The study contained 4 tasks, which were divided into two groups. Each child did 2 tasks on one day and 2 tasks on the next day. Each interview took approximately 10 minutes.

4.2.1.3 Materials and Procedure

The materials used were four pairs of black and white photographs: a. Bus-Aeroplane, b. Duck-Eagle, c. Girl-Woman, d. Orangina-Lemonade. The pictures used are presented in Appendix 4.1.

The children were asked to describe what they could see in one pair of photographs. Then they were asked, using their imagination, to try to transform one object (e.g. bus) into the other (e.g. aeroplane). I drew each of their changes and asked if they had anything else to change. Finally, I asked them "is that an aeroplane now or there is still something wrong with it? Why?

4.2.2 Results

Almost all of the children said that the object had been successfully transformed into the other in all tasks. However, two of them in the case of the transformation of a bus into an aeroplane and one in the case of the transformation of a duck into an eagle said initially that it was not yet an aeroplane or an eagle respectively. So, they were asked why and they described to me some more changes (e.g. put an engine at the back, make the windows smaller). After these further changes, the children said that the objects had been successfully transformed.

In their transformations the children kept some things constant such as the windows (transforming the bus into the aeroplane), the shape (transforming the duck into the eagle), the identity-humans (transforming the girl into woman) and the bottle (transforming the lemonade into orangina). It was an unexpected result that the children kept things constant since in most of the cases there were differences in the things that the children kept constant between the two objects. For instance, the windows of the bus were not exactly the same as the windows of the aeroplane, but it seems that in these cases the children had a general scheme that fits well to both instances However, the children mainly changed things.

The children changed both material and non-material things. Material things which were transformed were internally visible, such as adding insulating material to transform the bus into an aeroplane, or externally visible things such as removing the old wheels from the bus. The non-material changes were about:

a. Physical abilities. The bus needs "high speed" to be an aeroplane, or similarly the duck has to "go faster" to be an eagle. Also, we have to "change the age of the girl", and "she has to grow up" to be a woman

b. Quality. The bus needs "more resistant windows", and we have to "change the taste of lemonade" to be an orangina.

c. Emotions. The duck needs the "eagle's glance", and "more aggressive wings"

d. Cognition. The girl needs "more knowledge" to be a woman

e. Social such as independence (the girl needs to "change the way of life" or "find a job by herself") or qualifications (the girl needs "more experience" or "finish school")

The changes are related with the existence of some parts or with the modification of some parts into new forms. Considering existence, the children preferred to add rather than remove things. They added things such as:

- wings, tail, lights, antenna, appropriate seats, cock-pit, engines, windows, a big window at the front, transforming the bus into aeroplane
- beak or a "sharp nose", wings at the leg, transforming the duck into eagle
- lemon juice, lemon, sugar, carbonate, transforming the lemonade into orangina

There are very few cases where the children removed things, such as removing the wheels of the bus, or removing the lemonade from the bottle. Also, in the transformation of the girl into woman, the children did not add or remove things. Instead they proceeded by modifying the form of things. This particular transformation happens in reality, and it seems that the children knowing this, just modified the existing parts of the girl.

In many cases the children modified a part of an object or relations. They modified the size of parts: the bus needs "smaller windows" and have to be "lower", the duck needs "bigger wings", and in the case of the lemonade the lemon has to be modified into orange, the label and other components of lemonade has to be changed. Also, the children modified the shape of some parts. The bus has to be made "aerodynamic in front" and in the back , the duck needs a sharp nose or beak and to modify its legs, tail, body and eyes into the eagle's parts, and the girl has to modify her clothes into the woman's clothes. Furthermore they modified relations of:

a. position-spatial. The bus needs the engine at the back, and the girl has to change her position in the picture.

b. proportional. The bus needs smaller windows, the duck needs bigger wings and tail, the girl has to be taller and have bigger mass, and the lemonade needs more sugar.

In the various tasks, the emphasis was on the transformation of different groups of elements. In both transformation tasks between artifacts, the "bus-aeroplane" and the Orangina-Lemonade, the emphasis was first on "add new parts" and then on the modification of external or internal parts. However, they made the transformations between living things, the duck into an eagle and the girl into woman, mainly by modifying already existing parts. Furthermore, in the "duck-eagle" task the emphasis was on the modification of the parts considering their "shape", and on some "non material" characteristics, which in the "girl-woman" task, emphasised socio-psycho, non-material transformations.

The elements (mainly the material parts) that result from the transformations were common to most of the children. Also, it seems that there was an indication of a specific order in their appearance. Evidence of the order might be the following:

- Eight of the children put "wings" at the first stages of their transformations of a bus into an aeroplane, while "windows" appeared at the last stages.
- Four children asked to make the “nose” of the duck sharper and three to modify the wings of the duck to be bigger as their first choice
- Five of the children suggested that the girl has to grow up and to be taller as their first choice
- Five children asked to add lemon juice, and two asked to keep the same bottle as their first choice.

4.2.3 A summary of the exploratory study

The children easily made the transformations between objects which belonged to the same ontological categories. This fact generated the question for the next step in the main study, where the aim was to explore transformations *across* ontological categories.

The children changed material (external or internal) or non material things (physical abilities, quality, emotions, cognition and social changes) and they made changes related to the existence of some parts or with the modification of some parts into new forms. They used different sorts of changes to transform objects which belong in different ontological categories. So, they preferred to "add" things when they transformed an artifact into another while they mainly used "modifications" when they transformed a living thing into another. Also, the children preferred to "add" things rather than "remove" them.

The children kept some things constant when transforming an object into another. It is possible that they would have kept more things constant if they had known that they were allowed to do so, since at the beginning they were asked to transform an object into another and the word transformation is related mainly with changes. As a result, in the main study, the term 'transformation' was clarrified by asking them about what changes they wanted to make and what they wanted to keep the same.

Furthermore, the patterns in the order of transformations may indicate the existence of prototype empirical schemes.

4.3 Main study: Transformations across ontological categories

4.3.1 Methods

4.3.1.1 Design of the tasks and Aims

In the main study, the "power" of children's concrete empirical schemes was tested. Empirical schemes by their nature are common abstractions which are cross-categorical. Does their existence make possible cross-ontological category transformations? Is there evidence about any asymmetric character of prototypes?

It must be made clear that these tasks were very different from Keil's studies (see discussion in Chapter 3), considering the methodology and the questions he tried to answer. In his studies, children were judging the result of a transformation process that he had already given to them and it is possible that the changes he suggested to children were not enough for them to accept that the object had transformed into another changing its identity. Also, this study is not concerned with how strong the boundaries are between different ontological categories (as Keil is), but is interested mainly in the way that children can reason about what a thing can do, transforming one thing into another using empirical schemes.

In this main study, four transformation tasks were used. In these tasks the objects did not belong to the same category - as in the exploratory study - one of them being a natural kind (e.g. an eagle), while the other being artificial (e.g. an aeroplane). In some pairs, the parts that constituted the two objects were made of different materials but they could do similar things; they had common functional schemes (e.g. fly). In contrast some other pairs did not have common functional schemes. Another question which was introduced in this task investigated what children kept constant through their transformations.

The aims of these tasks were to identify variations and changes in children's use of concrete empirical schemes and the way that they produce, manipulate and modify these concrete empirical schemes. Also, the transformation tasks aim to identify "packages of elements"- that children use in their transformations, which may indicate the use of prototypical empirical schemes. Also, it seems interesting to look at the order of appearance of changes in the process of transformation. This order can provide an indication of the existence of prototypical empirical schemes.

Furthermore, it appeared interesting to me to explore questions such as, given two things A and B, whether children make different transformations when they transform A->B and B->A. If we find that children prefer to use different changes for the different directions, this might be further evidence for an asymmetry between two examples and for the existence of prototypes.

In summary, the aims of this task were:

(a) Can children make cross-ontological category transformations? Does the existence of common functional schemes help these transformations?

(b) The identification of "packages of elements" that children use in their transformations, and more particularly the order of appearance in the process of transformation.

(c) What kind of things did they keep constant in their transformations? What kind of things are the same for members of different categories?

(d) Is it easier for someone to transform an object A into an object B rather than the other way round?

4.3.1.2 Participants

Thirty eight Greek children, mean age 11 years 8 months, participated in each of the four tasks (each child did one task). All the children attended the last class of public primary schools. Most of the children came from a predominantly middle class background.

4.3.1.3 Materials and Procedure

The materials used were four sets of two black and white photographs (see Appendix 4.2). They consist of objects which belong to different ontological categories, two pairs consisting of objects with common functional empirical schemes and two lacking common functional empirical schemes (see Table 4.2).

Each child was tested individually in a room familiar to them (another classroom). The particular task took 4 to 5 minutes maximum. All the children were initially questioned to ensure that they understood the pictures. They were presented with the two pictures (one beside the other) and were asked to describe what they could see in those pictures. Then they were asked using their imagination to transform an object (x) into another one (y). I drew each of their changes and asked if they had anything else to change. Finally I asked them "is that a y now or there is still something wrong with it? Why?

Table 4.2: Choosing objects from different ontological categories

Different Ontological Categories	
Common Functional Empirical schemes	***Not Common Functional Empirical schemes***
Eagle - Aeroplane Human - Robot	Bird - Toy Car Human - Rocket

In each task, there were two groups of children assigned to two different conditions. Children who belonged in the first group (Case A) were asked to transform the natural kind stimulus into the artifact (e.g. an eagle into an aeroplane), while those who belonged to the second group (Case B) were asked to make the opposite transformation (e.g. an aeroplane into an eagle).

4.3.2 Results

One child made the following changes to transform an eagle into an aeroplane:

Inter: What you can see in those pictures?

Child: I can see an eagle.

Inter: Yes.

Child: And an aeroplane.

Inter: Well, now I would like you, using your imagination to change the eagle into an aeroplane. Could you tell me what we are going to change and what we will keep the same?

Child: Yes, we are going to keep the wings.

Inter: Yes.

Child: We will put machines, turbines.

Inter: Yes.

Child: We will put the back tail.

Inter: Yes.

Child:....

Inter: What ?

Child: I simply believe that we would leave it and we would put a wing standing up.

Inter: Well.

Child: In front, instead of an eye, we would put a glass.

Inter: Yes.

Child: We would put wheels instead of legs.

Inter: Well.

Child: And we would put a pilot in order to fly.

Inter: Yes.

Child: And fuel.

Inter: Well, anything else ?

Child:.....we would put small windows.

Inter: Yes

Child: We would fix the wings to be more straight.

Inter: Right.

Child: And we would take the beak out, and we would put the "nose" of the aeroplane.

Inter: Well, anything else ?

Child: We would put a steering-wheel in order to turn.

Inter: Yes, anything else ?

Child:.... We will keep the back wing.

Inter: Yes, anything else ?

Child: And the shape, we will keep same the shape of his body.

Inter: Well, something else ?

Child: We will put wheels.

Inter: Yes.

Child: Machines.

Inter: Yes.

Child: Let's put a special container in order to put in the fuels.

Inter: Yes.

Child: Instead of eye we will put a glass.

Inter: Yes.

Child: We would take out the beak (we have already said that) and we would put turbines.

Inter: Yes, is it now an aeroplane ?

Child: We would take out his mouth and, and we would make a more aerodynamic shape.

Inter: Yes.

Child:..... We would make better the shape.

Inter: Yes, we would make it, anything else

Child:....

Inter: Is there anything else that you would like to change or to keep the same?

Child:.....No.

Inter: Ok. Is it now an aeroplane ?

Child: Yes,... I believe that it is an aeroplane.

Inter: Thank you very much.

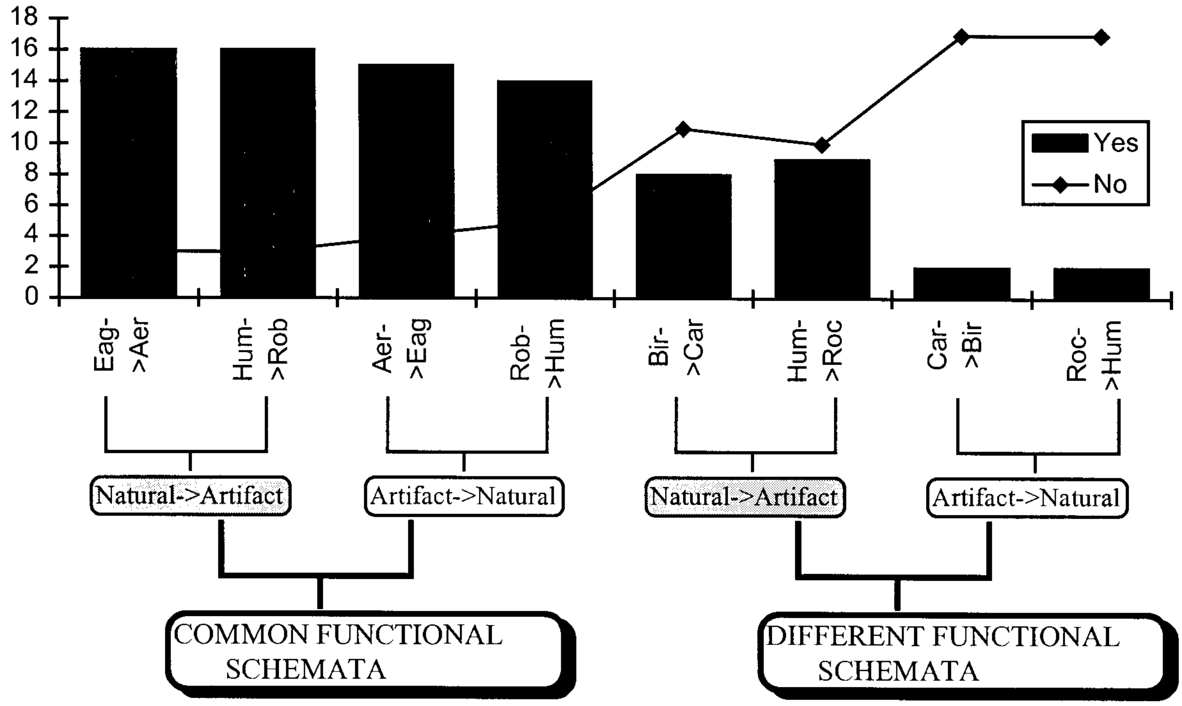
The child made many changes in order to transform the eagle into the aeroplane. He kept some things the same such as the wings and the shape of the body. Looking at the wings and the shape of the objects as they appeared in the pictures, there are many differences between the two objects considering their shape and their size. However, what the child kept constant was not the image of wings or of the shape but the empirical schemes 'wings' and 'aerodynamic shape'. The instances of the empirical schemes 'wings' and 'aerodynamic shape' may vary comparing different types of aeroplanes, or comparing an aeroplane with an eagle, or may vary even more comparing other objects. But the wings as horizontal surfaces on the two sides and the aerodynamic shape of both objects serve a common function, making both objects able to move fast and fly. So, the child kept constant 'common functional empirical schemes' independently from the differences in their appearance in the various instances.

Also, he added parts of the aeroplane and removed parts of the eagle. He recognized the lack of 'autonomous action' of the aeroplane and he added 'a pilot in order to fly'. Also, he added machines to give power to the aeroplane and a back tail to define its direction. He made some modifications of parts such as 'instead of the eye we will put a glass' and removed things for which he could not find any corresponding part in the aeroplane, such as the eagle's beak. At the end the child accepted that the identity of the eagle had been changed.

4.3.2.1 Successful Transformations

The number of children who said after their suggested changes that the object A had changed its identity and was now an object B are shown in Figure 4.2, as 'successful' transformations.

Figure 4.2: Did children regard their transformations as successful?



Looking at the pairs which lack common empirical schemes, we see that it is easier for the children to move from natural kinds to artifacts than the reverse, and that many children did not accept as successful the transformations of an object into another which belong to a different ontological category. This implies that these ontological categories exist. So, the present findings add to Keil's (1989) findings that when children are presented with transformations they resist ones which alter ontological categories.

However, common functional empirical schemes (e.g. they can fly, move etc.) can make the transformation between objects from different ontological categories easier. So, there were more children who successfully transformed natural kinds to artifacts when both objects have common empirical schemes than when they do not (x^2=13.O4, df=3, p=0.005). Also children found more difficulties when they attempted to transform an artifact into a natural kind when there are no common empirical schemes than when there are (x^2=33.58, df=3, p=0.0000) (see Appendix 4.3).

The present findings show that most children (12 years-old) using their concrete empirical schemes can make "difficult" transformations across ontological categories (i.e., natural kind into artifact). In these transformation tasks children used their concrete empirical schemes in a specific context, and gave emphasis to functional similarities between the two things and their parts that were used as stimuli, though it must be conceded that the design of the task led them in this direction.

4.3.2.2What sort of transformations did the children use?

Table 4.3 presents changes used by the children with frequency more than 25% (up to 5 children). Both the children who attempted to transform a natural kind into an artifact and those who attempted to make the opposite transformation of the artifact into the natural kind, used mainly the same or reverse (i.e add wings instead remove wings) sorts of transformations in different order and some different sorts of transformations.

Let's consider for example the transformation of an eagle into an aeroplane and vice versa. Most of the children kept the wings constant (15). Also, they added a propeller (12) in order to make movement possible. "Thus children know that animals are capable of self generated motion but artifacts typically are not" (Keil, 1989, p139). An aeroplane needs wings and propeller. Also, half of them modified the shape of the eagle's tail (9) putting a vertical wing on it. On the other hand, most of the children, when transforming the aeroplane into the eagle, modified the tail of the aeroplane (13) pulling out the vertical wing. Also, it seems that they worry about the state of the material. So, they modified the wings to be non-rigid (10) giving the eagle the ability to fly, as well as transforming the material into a non-metal (10). They also modified the front part (10), mentioning especially the beak) and they kept the wings constant (9), removing the propeller.

Table 4.3: The most frequent transformations the children used

Eagle -> Aeroplane TRANSFORMATIONS	Number of children
Constant wings	15
Add propellers	12
Modify tail	9
Add windows	9
Add wheels	6
Add engines	7
Modify stable-wings	6
Add various things	6
Constant body	6
Add seats	5
Modify bigger	5
Modify front	5
Modify legs	5

Aeroplane -> Eagle TRANSFORMATIONS	Number of children
Modify tail	13
Modify non-stable wings	10
Modify front part	10
Modify non-metal	9
Constant wings	9
Remove propellers	8
Remove windows	7
Constant shape	6
Add legs	5
Modify smaller	5
Modify wheels	5
Remove engines	5
Constant front	4

Human -> Robot TRANSFORMATIONS	Number of children
Modify body	10
Modify hand	10
Modify foot	8
Modify head	8
Modify metal	6
Constant hand	6
Constant foot	5

Robot -> Human TRANSFORMATIONS	Number of children
Modify foot	12
Modify hand	11
Modify head	9
Constant foot	8
Constant hand	8
Constant movement	5
Modify body	5

Bird -> Toy Car TRANSFORMATIONS	Number of children
Modify wings	9
Modify legs	8
Add engine	5
Remove legs	5
Remove wings	5

Toy Car -> Bird TRANSFORMATIONS	Number of children
Add wings	11
Add beak	11
Add legs	9
Modify wheels	8

Human -> Rocket TRANSFORMATIONS	Number of children
Modify foot	12
Modify hands	12
Modify head	11
Add turbine	7
Add wings	6
Modify body	6
Add front part	5

Rocket -> Human TRANSFORMATIONS	Number of children
Add hand	11
Modify turbine	10
Add foot	9
Add head	8
Modify front part	8
Modify body	5

The transformations the children made can be grouped into kinds which are similar in nature. They mainly used four different sorts of transformations: "Keeping constant", "add", "modify" and "remove". In Table 4.4 and Figure 4.3, the total numbers (actual numbers and percentages respectively) for each sort of transformation that the children made in each case is shown:

Table 4.3: The actual number of children who made each sort of transformation

	Constant	Add	Modify	Remove
A1. Eagle -> Aeroplane	30	63	41	12
A2. Aeroplane -> Eagle	22	21	62	34
B1. Human -> Robot	26	34	47	8
B2. Robot -> Human	28	16	57	19
C1. Bird -> Toy Car	4	18	34	27
C2. Toy Car -> Bird	2	42	37	10
D1. Human -> Rocket	1	27	49	11
D2. Rocket -> Human	3	50	34	9

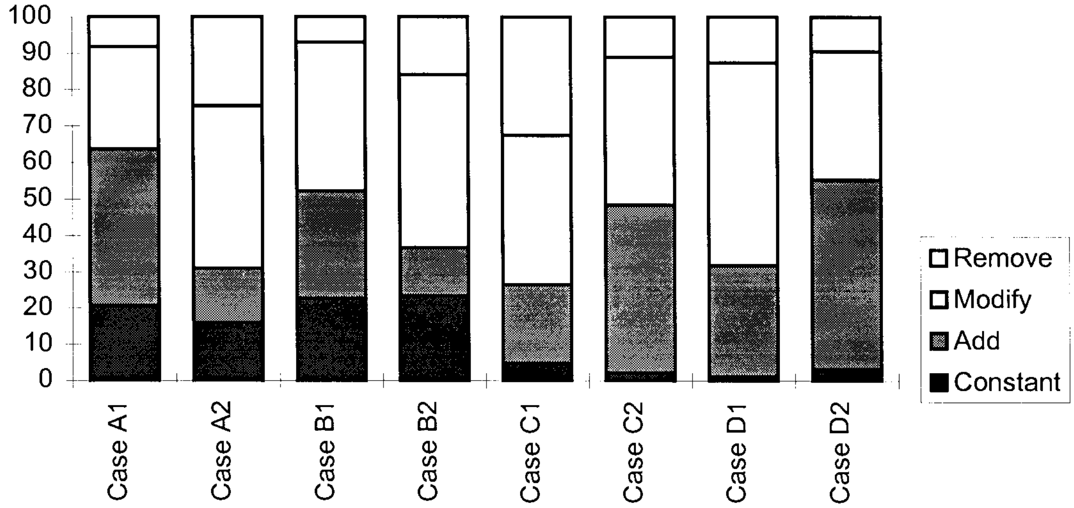


Figure 4.4: The percentages of children who made each sort of transformation

a. Keeping constant

In these tasks, the children used concrete empirical schemes to make a cross ontological shift. One important indication for the existence of these empirical schemes (considering mainly functional empirical schemes) is what children keep constant through their transformations. In the transformation of the pairs without common functional empirical schemes, only one or two children in each task kept constant things such as the shape of the body (oval) and the movement.

Children mainly kept constant in the transformations of objects which had common functional empirical schemes, and they kept constant things such as:

- wings, shape of the body, front part, tail, fly (transforming the eagle into aeroplane or vice versa),
- foot, hand, eye, face, shape of the body, head, movement (transforming the human into robot or vice versa),

In other words, they kept constant the following things:

a. actions (or functions), that is what both objects can do (fly, movement)

b. the parts (wings, foot) that are responsible for the particular (similar) sort of movement (fly, walk), that is which have the same function. Also other parts with the same function (eyes and hands in the case of the human and the robot)

c. features of the objects that are needed for or make easier their (similar) actions (shape of the body, aerodynamic for eagle and aeroplane and vertical orientation for human and robot)

d. parts of the objects which have similar positions (front part, tail)

In both pairs, the objects had many differences since they belonged to different ontological categories. For instance, the eagle and the aeroplane are very different at a surface perceptual level, mainly because of the material that they are made of and their size. However, their similar function (they fly) has as result that they consist of similar things which are appropriate for this function (e.g. wings, aerodynamic shape, a tail at the back etc.). So, it is notable that in many cases the children ignored the difference, and kept constant some things which had a common schematic representation like the wings. The relation is based on what they can do rather on what they are made of.

The ‘keep constant’ category was used by children in the two tasks with common functional empirical schemes at around 20%. In contrast in the two tasks with no common functional empirical schemes, the ‘keep constant’ category appeared with a frequency less than 5%.

In general, there were no big differences in what they kept constant between the cases where the children transformed a natural kind into an artifact and those where they transformed an artifact into a natural kind.

However, one notable difference is that 15 of the children who transformed an eagle into an aeroplane kept the wings constant whereas only 9 of the children kept the wings constant when they transformed an aeroplane into an eagle. This difference may have happened because an eagle's wings are more prototypical examples of the scheme 'wings' than are an aeroplane's wings. Also, there is a difference in what these two things need in order to be able to fly (their common function). What an eagle needs is just wings, while the aeroplane, although it has wings, needs also propellers in order to fly. So, what may have caused the difference in this category is the difference in movement. Also the children in their transformations preferred to keep something constant and add another part to it, than to keep something constant when it is necessary to remove something from it.

Furthermore a similar tendency - more children keeping constant some particular things when they transformed a natural kind to animals rather the other way - appeared in the other pair with the transformations between human and robot. More children asked to keep the hand, head, foot and movement constant when they transformed a human into a robot than in the other direction. These results suggest that children's prototypical empirical schemes are based on the natural kinds rather than on artifacts.

b. Add and Remove

The children "added" propellers, windows, wheels, engines, seats, steering-wheel, front part, wings at the back, cockpit, persons etc. and "removed" the beak, inside organs, life, tail, mind, eyes, to transform the eagle into the aeroplane. Furthermore the children who transformed the aeroplane into the eagle, "added" legs, eyes, beak, heart, mouth, organs and "removed" propellers, windows, engines, people, seats, wheels, cockpit, oil. The things of the two objects that more than 20% of children asked to be added or removed, were for the aeroplane the propellers, the windows, the engines, the seats, and the steering wheel, while for the eagle they were the legs and the eyes.

Very few children (less than 20% in all cases), used the categories "add" and "remove" to transform a human into robot and vice versa. They transformed a human into a robot by adding metal, battery, buttons and removing heart, hair, clothes. Also, the children transformed a robot into a human by adding hair, heart, mind, organs and removing wires, head, metal, light.

In the case of transformation of a human into a rocket, children "added" a turbine, wings, a front part, metal and "removed" the foot, the hand, the head, organs. They added the hand, the foot, the head, clothes, organs, mind, the nose, the body, the eyes, the face and removed the front part, to transform a rocket into a human.

The children transformed a bird into a car, by adding an engine, metal, wheels, seats, lights, windows, wires and removing wings, legs, the beak, eyes, the skin, the head, insides, the neck. They transformed a car into a bird by adding wings, the beak, legs, the head, organs, the heart and removing the battery.

In general, the categories "add" and "remove" were used by the children, for difficult transformations. In other words, the children added or removed something when they could not keep constant a thing or they could not change or modify it. Most of the children added or removed the following:

- a source of movement (e.g. propellers, engine, battery),
- things that are responsible for a particular sort of movement (wheels, wings, legs, foot, hand)
- the material that an object is made of (metal)
- things that make an object a living thing (heart, inside organs, mind)

Adding and removing was used by children for things which are not easily 'converted' between natural kinds and artifacts.

In the tasks with common functional empirical schemes, the children preferred to use the "add" category when they attempted to transform a natural kind into an artifact rather than to use the "remove" category, while the category "remove" was more popular when they transformed an artifact into a natural kind (see Table 7). So, 13 children added propellers when they transformed the eagle into the aeroplane, while only 8 of them removed the propellers when they attempted to transform the aeroplane into eagle (see also similar differences for windows 9-7, engines 7-5, seats 5-4).

This unexpected result could be interpreted in two ways:

a. The artifacts (aeroplane, robot) by their nature have a greater variety of more salient parts

b. Children distinguish more easily the parts of an artifact than those of a natural kind.

The second explanation seems to be more plausible, because for the first there is no substantial evidence. The second explanation can arise because:

A. In natural kinds the groups of elements are designed and determined by nature. So the existence of these specific packages is obvious. In contrast people have to select and put elements together for a specific artifact. So, a child might mention that an aeroplane has windows and wings (this strange combination happens only in aeroplanes) while he might not mention that an eagle has wings and legs, because the latter is obvious (all birds have the same).

B. Children probably learn and know more about the parts of artifacts than about the parts of animals. An analogous explanation is given by Simons and Keil (1995) about the knowledge of young children about the insides of machines and animals. In one of their tasks children were shown computer-drawn animals and machines with a combination of "animal insides" and "machine insides". They found that many of the children responded correctly to the machine photographs but not to the animal ones. A reason for this difference could be that children probably "learn about the insides of machines before they learn about the insides of animals; they are likely to have more experience with the insides of toys and machines than they do with the insides of animals"(Simons & Keil, 1995, p153)

It is notable that the above pattern for the pairs with common functional empirical schemes did not appear in the pairs without common empirical schemes. In these cases the objects did not have also a surface similarity and it is possible that the specific natural kinds consisted of more parts than the artifacts. So, more children used the "add" category when they transformed an artifact into a natural kind than in reverse, and more children used the "remove" category when they transformed a natural kind into an artifact.

c. Modify category

Children modified the back (tail), the rigidity of wings (rigid or non rigid), the size (bigger or smaller), the front part, the legs or wheels, the body, the eyes, the material it is made of (metal or non metal), the existence of life, and the engines, to transform the eagle into the aeroplane and vice versa.

It is notable that only 2 children transforming the eagle into an aeroplane modified the non-metal state of the eagle into a metal while in the reverse transformation 10 children modified the metal state of the aeroplane into a non metal state. In a similar way 6 children asked to modify the non rigid wings into rigid ones when transforming the eagle into the aeroplane, while 10 children asked to modify the rigid wings of the aeroplane into non rigid ones in the reverse transformation. It seems that it was more difficult for children to make a "Frankenstein's" transformation in which they had to make alive and flexible a metal thing (most of them mentioned that particular transformation), rather than the other way round (to modify a living thing into a non living).

Also, they modified the foot, the hand, the head, the body, the metal, the face, the belly, the colour, the eye, the mouth, the shape, the size, the buttons etc., to transform a human into a robot and vice versa.

In the transformations of objects with common functional empirical schemes, the "modify" category was more popular when the children transformed an artifact into a natural kind than the reverse. It might be argued (see also add and remove categories) that the aeroplane/robot consists of a greater number of parts than an eagle/human. But this reason cannot explain the greater number of modifications that children used in their transformations. That is, this asymmetry can be a result of an asymmetry or in other words prototypicality in children's mental representations-empirical schemes rather than of an asymmetry in the natural world. It seems to me that the children had a clearer distinction between the parts that constitute the aeroplane or robot rather than the parts of the Eagle or the human (see also previous comments about the add and remove category).

The children modified the following things to transform a human into a rocket and vice versa:

a. the parts considering their position
  - the upper part (the head and the front part of the rocket), and some specific parts of them (face and eyes of the human)
  - the middle part of the body
  - the edges of the body in a horizontal axis (hands and wings)
  - the bottom part which is responsible for the particular sort of movement (foot and turbines),

b. the shape and the size

c. the source of movement (organs and fuels)

d. the material that they are made of (metal and non metal)

Also, they modified the following things to transform a bird into a toy car and the reverse:

a. the parts considering their position
  - the bottom part (legs and wheels)
  - the front part (beak or head and front part of the car) and some specific parts of it (lights into eyes)
  - the middle body
  - the edges in a horizontal axis (wings into doors or windows and vice versa)
  - the part at the back (the tail and the back part of the car)

b. the shape and the size

c. the source of the movement (organs and engine)

d. the ontological kind of thing (not living into living)

e. the position (from the air down to the earth)

In the above transformations of objects without common functional empirical schemes there is a similarity. In both the children modified mainly parts considering their position while in the transformations between objects with common functional empirical schemes they modified mainly what parts can do (rigid or non rigid wings) and the material that the objects are made of. It seems that they have used mainly empirical schemes relevant to position-space (up, bottom, front, back parts) rather than those relevant to functions. Also, in contrast with the transformations between objects with common functional empirical schemes, in these cases more children used modifications when they transformed an artifact into a natural kind rather than the reverse.

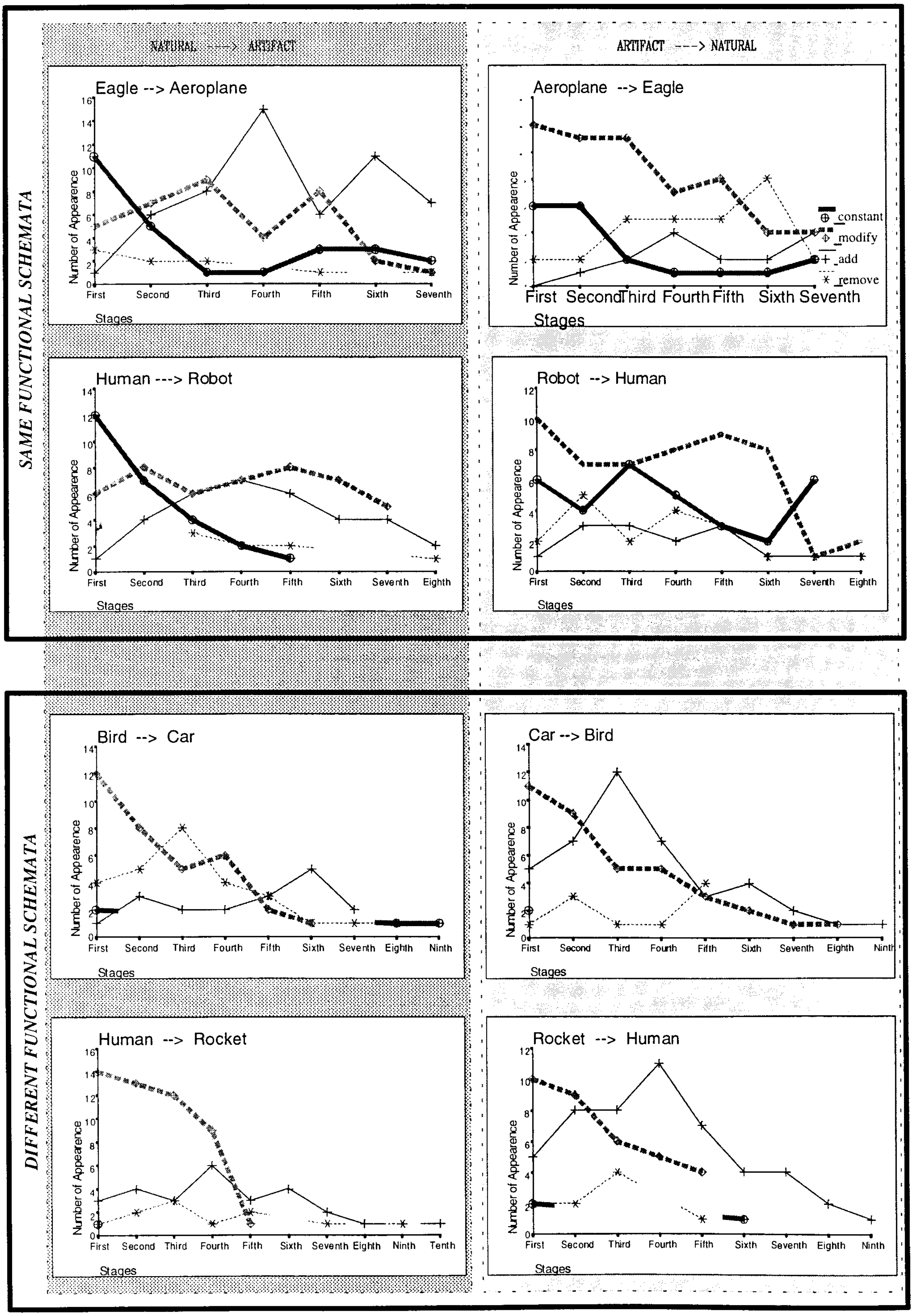
4.3.2.3 Sequence of change

Figure 4.4 shows the number of children that used each of the four sorts of transformation in each stage. In the case of objects without common empirical schemes, there is no pattern in the order of the transformations. However, the existence of patterns in the order of sorts of transformation for pairs who have common empirical schemes, is clear.

Thus, the children transformed the eagle into an aeroplane firstly by keeping constant things such as the wings, the shape of the body or the front part. In stage 2 the modify category is the most popular, when they then modify the state of the eagle, making the wings rigid, the size bigger etc. After the third stage the numbers of "modify" and particularly of "add" transformations increased, since the children stopped keeping things constant and started to add external characteristics such as propeller, wheels, windows and internal parts such as engines, seats. It is notable that the number of children who used the category "remove" was very low at all stages.

A different pattern of the order of sorts of transformations appeared when the children attempted the reverse transformation of the aeroplane into the eagle. In this case the category modify was the most popular category at least for the first five stages. In the first stage the category 'constant' appeared as the second choice. After the second stage we observe a tendency of "remove" and "add" categories to increase their numbers. In general the category "remove" is more popular than the category "add".

Figure 4.4: Sequence of change in children's transformations



Patterns very similar to the above appeared in the transformation of a human into a robot and vice versa. In summary the pattern of order of sorts of transformations was as follows:

a. transformation of a natural kind into an artifact. Firstly the children kept something constant. Secondly they started to modify things continuing to keep some things constant. Then for the next steps they modified things and added some other things.

b. transformation of an artifact into a natural kind. The children mainly modified things at all stages. In the beginning also they preferred to keep things constant. Also, after the second stage they started to remove things.

4.4 Overview of the first study

Children can make succesful transformations within and across ontological categories. Their response, should not however be interpreted as showing that children do not understand important (ontological) differences between animals and artifacts. Ontological categories exist but their boundaries may become weaker through the use of empirical schemes acting across them.

The children used four sorts of transformations: “keeping constant”, “add”, “remove” and “modify”. In the transformations of objects which have common functional empirical schemes, they kept constant empirical schemes of actions (or functions), the parts of the object which are responsible for a particular function, some features which make this function easier, and some parts which have a similar position. Also, the children used the add and remove categories for difficult transformations in the case of the transformation of an animal into an artifact and vice versa. Difficult transformations were those of empirical schemes of a source of movement, of things that are responsible for the particular movement, the material that an object is made of, and things that make an object a living thing. Futhermore, in the transformations between objects with common functional empirical schemes, the children modified empirical schemes of what parts can do and of the material that objects are made of. However, in the transformations between objects without common functional empirical schemes the children modified mainly parts considering their position in the space rather than those relevant to functions.

In some pairs of objects, it appeared easier for the children to transform A->B rather than B->A. This may happen because the schemes are more prototypical in object A, and the children kept these prototypical shemes constant while in the opposite transformation they had to change some schemes into their prototypical ones (see in the previous section the discussion about 'wings'). Asymmetries between the transformations of an animal into an artifact and of an artifact into an animal, in the sort of transformations and the sequence of changes are indications for the existence of prototypical examples of objects, their parts or actions.

In general, empirical schemes are 'bridges' which make possible transformations even between categories that have strong boundaries between them. This study is exploratory in nature, but it suggests that empirical schemes in their more powerful versions can be seen as "Functional bridges" between categories. That is, when a child thinks about two objects which belong to different ontological categories it is possible that he will resist making a transformation of one object to another if his focus is on "what are they?" or "what are they made of?". However, it is easier to do the transformation if the focus is on the function of the objects and their parts. So, functional empirical schemes appear in this case as "bridges" which make possible the "connections" between the two objects through a transformation process. The results of this study suggest that learning in science - which involve difficult conceptual transitions - can be based on the imaginative transformation of concrete examples of the concepts that belong to different ontological categories. These transformations will be easier for children if the focus is on common functions of examples.

Chapter 5:
EXPLORING ANALOGIES USING SCHEMES

5.1 Introduction

This chapter reports on studies related to children's analogical reasoning. In a preliminary exploratory study, children manipulated an analogy that had been used in their (previous year) science textbooks, its purpose being to help in the understanding of the role that the switch plays in the function of simple electric circuits (open and closed). In the main study, a larger number of children looking at the same pictures of an open/closed electric circuit generated analogies (focusing again on the role of the switch).

In both studies children were asked to transform an event into an analogical one, and a simple electric circuit was used as a target domain of an analogy. The selection of the particular domain was not random. The difficulty with its introduction in the early stages of the science curriculum (last two years of the primary school in Greece) make teachers frequently use analogies as a helpful tool in the teaching of this domain.

5.2 Exploratory study: Transforming analogical events

5.2.1 Aims

The aims of the exploratory study were to explore:

(a) the components of an event that children transform, to match this event with an analogical one

(b) the schemes that children keep constant, when transforming an event-example into an analogical one

(c) the level of these transformations (do children transform whole objects, whole events or parts of them?)

5.2.2 Methods

5.2.2.1 Participants - Procedure

The subjects were 10 children with a mean age of 11 years and 5 months old. Children were asked to describe and compare a pair of analogical picture examples and then using their imagination to choose and transform one into the other.

5.2.2.2 Materials

Two pairs of black and white drawings were used. On the left side of the first, a bridge was open while on the right side it was closed. In an analogous way, on the left side of the second picture, a switch in a simple electric circuit was open while on the right side it was closed. The pictures used are presented in Appendix 5.1.

5.2.3 Results

5.2.3.1 Common schemes

Children's descriptions of both events (the pictures of the electric circuit and of the bridge) comprise three elements: (a) objects such as switch, battery, lamp, wires, bridge, cars, river, road, ship etc., (b) processes such as open/close, can/cannot pass, turn on/off, movement/stop movement, go up/down etc., and (c) relations between objects such as one object being next to another, being bigger than another, etc. Also in the case of the electric circuit, another kind of element can be identified, namely scientific entities (concepts) such as the flow, the electricity, the light.

Almost all the children comparing the two pictures, easily recognised that the picture with the bridge had some "common things" with the picture with the switch:

> *"...when the bridge is open and the switch is open, we have neither circulation of the cars nor of the flow. Meanwhile, in the other picture we see that the bridge is closed and so the cars can go and pass it, and in the electric circuit the flow can circulate and so the lamp turns on."*

They tended to keep constant in their transformations the way that the switch and the bridge open and close the circuit, describing it as an action:

> *"We will keep the same that in both of them, the same action happens but in the one it happens through the flow and in the other through the cars"*
> and "We will keep that the switch opens and closes as the bridge does"

Five of the children kept constant the action 'open and close' or 'go up and down' while one child kept constant the energy that the battery and the river (which the child thought analogous to the battery) both have. The battery has power - essential to its nature. So, the child looked for something in the other picture which 'has power'. A possible choice for such an object is the river. But the river does not make the car move. However, there isn't any one thing corresponding to the battery which makes the cars move. Thus, the child chose the river as analogue to the battery.

In general, the children made transformations keeping constant some of the processes, and changing mainly the objects and in very few cases the scientific entities. The relations between objects were used very implicitly, not mentioned explicitly. Processes are connected closely with actions, and their meaning derives from actions. They are embodied patterns - empirical schemes - which are used for organizing our actions, perceptions and conceptions. Processes contain structural features that are common to many different objects, entities. So, although a human, a lion, a car and an electron move in a different way, we describe their change of position in space with the common scheme of movement. Such common features of empirical schemes lead children to keep constant some processes.

5.2.3.2 Finding the one to one correspondence of the objects

Four children chose to transform the picture with the bridge into the picture with the switch and six of them to make the opposite transformation. Almost all of them (nine) transformed the switch into the bridge (or the opposite), since both are responsible for stopping the circulation of the flow or the cars and their function is very similar. One child transformed the switch into the ship because this was identified as the responsible factor for stopping the circulation of the cars, since "when the ship, when it passes, the bridge is raised and the cars cannot pass, and if the switch is not down, this (the lamp) does not light". So, the child identified a correspondence between the action of a person on the switch and the effect of the ship on the bridge.

Apart from this popular transformation (between switch and bridge) the children gave a variety of further transformations. The lamp was transformed into a car and the opposite (four children) both being seen as the location of an effect. This transformation was based on the fact that both objects 'function' under the same condition. When the circuit is closed, they do something (cars move or the lamp lights). Another child following a similar line of thought transformed the lamp into the ship, seeing the ship as an object which moves, again the location of an effect. Three children more abstractly transformed the light (or the flow) into the movement of the car or vice versa, seeing the analogy as between not the objects but the processes.

Also there were transformations between wires and road (three children) since both are used as 'paths' and the movement of the current or of the cars takes place in/on them. However, one child transformed the wire into a car and another one the road into the battery.

It was hard for the children to find an object to correspond to the battery of the electric circuit. Only a few of the children (four) used it in their transformations. Two of them made transformations between the battery and the river (or the water), seeing the battery as an object which can make other things move. One of them transformed the battery into the ship and one the lights (next to bridge) into the battery. Both objects of these pairs can make other things move, they are a 'source of movement'.

It seems that the children identified a similarity between the two analogical examples having their focus on similar actions (open-close or go up/down), the elements that have similar functions (e.g. switch-bridge) and which can be described by common schemes (barriers, links, paths, source of movement), rather than on the surface similarity of the parts and the relations between them. So, the transformations are based on the similarity of schemes describing actions and functions rather than on the surface similarity between the objects. As with the transformations between objects, functional schemes played an important role in the transformations between events.

5.2.3.3 Transforming objects not parts of them

In this task the children were asked to transform events rather than objects into one another (see chapter 4 about the transformations of objects). In contrast with the way that the children transformed objects, when they attempted to transform events they usually made direct transformations from an object into another without middle stages. So, the switch was transformed directly to a bridge without any intermediate change (make it two parts, make it bigger, make it from cement etc.).

Transformations seem to be possible at different levels. In each case, the level is defined by the focus and the goals of the person who makes the transformation. So, when the children attempted to make transformations of objects, they made many transformations of the parts of an object and their relations. In transforming events they used whole objects as units. It seems to me that they were more interested in finding an analogous object which had a similar function, than to construct an analogous object with similar parts.

5.2.4 A summary of the exploratory study

It is clear that when the children attempted to make transformations between analogical examples their focus was on actions (using ‘functional schemes’) and schemes that describe them rather than on parts and relations. Most of the children made their transformations in these "perfect analogical" examples (they are found in the school text books) giving a great variety of transformation-matching. They did not worry about the transformation of all parts and relations but their focus was on keeping similar actions or functions and common schemes stable.

However, in the exploratory study, the use of a 'perfect analogy' may lead children to these responses. That is, the two analogical events had been selected by the author (of the science textbook) in a way that the focus of the analogy was on common actions and schemes and not on surface similarities. So, the main study was designed to explore the way that children produce by themselves spontaneous analogies, which can be "partial analogies".

5.3 Main Study: Children generate their own analogies

5.3.1 Aims

The aims of the task were:

(a) to explore the way that children produce spontaneous analogical examples

(b) to identify what common schemes are used in analogies, and how

(c) to explore the importance of actions and processes (rather than of parts and relations) in analogical projection,

(d) to identify groups of schemes that come together in the construction of an analogy

(e) to analyse the schemes that take part in an example, considering the interaction that exists between one scheme and other schemes of the group

(f) to put these groups of schemes in a dimensional space.

5.3.2 Methods

5.3.2.1 Participants

Forty two children of mean age 11 years, 7 months, (range 11;3 to 11;8) participated in this study. All the children attended the last class of public primary schools in Greece. In general, the children came from a predominantly lower middle class background.

5.3.2.2 Materials

The materials used for this task were two pictures. The pictures were black and white line drawings. The first picture presented an open simple electric circuit consisting of the following elements: a battery, a lamp, a switch (open), a wire. The other picture involved the same elements but the switch was closed and the lamp alight (see Appendix 5.2).

5.3.2.3 Procedure

The children were tested individually in a room familiar to them (another classroom). The task took 4 to 5 minutes. All the children were initially questioned to ensure that they understood the pictures. I presented them with the two pictures (one beside the other) and asked them to describe to me what they could see in these pictures.

After this description, I asked the children to imagine that they were teachers of the year six classroom and that their pupils could not understand what all these things were. I suggested that in order to help them understand the teacher (child) might say: "it is like....." Then I asked them what they were going to say? All the children were required to justify their suggestions, to explain the correspondence of the elements of their analogical example with the elements of the source example (electric circuit).

5.3.3 Results

Only three out of the forty two children did not give me any example. For the purpose of the analysis, the sample was divided into two groups. Twenty examples constituted the group named "literal similarity". It includes the examples that are very close to the example with the simple electric circuit. For example:

> *Pupil: It is like the light in our house*
> *Inter.: Yes*
> *Pupil: I would tell them, that when we press the button, the light turns on,*
> *while it is closed when we press the button again."*

The children in this group mainly kept constant in their target domain many elements from the source domain, changing only a few elements. This 'conservative' strategy lead them to the production of an analogy very close to the source example.

The remaining nineteen examples, constitute the second group named "analogies". It includes examples that are very different from the electric circuit, at least at the level of surface similarities. Consider for example the following analogy (straws connecting basins), which appears to be pure invention on the part of this child:

> *Pupil: It is like when we have a wash-basin with water*

Int. : Yes
Pupil: And ... we want to empty this into another wash basin that has also a drinking straw
Int.: Yes
Pupil: And the straws are not connected, so the water will not manage to pass
Int.: Right
Pupil: While if we connect the straws, the water will pass.

In this case, the child constructing his analogy using straws instead of a wire as a path where the water (which plays a similar role with the flow in the case of the electric circuit) will be able to move. As a source container the child used a full wash-basin instead of a battery. The focus of this child is on the straws (wire) and the water (flow).

In the second group of children, the target domains were very different from the source domain and that difference makes the analogy an 'interesting' one. That is, one has to think about the various objects, processes and relations that are described by that analogy while in the case of 'literal similarity' instances are mostly common to the source and target domain. In the case of the analogy, with the 'turning on of the light in the house' we have similar constituents such as the simple electric circuit which is used as a source domain. In this analogy, the child did not need to say anything about the 'flow' or the 'wires' since their existence is 'obvious', being common in both source and target domain. So, fewer words, explanations and interpretations are provided by the analogy.

5.3.3.1 Coding Data

A child gave for the simple electric circuit the following analogy:

Child:...It is like an orange
Inter.: Yes
Child: Suppose that there is juice inside, and suppose that this is the flow, and when we squeeze it, it provides energy
Inter.: Mmm
Child: And we drink the orange juice.
Inter.: Right
Child: Like we take vitamins from the orange, something similar happens with the battery which has a flow and the lamp takes the flow and alight.
Inter.: Yes, what about the switch?
Child: The switch, is like... when we squeeze the orange it is like when the switch closes.

In this analogy the target domain is very different from the source domain. The child is constructing his analogy using elements mainly from three general categories: objects, entities, processes. He chose an orange to play the role of battery (an object), and the juice as similar to the flow (a scientific entity) of the electric circuit. Finally, he described the squeezing of the orange to be similar to the closing (a process) of the switch. So, the orange produces juice, and more interestingly it produces energy in juice.

In general children constructed their own analogies using some elements of the following general categories:
(a). Objects (O): Switch (s), Battery (b), Lamp (L) and Wires (w)
(b). Scientific entities (E): Flow (f) and Light (l)
(c). Processes (P): Open/Close (o), Pass through the switch (p) and Turn on/off (t)
Considering this classification system, Table 5.1 shows the instances of elements which appeared in children's analogies. Relations between the things (e.g. next to) were, if presented at all, very implicit and the children did not refer to them when they judged correspondences.

The analysis of analogies was based on the semantic and pragmatic use of the elements in the child's argument. It was necessary to look at how the child saw all the elements working together, to justify assigning elements to broader categories (e.g. 'barrier', 'switch'). This research thus attempts to describe the 'content' of analogies using schemes. It would be very tricky to "pick out" each of the elements that are involved in an analogy and describe separately their nature. It is notable that these "elements" do not just come together in an example, but that the existence of one of them modifies the nature of the others, and might predict the existence of some others that constitute together a group of elements.

Table 5.1: The appearance of elements in analogical examples

Object 1 SWITCH	Object 2 BATTERY	Object 3 LAMP	Object 4 WIRES
A. barrier	**A. battery**	**A. television**	**A. wires**
B. switch	**B. heart**	**B. lamp**	**B. pipes**
C. clouds	**C. orange**	**C. kitchen**	**C. straws**
D. without switch	**D. wash basin**	**D. empty wash bas**	**D. chain**
E. money	**E. water face**	**E. appliance**	
F. tap	**F. liquid gas**	**F. electric bell**	
G. accelerator	**G. plastic glass**	**G. wheel**	
H. main switch	**H. terminal**	**H. match**	
I. rubber			
J. needle			

Entity 1 FLOW	Entity 2 LIGHT
A. water	**A. light**
B. sun	**B. move around**
C. blood	**C. vitamins**
D. flow	**D. work**
E. juice-energy	**E. fire**
F. gas	

Process 1 OPEN/CLOSE	Process 2 CAN/CANNOT PASS	Process 3 TURN ON/OFF
A. open/close	**A. can/can't pass**	**A. turn on/off**
B. press the button	**B. allow/doesn't allow**	**B. arise the sun**
C. exist/does not exist	**C. flow/doesn't flow**	**C. go anywhere**
D. exist/leave	**D. drink it**	**D. live/dead**
E. beat	**E. come out**	**E. go faster**
F. squeeze		**F. appropriate time**
G. connect		**G. start-begin**
H. pierce		
I. strike a match		

Thus it is necessary to describe which are the elements' attributes and how they appear in their "interactions" with the other things of the target example. So, because of the interest of this research in how the elements "interact" (the presence of one predicting the presence of another), they have to be analyzed at least in pairs. So, firstly pairs of elements that appear together in examples are identified and then the nature of the schemes that appear in the interaction between the elements are explored.

Later, the analysis attempts to identify clusters (groups that constitute more than two elements) of elements. Finally, the fundamental dimensions that lead children's reasoning to specific analogical examples will be identified, putting all these elements in an ontological space. That is, there are different levels of analysis, from a low level (pairs) to high levels (groups and the whole system).

5.3.3.2 Identifying pairs of elements

In order to find whether there is any correlation in the appearance between pairs of these 'elements', the correlations between all the possible pairs of elements which could appear together in children's examples were calculated, using chi-square. The statistically significant pairs for each of the sample groups are shown in the following Table where O means Objects, E means Entities and P means Processes (see Table 5.2)

Table 5.2: Statistically significant pairs for each of the sample groups

Type	***Examples (1-20) Literal similar.***	***Examples (21-39) Analogies***
O - O	Battery - Lamp (p=0.013)	**Battery - Lamp (p=0.07)**
	Battery - Wire (p=0.028)	**Battery - Switch (p=0.013)**
O - E	Lamp - Light (p=0.002)	**Battery - Flow (p=0.023)**
		Lamp - Flow (p=0.019)
		Lamp - Light (p=0.002)
O - P	Switch - Pass (p=0.017)	**Battery - Pass (p=0.067)**
	Battery - Turn (p=0.002)	**Lamp - Pass (p=0.046)**
	Lamp - Turn (p=0.013)	
E - E		
E - P	Light - Op/Cl (p=0.067)	**Flow - Open/Close (p=0.07)**
		Flow - Pass (p=0.011)
		Light - Pass (p=0.061)
P - P		**Op/Cl - Turn (p=0.033)**

Taking into account that there were 36 possible pairs that could appear in children's examples then if p=0.05 only about 2 of the observed pairs would be expected to occur by chance. So, the numbers of significant pairs 7 for Group A and 11 for Group B indicate that the appearance of many pairs is not random, and that there are patterns in children's examples.

In Table 5.3 we can see the number of appearances of statistically significant pairs in each of the element's groups . Also the last column shows the number of possible pairs of analogized elements.

Table 5.3: The number of appearances of statistically significant pairs

TYPE	*LITERAL SIM Significant Pairs*	*ANALOGIES Significant Pairs*	*TOTAL of Possible Pairs*
O - O	2	2	**6**
O - E	1	3	**8**
O - P	3	2	**12**
E - E			**1**
E - P	1	3	**6**
P - P		1	**3**

Table 5.4 is constructed using Table 5.3 and shows the total number of appearances of each element in statistically significant pairs, and their number in possible non-significant pairs.

Table 5.4: Number of appearances of elements in statistically significant pairs

TYPE	GROUP A (Lit.Sim)		GROUP B (analog)	
	Significant pairs	Non Significant	Significant pairs	Non Significant
Objects	6	20	7	19
Entities	2	13	6	9
Process	4	17	6	15

In Tables 5.3 and 5.4 we can observe the preference of the children who gave an "analogy" (Group B) to use more often in their pairs elements that come from the group of Entities and Processes. On the other hand, Group A (Literal similarity) more often used elements from the group Objects.

It seems that in Group A the children just transformed objects (from the source example) into other objects (target example) which were very alike without thinking about the way that the source example works. In contrast the children from Group B who were not interested in the surface similarities (mainly between objects in source and target examples), attempted through their empirical schemes to give a target example whose structure would be the same as the source example. That is, their focus was on scientific entities and processes, and not just on observable objects.

5.3.3.3 'Prediction logic' correlations of the pairs of elements

The correlations between the elements used by children were calculated using the chi-square test. However, the chi-square test does not show how one can interpret the correlation in terms of the appearance of one element as a result of the presence of the other. So, the "prediction logic" method was used, in order to interpret in a "logic language" what the significant correlations in a two way Table (identified by the chi-square method) could mean. An introduction to the prediction logic method follows since this method is not used very frequently in the literature.

The Prediction logic method

The prediction logic method can be defined by analogy to elementary logic: "just as a proposition in elementary logic may be stated unambiguously by identifying its domain and truth table, a prediction logic proposition may be stated precisely by specifying its domain and the set of error events it identifies" (Hildebrand, Laing, Rosenthal, 1977, p.30).

We can use formal logic to evaluate and classify propositions, e.g. the form "if x then y". In the prediction logic we use the connective ~→ (read "predicts" or "tends to be sufficient for") as the analogue to formal implication (→) and ←~→ (read "tends to be necessary and sufficient for") in the place of the formal connective (↔). These statement-forms in formal prediction assert that exceptions (falsifying events) should never happen. In contrast, prediction logic statements predicts that deviant or error events seldom happen.

Using prediction logic we can construct propositions for RxC cross classification tables. Particularly, we will use it for 2x2 tables. In the simple 2x2 case there are $2^4=16$ logically distinct “types”of tables. Of these, 14 contain one or more error cells (frequencies in these cells expected to be very small when compared with the other cells of the same contingency table). The tables expecting only ‘full’ or ‘empty’ cells are not amenable to analysis, that is, we exclude tautology and contradiction. In each of the remaining contingency tables, any error cell is shaded. Negation is indicated symbolically by writing, for example “not x” as $\bar{x}$. All the tables which are shown in Figure 5.1 are accompanied by one or two equivalent propositions (in prediction logic language). Each proposition in these pairs is equivalent with the other, because they have equivalent error structures. That is, they identify the same error cells in the same contingency table.

Consider for example the case 4 (see Figure 5.1). The two following prediction logic propositions can be interpreted:

a) $x \rightsquigarrow y$ “x predicts y”

“x tends to be sufficient for y”

“y tends to be necessary for x”

b) $\bar{x} \rightsquigarrow y$ “not y predict x”

“The absence of y tends to be sufficient for x”

Similarly in case 7 we can interpret the proposition as:

“$x \leftrightsquigarrow y$” “x tends to be necessary and sufficient for y”

“predict y if and only x”

The "prediction logic" method can help us to interpret in a "logic language" what a significant correlation in a 2x2 table could mean. We can measure the prediction success in the 2x2 tables by calculating the ∇_p value.

This value for predictions when we have

(a) a single error cell is: (consider for example case 3)

$$\nabla_p \, x \rightsquigarrow y = 1 - \frac{P_{21}}{P_{2.}P_{.1}}$$

(b) two error cells is: (consider for example case 7)

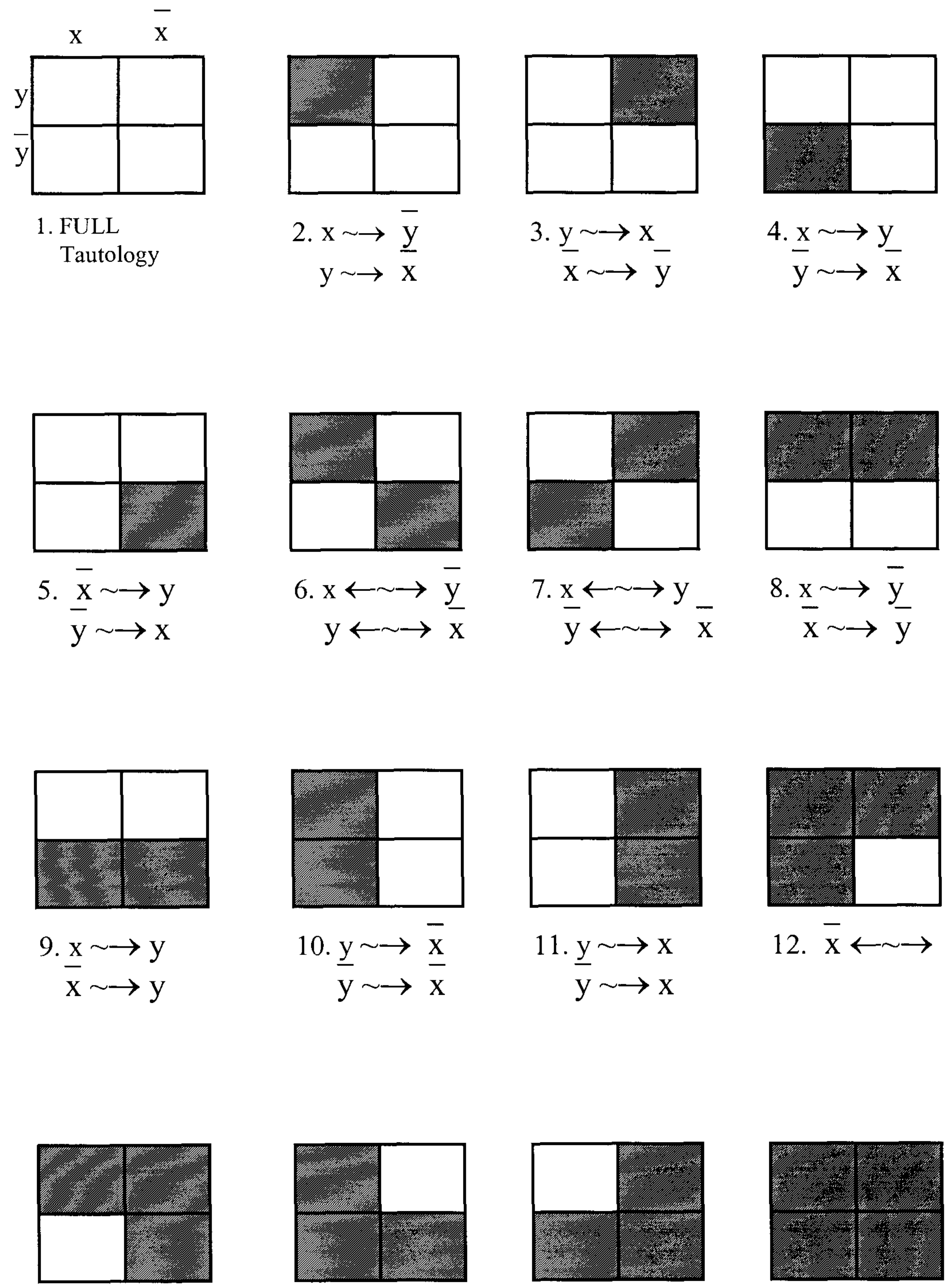
$$\nabla_p \, x \leftrightsquigarrow y = 1 - \frac{P_{12} + P_{21}}{P_{1.}P_{.2} + P_{2.}P_{.1}}$$

(c) three error cells is: (consider for example case 15)

$$\nabla_p \, x \leftrightsquigarrow y = 1 - \frac{P_{12} + P_{21} + P_{22}}{P_{1.}P_{.2} + P_{2.}P_{.1} + P_{2.}P_{.2}}$$

Successful prediction is indicated when this value ∇p is big, and perfect prediction is indicated when it is 1.

Figure 5.1: Error cells in prediction logic



1. FULL
Tautology

2. $x \rightsquigarrow \bar{y}$
$y \rightsquigarrow \bar{x}$

3. $y \rightsquigarrow x$
$\bar{x} \rightsquigarrow \bar{y}$

4. $x \rightsquigarrow y$
$\bar{y} \rightsquigarrow \bar{x}$

5. $\bar{x} \rightsquigarrow y$
$\bar{y} \rightsquigarrow x$

6. $x \leftrightsquigarrow \bar{y}$
$y \leftrightsquigarrow \bar{x}$

7. $x \leftrightsquigarrow y$
$\bar{y} \leftrightsquigarrow \bar{x}$

8. $x \rightsquigarrow \bar{y}$
$\bar{x} \rightsquigarrow \bar{y}$

9. $x \rightsquigarrow y$
$\bar{x} \rightsquigarrow y$

10. $y \rightsquigarrow \bar{x}$
$\bar{y} \rightsquigarrow \bar{x}$

11. $y \rightsquigarrow x$
$\bar{y} \rightsquigarrow x$

12. $\bar{x} \leftrightsquigarrow \bar{y}$

13. $x \leftrightsquigarrow \bar{y}$

14. $\bar{x} \leftrightsquigarrow y$

15. $x \leftrightsquigarrow y$

16. EMPTY
Contradiction

Using the "prediction logic" method for the statistically significant pairs we have the following statements:

LITERAL SIMILARITY Group (1-20)

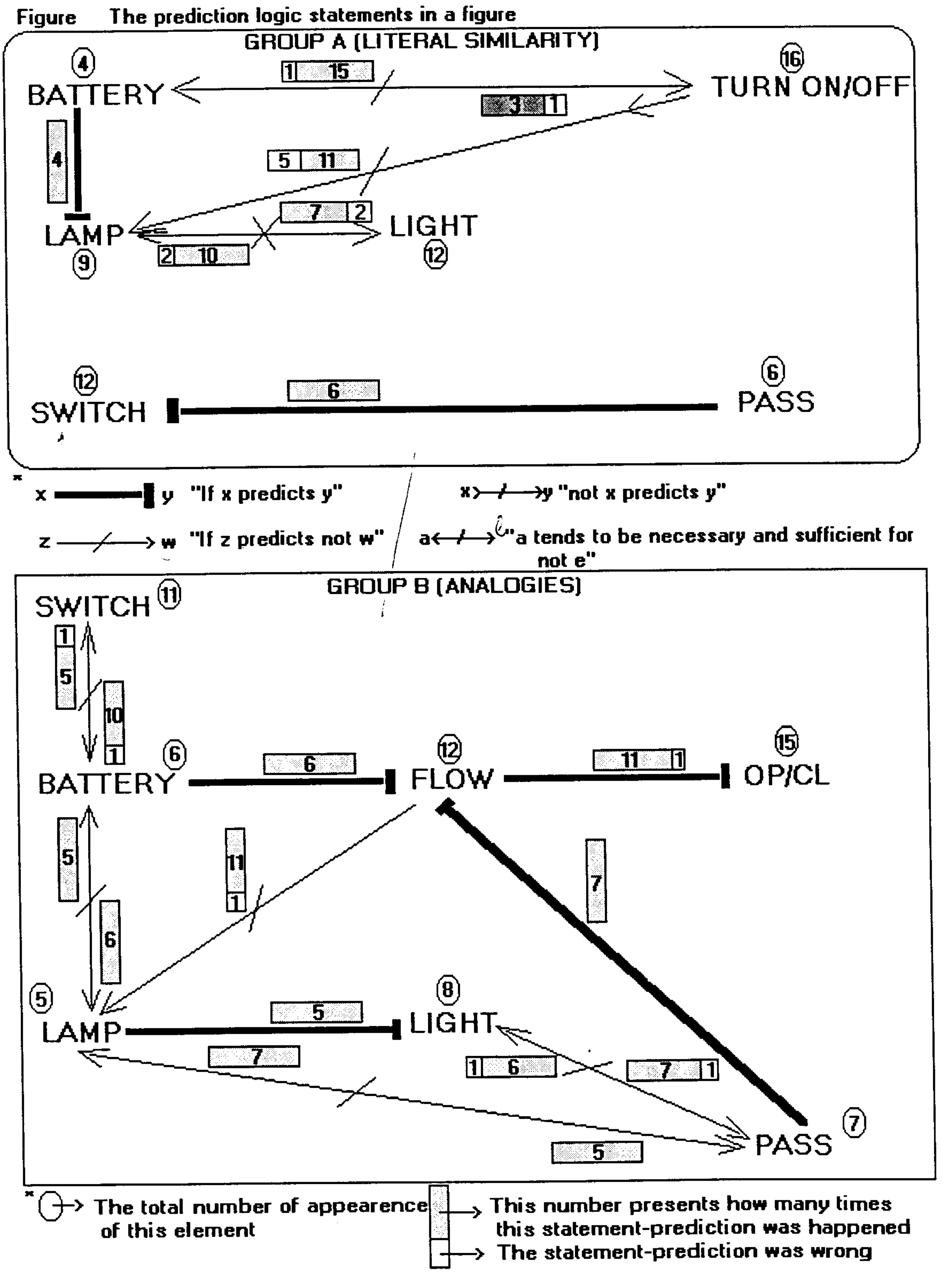
If Battery predict Lamp	If not-Lamp predict not Battery($\nabla p=1$)
Light tends to be necessary and sufficient for not-Lamp	Lamp tends to be necessary and sufficient for not-Light ($\nabla p=1$)
If Pass predict Switch	If not-Switch predict not-Pass ($\nabla p=1$)
Turn tends to be necessary and sufficient for not-Battery	Battery tends to be necessary and sufficient for not-Turn ($\nabla p=1$)
If not-Turn predict Lamp	If not-Lamp predict Turn ($\nabla p=1$)
If not-Op/Cl predict light	If not-Light predict Op/Cl ($\nabla p=1$)

ANALOGIES Group (21-39)

If Battery predict not-Switch	If Switch predict not-Battery ($\nabla p=0.64$)
If Lamp predict not-Battery	If Battery predict not-Lamp ($\nabla p=1$)
If Battery predict Flow	If not-Flow predict not-Battery ($\nabla p=1$)
If Flow predict not-Lamp	If Lamp predict not Flow ($\nabla p=0.71$)
If Lamp predict Light	If not-Light predict not Lamp ($\nabla p=1$)
If Pass predict Not-Lamp	If Lamp predict not-Pass ($\nabla p=1$)
If Flow predict Op/Cl	If not-Op/Cl predict not-Flow ($\nabla p=0.71$)
If Pass predict Flow	If not-Flow predict not-Pass ($\nabla p=1$)
If Pass predict not-Light	If Light predict not-Pass ($\nabla p=0.64$)

All the above statements can be seen in Figure 5.2

Figure 5.2: The prediction logic statements in a figure



b. Interpretation of the propositions for the "Literal Similarity" group

The focus of this section is on the analysis of the prediction logic propositions which provide "positive" relations between pairs of elements (such as the form x ~→ y). That is because the study attempts to identify pairs of elements, and not to explore the propositions which show whether the presence of an element predicts the absence of another element. From the prediction logic analysis we can draw the following conclusions for the literal similarity group:

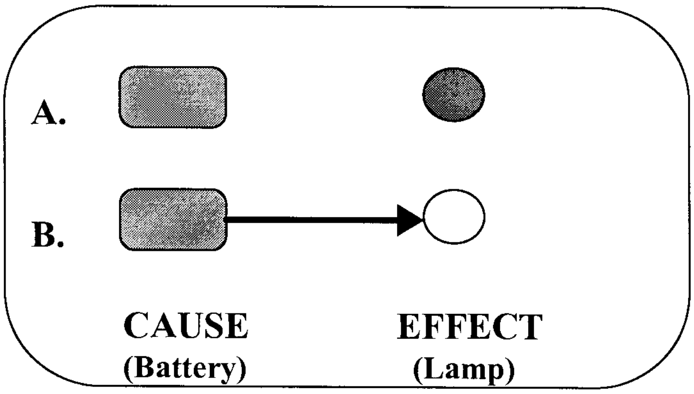
-"Cause" is a sufficient condition for "effect" or "If BATTERY predict LAMP"

The observed pairs are (the numbers shown are cases' numbers):

Battery →Lamp (38, 10, 6)
Battery →Pierce (Compass) (35)

In the particular examples the focus is on a direct relation between the battery and the lamp. The children are not interested in what a battery is, or what it contains. The "battery gives the power"(38) or "they are just all connected"(35,6,10). In all these cases children describe the battery as cause and the change of the lamp as the effect. "Cause" is a sufficient condition for "effect". In other words we cannot construct examples which will constitute a "cause" (battery) without there being present an "effect" (lamp) . So when children in their examples used a sort of "battery", at the same time they used a sort of "lamp" (see Figure 5.3) . This causal relationship (Cause-effect) connects the elements battery and lamp.

Figure 5.3: Interaction between Battery and Lamp



-**“A forward movement through links” is a sufficient condition for a “dynamic link”** or “If PASS predict SWITCH”

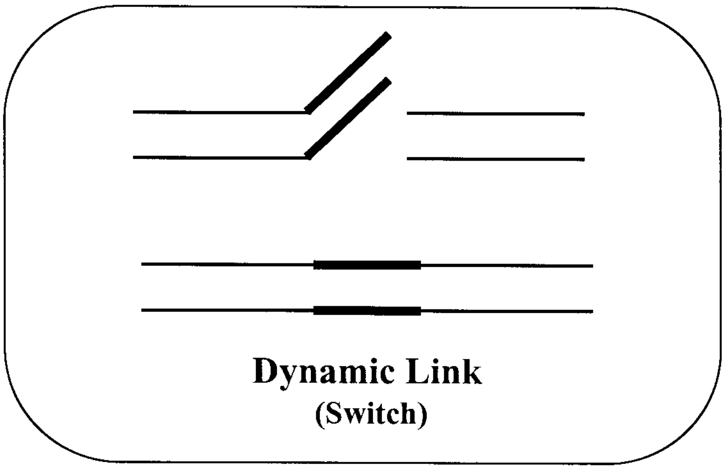
The observed pairs are:

Can/cannot pass → Switch (11, 15, 24, 25, 27)
Allow/doesn't allow → Switch (17)

The presence of one of the processes, that is ‘Pass’ (...the flow can pass...) predicts the presence of the object switch. The flow passes through a conduit. ‘Pass’ is a forward movement through "links". Links are the wires, the lamp, the battery, the switch. Except for the switch which is a "dynamic" link, all the others are static. For example the wire is a link that allows a flow to pass from a place A to a place B, without having any change of its position.

On the other hand someone has to move or change the position of the "dynamic link" switch in order to allow the flow to pass through it. It seems that when children say "pass" their focus is on the area near the switch (see Figure 5.4). This strong relation between “pass” and “switch” led them to use a sort of pass element only in the case where they had used a sort of switch as well. So, “a forward movement through links” (pass) was a sufficient condition for a “dynamic link” (switch).

Figure 5.4: Interaction between Pass and Switch



c. Interpretation of the propositions for the "Analogy" group

By contrast with the examples of "literal similarity group" in the case of the "analogical group" we can observe strong negative correlations between various objects. Particularly in both of the pairs switch-battery and battery-lamp the presence of the one component predicts the absence of the other. Also, the presence of an entity (flow) predicts the absence of an object (lamp). It seems that in this case the children have moved their focus from the surface similarities (between the source and the target example) where they use mainly objects, to the structural similarities that arise from entities and processes. Objects cannot themselves present what they "need" and so they predict the presence of an entity (e.g. battery-flow). It is notable that when the children in their examples did not use or refer to one of the processes (open/close) they had to use another. From the prediction logic analysis we can draw the following conclusions:

- The "source-container" is a sufficient condition for the "content of the container" or "If BATTERY predict FLOW"

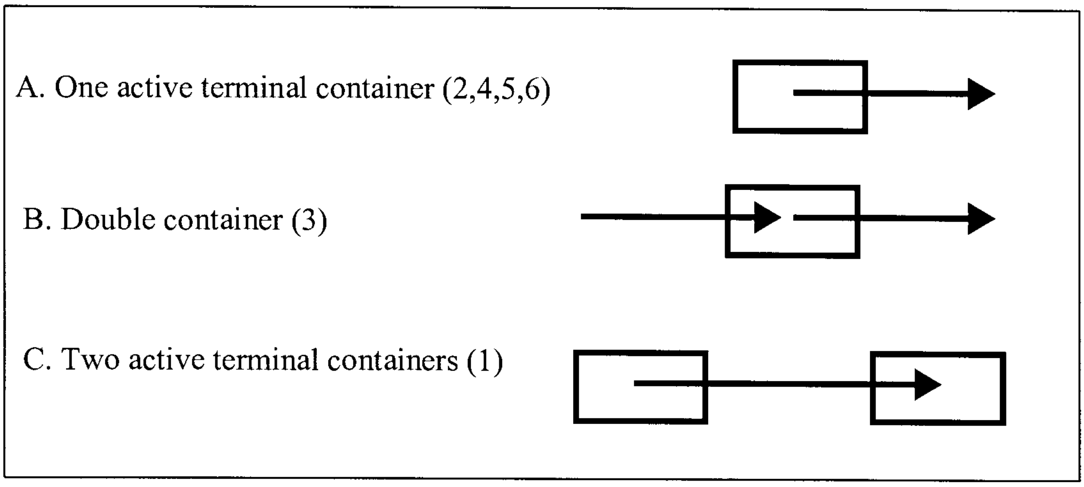
Particularly the observed pairs are:

Heart → Blood (7)
Orange → Juice (13)
Wash basin → Water (18)
Water face → Water (20)
Liquid gas → Gas (23)
Plastic glass → Water (30)

All the variations of "batteries" are containers. This scheme consists of a boundary distinguishing an interior from an exterior. In the examples, they contain mainly fluids (water, juice, blood) and gas, but not solids. This happens because it underlies their role as a source scheme. The battery in an electric circuit is the cause of the electrons' movement. It is difficult for someone to imagine as an analogy, a type of battery which contains a solid thing. In this case the solid thing would have to move all at once, or to be made of moving particles.

Because of its role as container the "battery" predicts the presence of its content, that is the "flow". Children didn't give any example with a 'battery' without giving some type of flow. So, the "source container" is a sufficient condition for its content (see Figure 5.5).

Figure 5.5: Interaction between Battery and Flow



We can identify three ways that the scheme source-container works (see Figure 5.5). By their nature, the main difference between them is whether there is a possible return path for the flow. In the first case, the "source container" provides us with flow without any returning while in the second case there is a possible returning path for the flow. The first case does not tell us what happens to the flow when it goes out of its container (battery). Some children solved this by constructing examples with two containers. In this case, the content of the one container goes to the other.

- A "continuous movement" is a sufficient condition for an "action on a dynamic link" or "If FLOW predict OPEN/CLOSE"

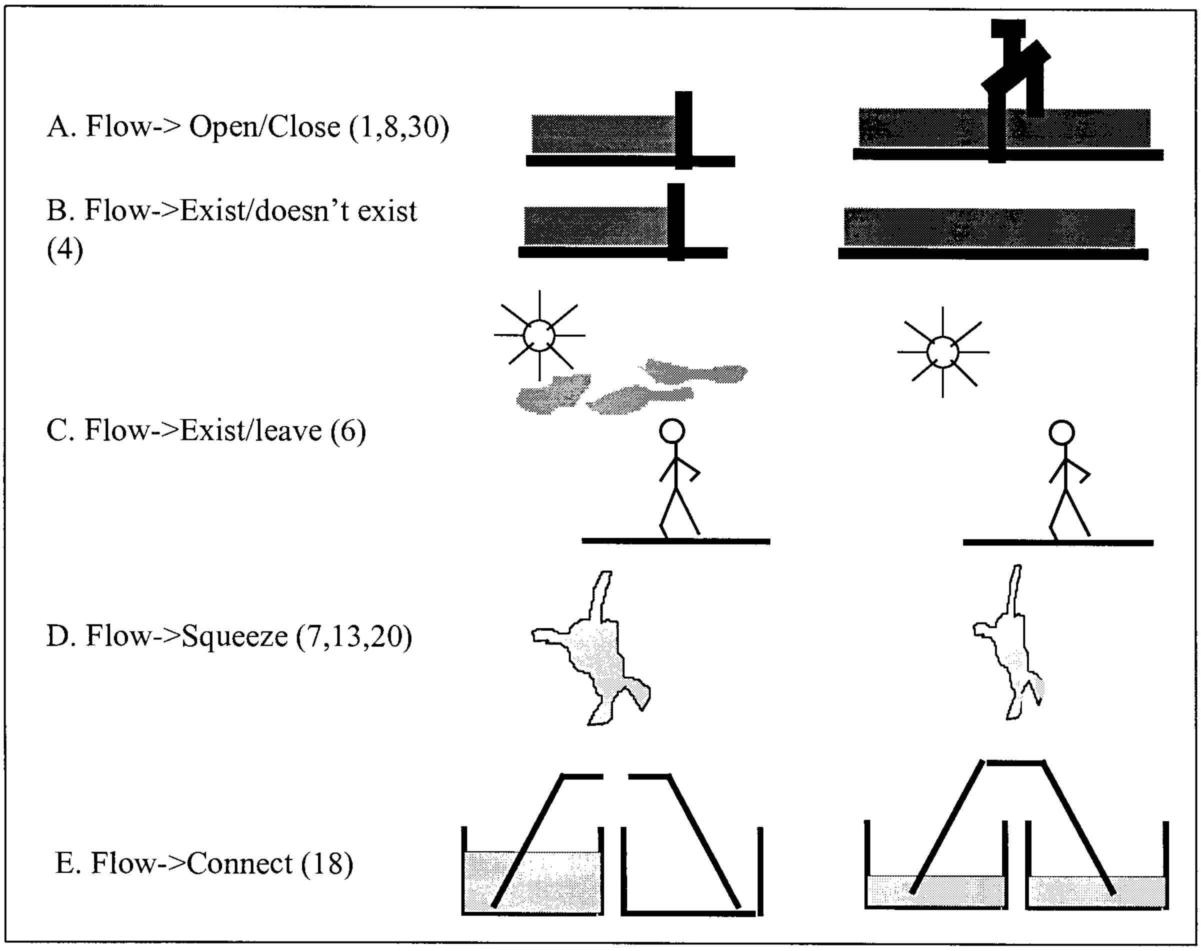
Particularly the observed pairs are:

Water → Open/close (1)
Water → Exist/doesn't exist (4)
Heat → Exist/Leave (5,6)
Blood → Beat (7)
Water → Open/close (8)
Flow → Press the button (9)
Juice → Squeeze (13)
Water → Connect (18)
Water → Squeeze (20)

Flow → Connect (22)
Water → Pierce (30)
gas → Open/Close

So, if we have a sort of "flow" then it can predict a way of opening/closing a "switch". A “continuous movement” is a sufficient condition for an “action on a dynamic link”. This happens because the flow has to stop somewhere, so it predicts an action in order to move. Again, the schema "action on a dynamic link" is obvious for the switch, whereas a schema of a "continuous movement" seems to fit to flow. The flow cannot be static, so its presence predicts a link in order to keep it in a continuous movement. The relation between flow and switch, as it appears in children’s examples can be classified in 5 models (see Figure 5.6).

Figure 5.6: Interaction between Flow and Open/Close



In the second picture presented to the children the switch of the electric circuit is closed and the flow passes through it. In the first of the children’s models (A)(Figure 5.6), the 'barrier' is closed, so - in order to allow the water to move - we have to open it. It is notable that in this model there is an opposite action to the source example. "Open a barrier" is analogous to "close the switch". This might happen because these actions have the same effect, that is, the flow or the water can move.

In the second model (B), the children suggested that the flow started to move when the barrier was disappearing. A similar case is the third model (C). In this model, the children suggested that clouds which do not let sunlight in to be seen, just leave.

In the fifth model (E), the presence of the flow predicts an action - connect the straws - that can give to the flow the ability of "continuous movement"

There are cases where the action (open/close) happens to a "switch" (A, B, C, E) and some others (D) where the actions happen to a "battery" when we have a modification (squeeze). In this case the "battery" is the "source container". The presence of flow predicts an action (squeeze) that can 'give' to a flow the property of continuous movement.

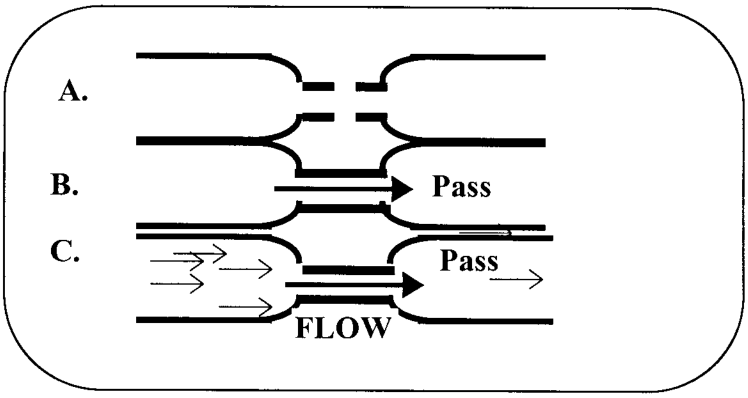
- A "forward movement" is a sufficient condition for "flow" or "If PASS predict FLOW"

The observed pairs are:

Can/cannot pass → Water (1)
Allow/doesn't allow → Water (4)
Flow/doesn't flow → Water (8)
Allow/doesn't allow→Water (18)
Come out → Water (20)
Come out → Gas (23)
Come out → Water (30)

The flow passes through the wires. In the children's examples, if the flow is able (or something allows it) to pass through the area of the switch then we will have flow. The "forward movement through the switch" is a sufficient condition for flow. It seems that 'pass' is mainly located in the area of the switch. The presence of the forward movement (pass) from one edge of the switch predicts the presence of the flow (see Figure 5.7).

Figure 5.7: Interaction between Pass and Flow



-**"Material is a sufficient condition for a change"** or "If LAMP predict LIGHT"

The observed pairs are:

Lamp → Light (27)
Appliance → Work (19)
Electric bell →Ring (22)
Wheel → move around (29)
Match → Fire (37)

The role of the "Lamp" in the examples is to provide evidence for a change. We cannot have this object in an example without seeing an effect or change in it. The effect is a result of a change in the state of an object or material. The "material" predicts that there will be a change. The lamp as material needs and so predicts the presence of an entity (light).

5.3.3.4 Analysis of elements in groups using multivariate statistical analysis

a. Cluster analysis

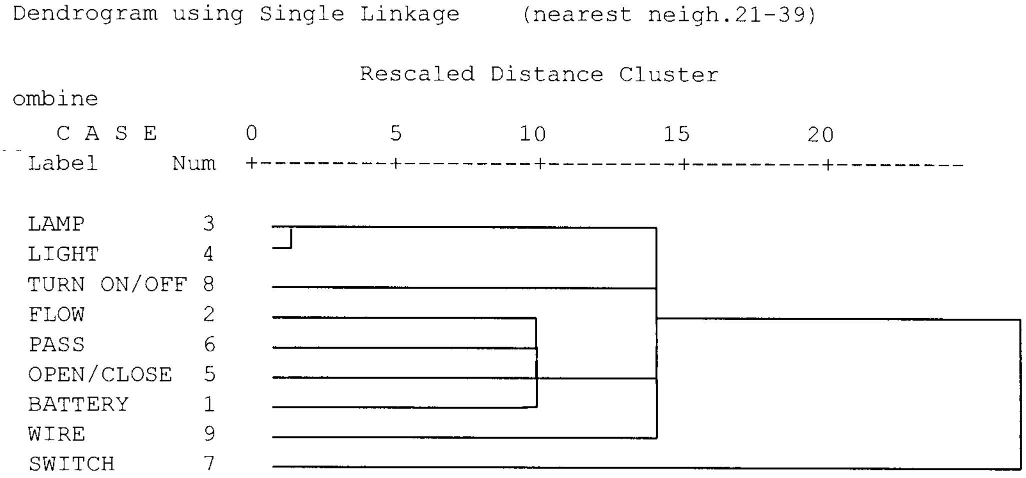
The next step, after the analysis of elements in pairs, is to analyze them in bigger groups. That is, to explore the elements that appear together in the children's target examples. So, in this section the aim is to group the elements into homogeneous classes or clusters (the members of a cluster are close to each other but differ considerably from those members of another cluster), through the method of cluster analysis.

Cluster analysis can generate unknown groupings which suggest relationships between the members of each group, to be investigated. One of the reasons for the use of cluster analysis is that it classifies the elements into "true" groups (Manly, 1986).

Elements (Switch, battery, light etc.) have been chosen as the variables of cluster analysis, and their appearance or not in target examples provides the measure for "distances" between them.

In this research "Hierarchical clustering" is used. In this, the elements are first separated into a few groups, each of which is further divided into smaller groups, and so on until terminal groups are generated which are not further subdivided (Everitt, 1980). Particularly, the Nearest Neighbor or Single Link Method is used. In this method, the distance between the groups is defined as the distance between their closest members. Cluster analysis used for the analysis of the "analogies" and not of the "literal similarities" since the focus of this chapter is on the analogies, and on whether the analogical examples (which are very different from the source example) have a structure that brings their elements together in groups. Using the nearest neighbor technique we obtain the following dendrogram (see Fig.5.8) for the "analogy" group (Cases 21-39):

Figure 5.8: Dedrogram



The dendrogram indicates that there are small distances between (a). Lamp-Light and

(b). Flow-Pass-Open/Close-Battery

suggesting that the appearance (in the target example) of each of the members of a group has its origins in a common scheme. In other words, there is one or a number of schemes that demand the simultaneous existence of a "package" of elements. It is notable that the above groups are constituted from the elements that in the "logic prediction" analysis were in "pairs" with relationships.

The first group (Light-Lamp) has already been discussed (see previous section with prediction logic). It is interesting to attempt to explore the nature of schemes for the elements that constitute the second group (Flow, Open/Close, Pass, Battery) taking their interaction, not just at the level of pairs, but as a whole group.

It seems that in this group or package of four elements there is a central one (see Fig.5.2) which is Flow. According to this package an entity such as "Flow" cannot appear alone in an example. Its scheme (continuous movement) comes into an integration with other schemes that can give answers to the following questions that "bring" with its appearance the specific entity:

a. Where does it comes from? A "source container" (Battery) is needed.

b. What does it can do? It can Pass (with a "forward movement" from one edge to another one)

c. What has to be done to it? An "action on a dynamic link" can admit Flow to Pass.

One child, for example, described in his example a plastic glass as a 'source container' full with water. The water can 'pass' outside the glass if we 'act' on the glass, making a hole at the bottom:

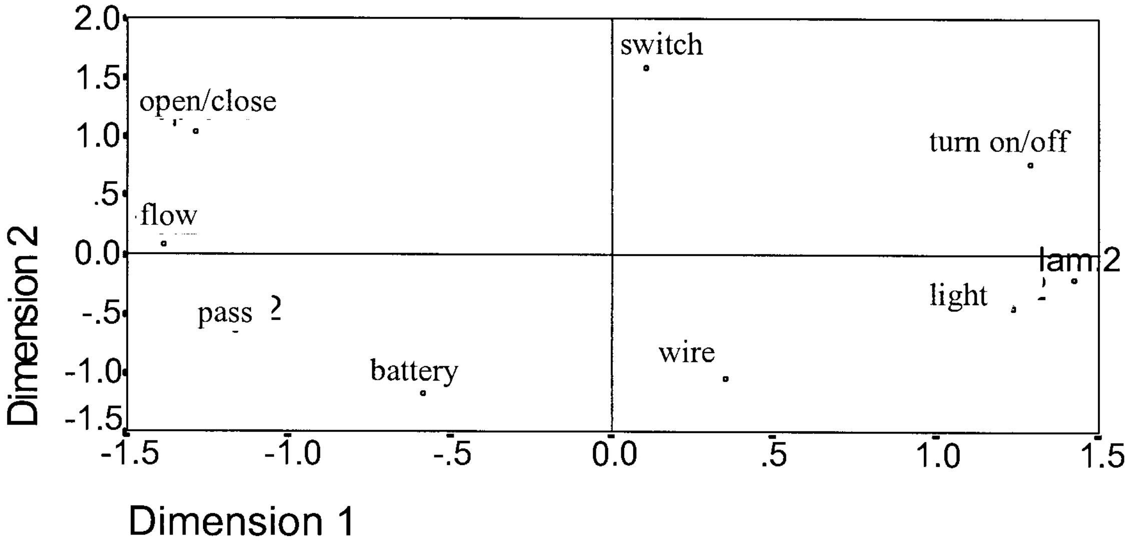
> *Pupil: Yes, for example, we full a plastic glass with water*
> *Interv: Right*
> *Pupil: If we do not make a hole at the bottom of the glass with a pin, then the water will not pass, but if we make a hole then the water will pass.*

It seems that all these elements that constitute this group ("cause") can give rise to a phenomenon (effect). This group will be discussed in more detail later in the analysis.

b. Multidimensional Scaling

The usefulness of Multidimensional scaling (MDS) comes from the fact that it can provide us with a "map" of n points in Euclidean space using information about the distances between the n objects (Mardia, et.al 1979). Using the distances between the "elements" it determines the best arrangement of their points in the space, while the relation between them is not known. The computer program ALSCAL was used and the Euclidean distances were calculated for the configuration of the points (see Fig.5.9).

Figure 5.9: Euclidean distance model



It is not easy to define the dimensions of the above "map". Firstly, meaningful clusters in the space have to be identified, using information from the cluster analysis.

In Figure 5.9 there are two big clusters which separate the space into two areas left and right. The elements that constitute the left cluster seem to be the "Cause" of a phenomenon (see previous analysis) while on the right there is a group that we can call "Effect".

In other words, the cause-effect relation consists of the following elements:

- We need a “source container” (battery) and an “action on a dynamic link” (open-close) that will allow to “flow” to “pass”.

- These four elements have as an effect the making of "light" in the "lamp". It is notable that the "Switch" is at the middle between these two groups of Elements. Its 'movement' provides a connection to those groups. So, the horizontal dimension can be called a Cause-Effect dimension.

Furthermore, the vertical dimension can be interpreted as a static-dynamic dimension since at the bottom there are "static" elements such as Battery ("container"), Wire, Lamp ("static objects") etc. while at the top there are "Dynamic" elements such as Switch ("dynamic link"), Open/Close ("action on a dynamic link"), Flow ("continuous movement").

5.4 Overview of the second study

In the exploratory study, the children transformed an event into an analogical one focusing on actions (keeping their schemes stable) rather than on parts or relations. These results were tested in the main study where the children generated their own analogies. The children generated their analogies, generally drawing on schemes. Schemes which were commonly evoked are the following: flow, path, container, open/close, barrier, link, forward and continuous movement. The analysis of the components of children's analogies shows that their thinking is well structured and based on groups of schemes. The presence of some elements of analogies predicts the presence or absence of others. Types of structure can be identified at the level of pairs (e.g. a "source container" is a sufficient condition for the "flow") and of groups of schemes (e.g. "flow" comes from a "source container" and an "action on a dynamic link" can admit flow to pass with a "forward movement" from one edge to another one). Also, at the level of the "whole analogy" dimensions 'cause vs. effect' and 'dynamic vs. static' were identified.

These results are supported by the findings of the research project 'Empirical abstraction and concrete reasoning schemes'. Results from the "imaginative denial of rules task" show that a scheme is a basic re-usable component in children's reasoning about familiar events. Schemes combine with one another to form packages. Possibly, one of the most basic schemes identified - as also in the current research - was the "up and down" (e.g. a kettle, a teapot and a cup were things which were turned upside down), and this was associated with the support, fall and containment schemes. So, a simple package of schemes appeared in reasoning: The "containers" (cup, teapot) are on a table and so "down", and they need to be "up". However, it was problematic since they had nothing to "support" them. So the children suggested that the objects could "float" in a topsy-turvy world to avoid the scheme "falling".

However, it is notable that the task of the current study and the "denial of rules task" identify packages of schemes at different levels. In the current research the greatest emphasis was on packages of various schemes while in the denial of rules task, the analysis emphasised packages of components of schemes. In the last case, schemes are built of packages or sets of possibilities (called "potentials"). So, the scheme 'support' can be seen as a package of 'something underneath', 'preventing from falling', 'above the ground'(Bliss and Ogborn 1997).

The current research explores the focus of the person who constructs the analogy. When the children were asked to construct an analogy, they mostly constructed "partial analogies". They focused their attention on a part of the source domain (some of the objects, or entities, or processes), and then they gave an example - the target example - which is analogous with that specific part of the source domain. The limitation of this study is that children's major focus on actions and common schemes could be to some extent explained as the result of the content of the particular event (open/close the switch of the electric circuit), suggesting that more events of different kinds should be explored.

Children's analogies can be a helpful tool in the exploration of their thinking and their focus. In the case of simple electric circuits the interaction of children with scientific knowledge appears to result in half of the children in this study thinking about an electric circuit focusing on a number of analogous processes, not simply on surface facts.

Chapter 6:
RESPONDING TO AND GENERATING EXAMPLES OF IDEAS

6.1 Introduction

Teachers and science text books frequently use various examples to clarify ideas. The use of examples in science teaching is routine but is at the same time very varied. The etymology of the Greek word "paradeigma" (Lat. exemplar) tells us that it is a part of a whole ("deigma" means sample), a part that can stand for the whole. Various examples as parts of the same whole can stand for that whole. But, what makes two examples that exemplify a given idea, both be about the same idea, but yet be different? Is there a sense in which one example is 'better' than another?

This research explores children's transformations of elements at various levels. Study 1 (chapter 4) focused on the transformations of objects while study 2 (chapter 5) focused on the transformations of an example-event into an analogical example-event. Both studies describe the role that schemes play in these transformations, which are between elements that both belong to the same level of the dimension abstract-concrete. Study 3, reported here, explores the transformations of abstract ideas into concrete examples.

The description of such transformations in the present study includes the presentation of the products of these transformations and an analysis of such products based on the identification of their underlying schemes. In this study, the products are themselves examples as seen by children. So, the purpose of the study is to clarify the process of exemplification, describing examples as they are used by children and as they appear in science textbooks.

6.1.1 Children's examples of ideas

A working definition of examples - proposed by Montaigne - might be that an example is a link between a concept and a unit of experience that can be subsumed under that concept. However, Montaigne mentions the problem of the "fit" of an example to its generalisation. He argues that attempts to abstract from experience to a general law are as difficult as the attempt to move from a general law to specific instances. General laws have to be read "by some round-about, forced, and biased" method in order to be applicable to various cases (Lyons 1995). So, ideas do not work in the same way for all of us.

Karlheitz Stierle claims another kind of linkage between example and generalisation: the need to think of a generalisation which is not given in order to be capable of speaking of the particular example at all (Gelley, 1995). The effectiveness of an example of a generalisation depends on how the person will imagine the relevant generalisation.

Children construct links or connections between an abstract idea and examples from their own perspective. What do children understand looking at some simple science ideas that they have already being taught about? How do they transform an abstract idea into a concrete instance? A way that we can look at this is to see how they exemplify these ideas. What are the components of their examples?

In classrooms, teachers - sensing a gap between their own and their pupils' understanding - use examples. They frequently say: 'Let me explain this idea to you. For example...'. However, in this part of the study the principle can be expressed as 'let children explain to us what they understand about an idea by giving examples'. Do children use the examples provided in their textbooks? Are there patterns in the components of examples they give?

6.1.2 Children's understanding of various examples used in science textbooks

Various entities take part in examples of ideas. In order to analyse and compare different examples we need to be able to refer to some common or different features that appear in them. However, since different entities usually take part in different examples, we need a more general 'point of reference' (which appears across all examples) to make comparisons or analysis of examples.

This study suggests a novel way of analysing examples of ideas. In this analysis we explore how children describe the various entities that take part in an example, using in the analysis a definite number of schemes (common for all examples). In each example the schemes which describe the features of the entities that take part in an example were identified. So, the focus of this part of the study is on the analysis of: Examples of ideas in terms of objects which can be seen schematically.

Objects can be described by some schemes such as barrier, support, rigidity, autonomous action etc. For instance "a child" can present autonomy or can support other things, while "a tree" or "the ground" can support other things but does not present autonomous action. What are the schemes that can cover a wide range of objects (thinking about them in every possible case)? A given example consists of some objects behaving in particular way -for instance a child up a tree as an example of potential energy. In that example "objects" such as the child, the tree, the ground take part. What schemes has one to select to describe objects that take part in an example of such an idea?

The process of using examples, is a picking out of the features to which the exemplification will refer. A tailor's swatch exemplifies its colour, weave and thickness, but not the size and shape of the garment. Exemplification does not run in a direction from label to what the label applies to, but in the opposite direction. Exemplification is not just a mere possession of a feature but requires also reference to that feature (Goodman 1981). This study aims to explore the way that examples of ideas constrain (define to some extent) the schemes which are used in the description of the entities that take part in the example. An event can constitute an example of an idea only if it can define clearly the role of the elements taking part in it. So, in an example of an idea such as "when things are raised they have potential energy" an entity like the "air" should appear to lose its dynamic features (e.g. motion) since this plays no role in the example. Which schemes of entities are suppressed and which are highlighted by particular examples?

Similarity and dissimilarity play an important role in the formation of examples. The similarity which makes different examples all part of the same idea cannot be identified and explained at the level of objects, since different objects take part in them. However, similar schemes could be identified across the examples. Is there any indication of the structure of such schemes in groups or packages? An idea of potential energy might need a simple package of schemes that consists of a 'moveable object' which is 'high up' and (often) supported. If, there is a structure like this, does a particular example define a configuration of its entities at that more abstract level? Which groups of schemes can be described by more abstract dimensions or factors? Can similar dimensions or factors be identified for different ideas?

There are various objects which play a similar role in different examples (e.g. their behaviour can be influenced by a certain scientific concept such as potential energy) or they have a similar nature (e.g. they are abstract entities). Schemes or their packages can also be used for the description and comparison of the entities which take part in an example at the levels of the role that these entities play or at the level of their nature. Are there any differences between the entities that take part in examples concerning their nature and the specific role that they play in examples? Are there any similarities/differences between the entities that play a similar role in examples?

The method of investigation used here is to present situations (possible examples), first isolated and without reference to an idea they might exemplify, and then with reference to such an idea. That is, first cases such as 'a child' 'a tree' were given, and then the same cases in a new form 'a child up a tree as an example of potential energy'. We predict that general features (schemes) applicable to the objects 'child' and 'tree' will alter in their importance in the two cases, some becoming more important and some less.

An indication of 'badness' of an example would be its inability to constrain in an appropriate way the entities in it. Which examples are unable to some extent to constrain the schemes that describe the entities taking part in it?

6.2 Methods

6.2.1 Design of the questionnaire and Procedure

The idea of the study was to choose some general ideas in science (e.g. potential energy), and ask children to give their own examples of these ideas. Then, presenting to the children the same ideas together with examples of each idea (e.g. a flower pot on a balcony) used in science textbooks, to investigate the way in which the examples from the science textbooks worked (or not). The method used was intended to make it possible to analyse children's examples of these general ideas, and to compare the working of examples (from textbooks), for different examples of the same idea, for examples of different ideas, and for counter examples.

The fundamental idea behind the design was that the elements of an example (e.g. flower pot, balcony, air, ground) given in a science textbook, will be thought about differently when used as an example of (say) potential energy, than when not used as an example. This idea led to the following steps in the construction of the research design (instrument):

(1) choose several general ideas in science,
(2) for each, choose more than one textbook example,
(3) distinguish for each example, its component elements (e.g. child, tree),

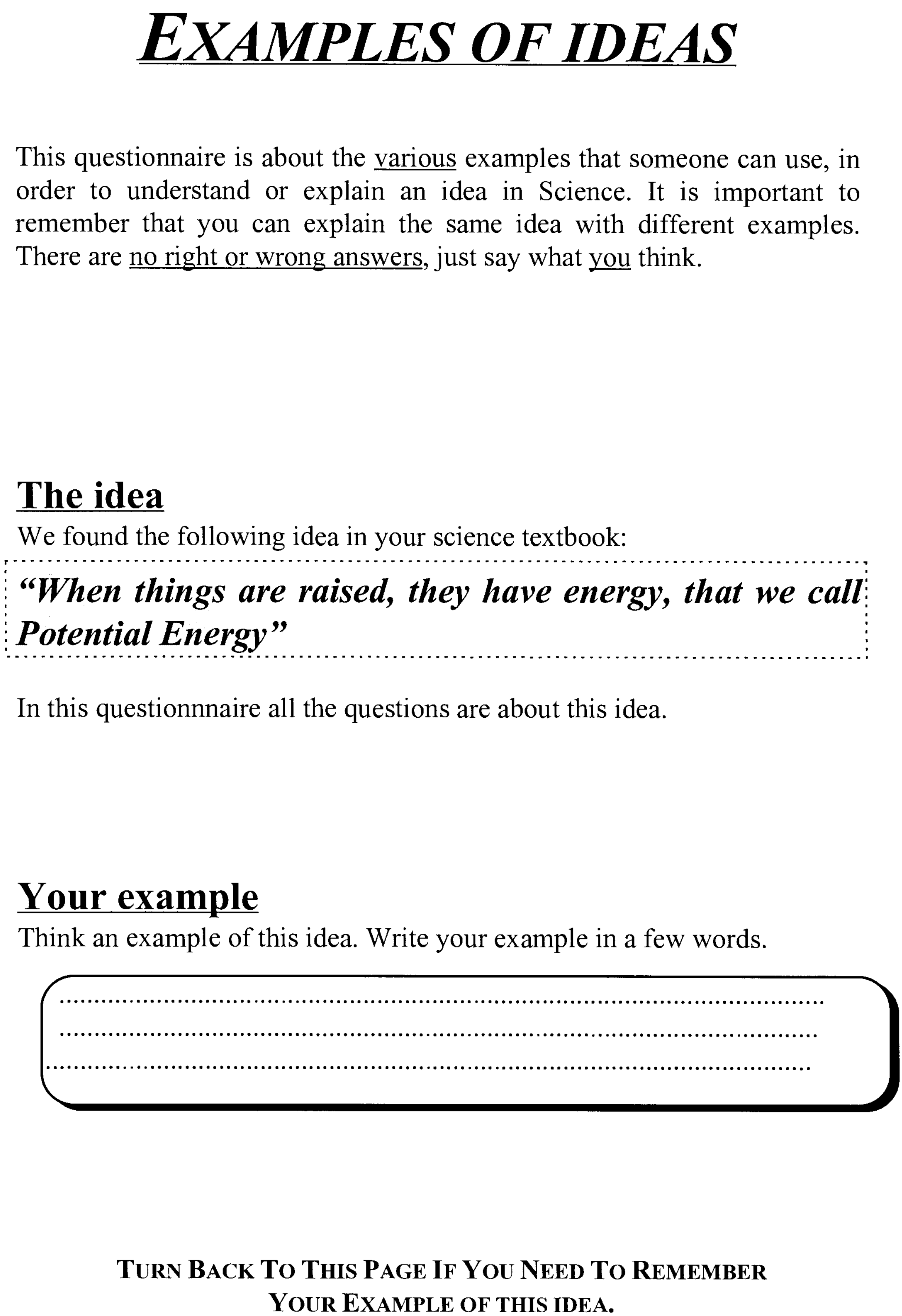
(4) present children with various ideas and ask them to give their own examples of these ideas (see Figure 6.1)

(5) present children first with the elements, but not yet presented as an example of anything (see Figure 6.2). Then present them with the elements again, but now as an example of a given idea (e.g. potential energy, see figures 6.3 and 6.4),

(6) in both cases (see step 5), find out how children think about the elements of the example, in terms of a set of schemes common to all the examples.

So, five scientific ideas, all of which appear in the school text-book, were selected. For each, two examples were chosen, again from those in the textbook. Ten questionnaires, identical except for the idea chosen and the example selected for each idea, were constructed. A further two questionnaires, making 12 in all, had the same structure but now each asked about one counter-example of each of two further ideas. Thus the twelve questionnaires were all essentially the same, but different in the idea used, and the example or counter example of it given. Each child was asked to fill out one of the 12 questionnaires. The children were first asked to give their own example and to describe examples from their textbooks of the same idea. The children who participated in this study had used the science text book, from which the examples were taken (Ο.Ε.Δ.Β., 1982), in their previous year in the school (at least twelve months before).

Figure 6.1 The first page of the questionnaire



EXAMPLES OF IDEAS

This questionnaire is about the various examples that someone can use, in order to understand or explain an idea in Science. It is important to remember that you can explain the same idea with different examples. There are no right or wrong answers, just say what you think.

The idea

We found the following idea in your science textbook:

"When things are raised, they have energy, that we call Potential Energy"

In this questionnnaire all the questions are about this idea.

Your example

Think an example of this idea. Write your example in a few words.

....

....

....

TURN BACK TO THIS PAGE IF YOU NEED TO REMEMBER YOUR EXAMPLE OF THIS IDEA.

Figure 6.2: The second page of the questionnaire

On the right part, we have written some elements-things (air, boy,..). Thinking about our everyday life we meet these things many times. In order to answer the questions on this page you have to thing what these things ***can do****.*

Can each of the five things do something .... ↴	AIR	BOY	POTENTIAL ENERGY	GROUND	TREE
like a barrier, or a wall can?	☐	☐	☐	☐	☐
like a support for other things, like a table can?	☐	☐	☐	☐	☐
like a container can do, have something else inside it?	☐	☐	☐	☐	☐
like a rigid thing can do, to resist a change of its shape?	☐	☐	☐	☐	☐
like being contained in something else?	☐	☐	☐	☐	☐
like making other things move?	☐	☐	☐	☐	☐
like moving or stopping moving when it wants?	☐	☐	☐	☐	☐
be really there, even though we can not see it or touch it?	☐	☐	☐	☐	☐

Figure 6.3 The third page of the questionnaire

DESCRIBING EXAMPLES OF IDEAS

It is important to remember that you can explain the same idea with different examples. Some of these examples are better than others and some are worse. What we want to find here is the way that you understand some examples from your science textbook. There are no right or wrong answers, just say what you think.

The idea

We found the following idea in your science textbook:

"When things are raised, they have energy, that we call Potential Energy"

In this questionnnaire all the questions are about this idea.

An example

We found the following example of the above idea, in your Science textbook.

The child high up the tree, has Potential Energy

TURN BACK TO THIS PAGE IF YOU NEED TO REMEMBER THIS EXAMPLE OF THE ABOVE IDEA.

Figure 6.4 The fourth page of the questionnaire

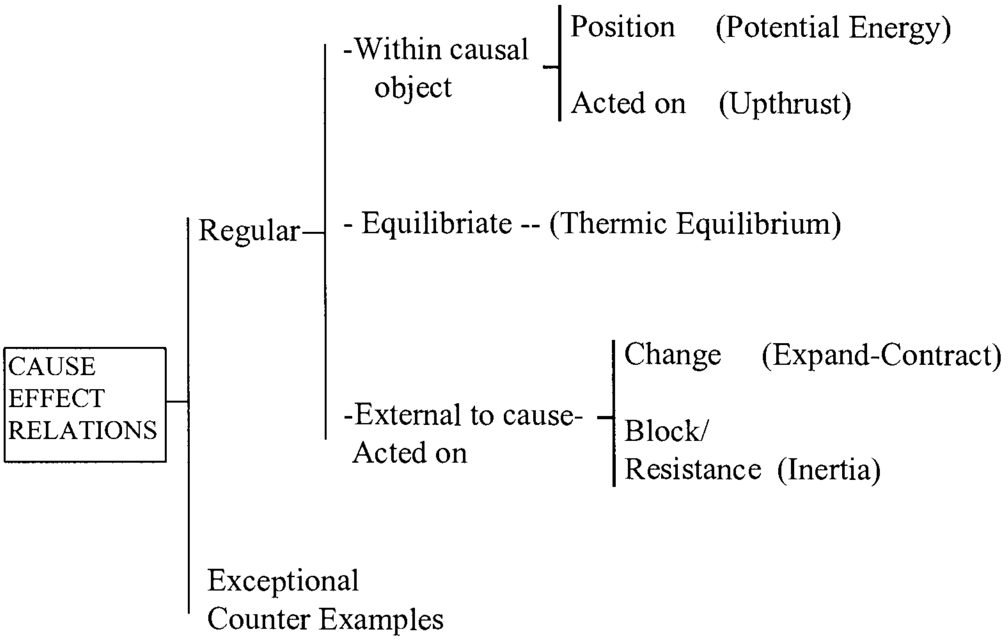
Look at the the example a boy up a tree of the idea When things are raised they have pottential Energy. Think which is the role of each element-thing (air, boy,...) in this example.

Put a tick in those that you think they do a similar thing ....

	AIR	BOY	POTENTIAL ENERGY	GROUND	TREE
like a barrier, or a wall can?	☐	☐	☐	☐	☐
like a support for other things, like a table can?	☐	☐	☐	☐	☐
like a container can do, have something else inside it?	☐	☐	☐	☐	☐
like a rigid thing can do, to resist a change of its shape?	☐	☐	☐	☐	☐
like being contained in something else?	☐	☐	☐	☐	☐
like making other things move?	☐	☐	☐	☐	☐
like moving or stopping moving when it wants?	☐	☐	☐	☐	☐
be really there, even though we can not see it or touch it?	☐	☐	☐	☐	☐

For the selection of the ideas a simple network was constructed at the beginning, which described some major categories of ideas (which were found in the book) starting from their cause-effect relations (see Figure 6.5). This study (study 3) aims to explore the differences and similarities of examples of ideas, including categories that differ in respect of processes based on the classification of processes (cause-effect processes) and not on the classification of things (this criterion was used in the study 1 where the classification of things in categories such as natural and artefacts were explored). One idea for each of these categories was selected.

Figure 6.5 Categories of ideas



Ideas frequently used in science textbooks for the development of science vocabulary use technical terms which describe abstract concepts (e.g. upthrust) or name phenomena (e.g. expansion). But how are the technical terms related to the abstract concepts? The relationship is generated in two ways:

(a) Introducing a technical term. This may be done through naming and through definition (Wignell, Martin, Eggins 1993). In this research three of the ideas used introduce an abstract concept through naming. A technical name is attached to some already known abstract term or to the whole phenomenon. The ideas of potential energy and upthrust introduce a technical term for naming a sort of energy and force respectively, and the idea of expansion introduces a technical term for naming a phenomenon. Potential energy, upthrust and expansion are introduced in the ideas by a projecting verbal process, "we call x, y".

(b) Manipulating a technical term. In two further cases - thermal equilibrium and inertia - these terms had been introduced in the textbook in the previous paragraph from that which was used in the questionnaire. In these cases the term itself was to be understood through examples.

To make the results from different examples and different ideas as comparable as possible, two further steps were taken:
(1) assign elements to a common set of schemes,
(2) assign elements to a common set of categories.

In order for the schemes to be used as a reference point for the comparison between various examples, a fixed set of general schemes for all examples had to be selected. Children were asked to answer whether the entities involved in the example can be described by one or more of the following eight schemes: barrier, support, container, rigidity, contained thing, force, autonomy, invisible entity. The questions (see figures 6.2 & 6.4, and Appendix 6.1) which were influenced by the work of Mariani and Ogborn (1991) were as follows:

Can each of the five things do something....

(a) like a barrier, or a wall can?
(b) like a support for the other things, like a table can?
(c) like a container can do, have something else inside it?
(d) like a rigid thing can do, to resist a change of its shape?
(e) like being contained in something else?
(f) like making other things move?
(g) like moving or stopping moving when it wants?
(h) be really there, even though we can not see it or touch it?

Furthermore the choice of elements for each example was not random. The elements which were chosen fell into one of the following five broad categories (see Table 6.1):

(a) Scientific concepts. This category includes scientific concepts such as potential energy.

(b) Protagonist (object A).The object which has or shows the behavior of the scientific concept.

(c) Structure related objects (object B). The existence (or modification) of the concept based on the relations (e.g. distance, size) between object A and object B. The protagonist and object B are connected by structural relations

(d) Surface related objects (object C). Object A is in contact with object C. The protagonist and object B are connected by surface relations.

(e) Unrelated objects (object D). Object D does not play any role in the example. Its possible absence does not make any difference to the example.

Table 6.1 The classification of the elements that were used in each example

IDEA	Example	Scientific concepts	Protagonist	Structure Related obj	Surface related obj	Unrelated
Potential Energy	“pot”	Pot.energy	Pot	Ground	Balcony	Air
	“child”	Pot.energy	Child	Ground	Tree	Air
Expansion	“railway”	Expansion	Railway	Sun	Train	Ground
	“wires”	Expansion	Wires	Sun	Pylons	Ground
Thermal Equilibr.	“contact”	Heat	Hot water	Cold water	Containers	Air
	“inside”	Heat	Hot water	Cold water	Containers	Air
Inertia	“lorry”	Inertia	Lorry	Car	Ground	Air
	“elephant	Inertia	Elephant	Toy Elepha	Ground	Child
Upthrust	“ball”	Upthrust	Ball	Water	Child	Plastic ba
	“stone”	Upthrust	Stone	Sea	Child	Ground
Counter examples	“rocket”	Gravity	Rocket	Ground	People	Air
	“glass”	Heat	Glass	stove gas	hand	Air

The examples in the second column, are described more fully below.

6.2.2 Participants in each type of questionnaire

Data were collected from 23 classrooms (with 12 year old children who were in the last class in primary school in Greece) in an urban school district. Questionnaires were given to all children who attended the sixth class, in 12 out of 15 primary schools in the city of Karditsa (the remaining 3 schools did not want to participate in the research). Thus, 407 children participated in the study ranging in age from 11 to 12;3 years old with a mean of 11;6 years old.

a. Potential Energy

Seventy two children responded to the two questionnaires about the idea "When things are raised, they have energy, that we call Potential Energy". The first (A) was answered by 38 children (on average 11.59 years old), and asked them about the example of the idea "a child up a tree has potential energy". The second (B), answered by 34 children (11.54 years old), asked them about the example "a pot on a balcony has potential energy".

b. Expansion

73 children participated in this task. 33 of them with a mean age of 11.51 years filled out the questionnaire (A) and 40 with a mean age of 11.48 years old filled out the questionnaire (B). The idea in this task was the following: "Almost all solid things, expand when they are heated. This phenomenon is called expansion". The example used in questionnaire (A) was: "In the summer the electric wires of the P.C.E (Public Company of Electricity) are expanded between two pylons because of the high temperature, so they are loose", while the example that was used in B was: "In the summer the railways lines, expand because of the high temperature, so it makes the line bend up in an arc".

c. Thermal Equilibrium

In two questionnaires the following idea was explored: "When things come in contact, heat is transmitted always from the warmer to the colder." In questionnaire (A), 40 children with a mean age of 11.52 years were presented with the example: "We put two pots with water (one containing hot and the other cold water) in contact. The heat is transmitted from the hot to the cold thing." while in (B), 30 children with a mean age of 11.62 years were presented with the example "we put one metal pot with hot water inside another bigger pot that contains cold water. The heat is transmitted from the hot to the cold thing".

d. Inertia

Two questionnaires explored the idea of inertia: "The bigger the mass things have, the more difficulty they have to move, because they present big inertia". In the questionnaire (A), 38 children with a mean age of 11.52 years old were presented with the example "A lorry that has bigger mass than a car will move with greater difficulty and move slower than the car", while 23 children with a mean age of 11.53 years old were presented with the second questionnaire in which the example used was "A child can easily move a small toy-elephant, but it is much more difficult to make a big elephant move".

e. Upthrust

57 children were asked about the idea of upthrust: "on a thing that is in a liquid there is a force acting upwards from the liquid. This force is called upthrust". 36 of them with a mean age of 11.60 years were presented with questionnaire (A) in which the example used was "it is very difficult to push down a ball into the water, if you let it free it will come out, because of the upthrust that it gets from the water". 21 of them with a mean age of 11.50 years were presented with questionnaire (B) which was based on the example "A thing seems lighter in water than out of it, because of the upthrust from the water".

f. counter examples

The idea used in questionnaire A was "When things go up, they must come down (to the ground), because of the gravity" and the example used as counter example was "A rocket launched from the earth with speed more than 40,000 Km per hour. So it beats the earth's attraction and doesn't come back". 38 children with a mean age of 11.62 years were presented with this questionnaire.

In the second questionnaire the following idea was used "A lot of things allow heat to pass through them easily". In this case the counter example was "We can touch the edge of a glass tube without getting burnt, because the glass tube doesn't let the heat pass easily through it. 36 children with a mean age of 11.64 years old took part in this task.

6.2.3 Method of analysis

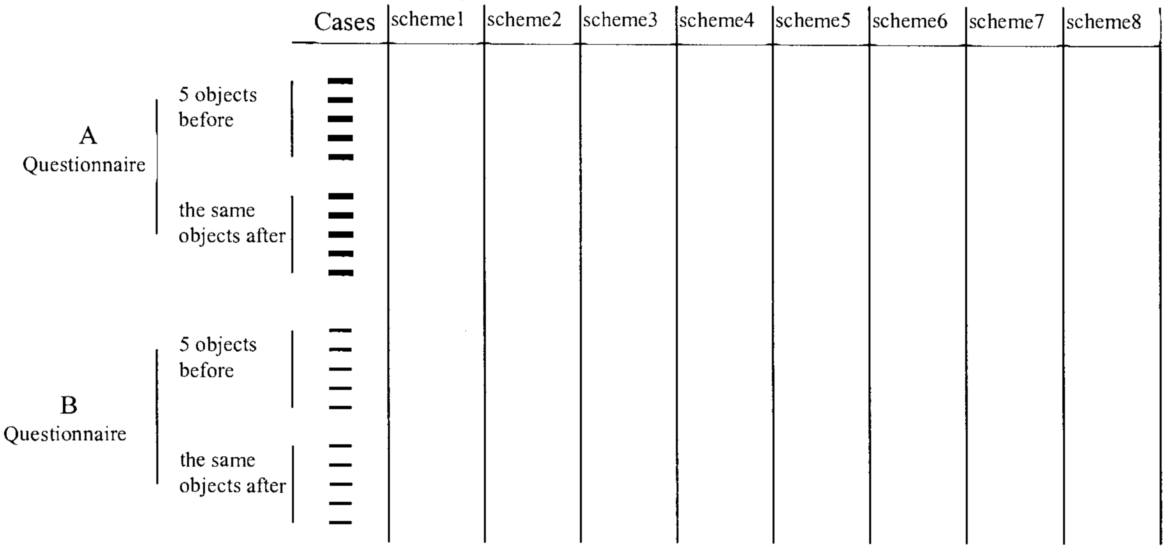
Children's own examples were analysed mainly qualitatively, using systemic networks. A systemic network was produced and is discussed with reference to children's own examples of each of the ideas.

In the case of the examples from the textbooks, in order to look at the relations of patterns between the schemes that children used to describe various objects, factor analysis was used. Using factor analysis we are looking for factors (dimensions which organise children's knowledge at a more abstract level than schemes) which can represent a group or package of schemes. So, it was expected that factor analysis would give an indication that there is a factor structure. Using this structure and the factor scores for each element we can describe any change or transformation from before and after seeing an example, in the use of specific schemes or in the way schemes are grouped together.

In factor analyses for each of the ideas, the eight schemes were used as variables while the various objects were used as cases. The cases were twenty in each factor analysis since in each type of questionnaire children were asked to describe five objects before and after seeing the example and there were two questionnaires for each idea (see Figure 6.6). The data consists of frequency counts of children's 'yes' responses for the objects that take part in the various examples in each of the eight schemes (variables). Factor analyses were conducted together for the pairs of groups presented with the two questionnaires, using different examples of an idea, to reduce the number of variables into smaller sets of more broadly conceptualised variables. Thus the factor analysis looks at the correlation between responses using the percentages of the total number of children who identified one of the eight schemes for a particular object.

Factors scree plots were graphed to help decide on the number of factors. A criterion of an eigenvalue greater than one, was mainly used for selecting the number of factors for oblique rotation from a principal component analysis of the data. Oblique rotation was used when factors were correlated. The method for oblique rotation which is available in SPSS is called oblimin. The value zero (0) was given to the parameter delta (δ) which controls the extent of obliqueness, which permits the maximum obliqueness.

Figure 6.6 Pattern of factor analysis



Also, the McNemar test was used to test the significance of any observed changes in children's responses before and after seeing the example ("the McNemar test for the significance of changes is particularly applicable to 'before and after' designs" (Siegler)). When the expected frequencies for the McNemar test were very small the binomial test was used.

In the analysis of the results for each idea, three types of figures are used to represent the data. These figures are representations of tables with numbers which were the outputs of factor analysis and McNemar analysis. I used figures instead tables with numbers because the enormous amount of data from this study makes the presentation and the understanding of the results in the form of numbers very compicated. The figures that were produced for the discussion of the results precisely represent the numbers of the analysis using dashes, arrows, arithmetic symbols (+ and -) and some symbols for the objects. The tables with the numbers that are used as a basis for the construction of these figures are presented in the Appendixes.

The first of the three figures in each case shows the schemes that have high positive or negative loadings for each factor. The bold symbols **+** or **-** represent a loading between 0.75 and 1 while the symbols + or - represent a loading between 0.50 and 0.74.

The second Figure shows the 'movement' of the objects' factor scores for all factors in relation to the context. I chose to use a cube as a representation of the factor structure because my aim is to discuss any movement of the objects related to all factors and for most of the ideas (except the counter examples) three factors were extracted from the factor analysis. There are two symbols in the cube for each object. The one of them represents the factor scores (for all three factors) of the particular object when it was described by children without having to see it as part of an example, while the other represents the factor scores of the same object when it was described by childen as part of an example of an idea. The arrows point to the factor scores in the exemplifying context.

The third Figure shows the percentages of children who used the various schemes to describe the objects as an example of an idea. The arrows represent the cases with statistically significant differences (decreases or increases) between the non-exemplifying and the exemplifying context. This Figure is used to explore and identify the schemes that are responsible for the movement of objects' factor scores.

In the interpretation of results the following expressions are used instead of numerical values: If the number of children that said 'yes' was bigger than 80% the expression "almost all" is used. In the cases 60-80% "many children", 40-60% "around half", 20-40% "quite a few", and if the number of children that said 'yes' was smaller than 20% the expression "a minority" is used.

6.3 Results

6.3.1 Potential Energy

6.3.1.1 Children's own examples of potential energy

At the beginning of the questionnaire, children were asked to give an example of the idea "when things are raised, they have energy, that we call Potential Energy". All children (72) gave some example. However, four of them gave as example an object which was in contact with the ground. Furthermore, no children gave an example which was in their last year's text book. Figure 6.7 shows a network that was constructed from the analysis of children's examples.

In general, children's examples of potential energy have as components the following:

(a) a protagonist,

(b) the object that supports the protagonist away from the earth (surface related object),

(c) a description of the position of the protagonist, in many cases in comparison with the ground (structure related object)

(d) a technical term, the name of the energy that the protagonist has (scientific concept)

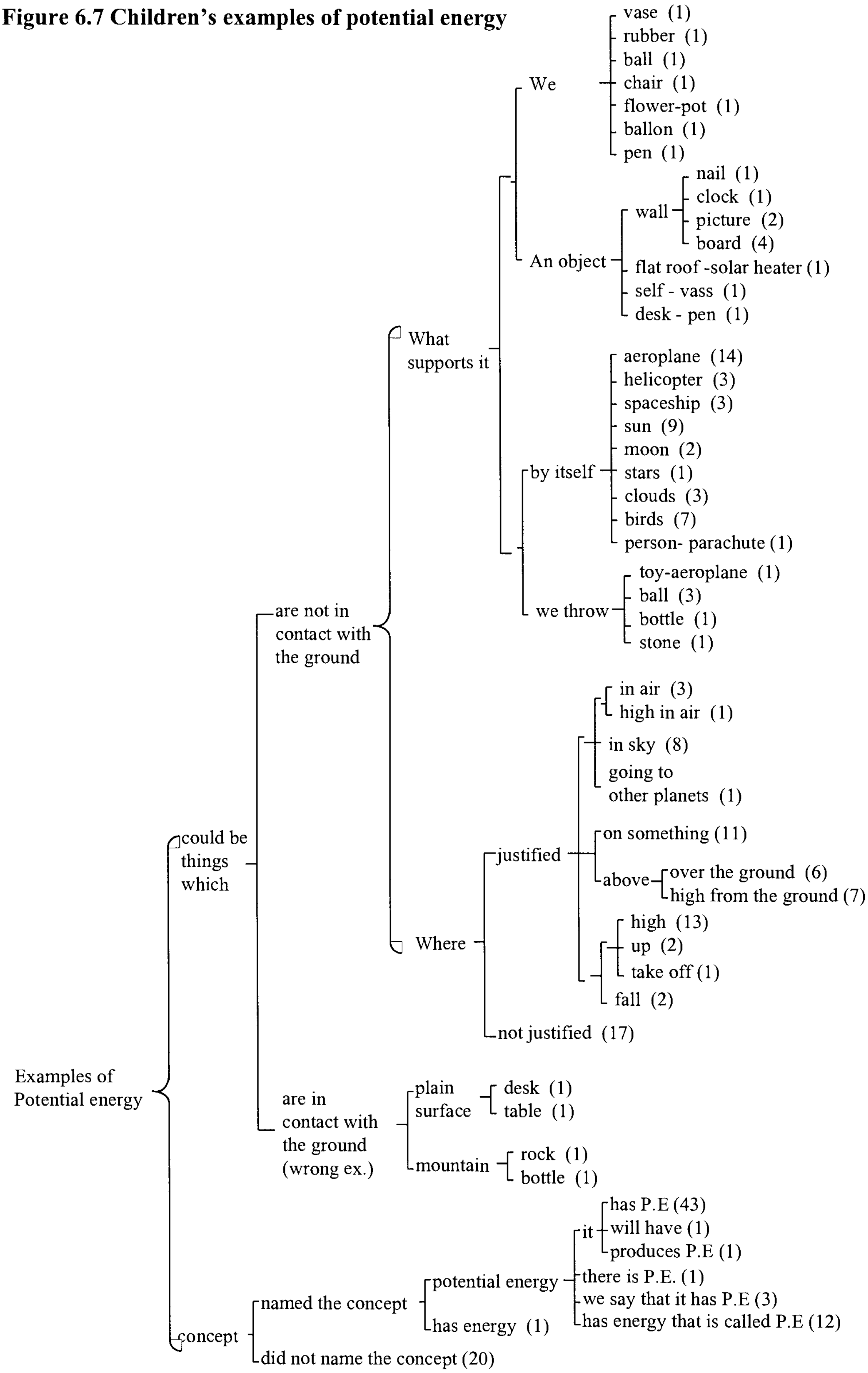
All children's examples of potential energy include Protagonists, objects which have potential energy because of their position. The most popular object used as protagonist was an aeroplane, and then the sun and birds. The sun is actually a complicated example. The sun and earth have a mutual potential energy because of the attraction, but the sun is not 'above' the ground. In general, it seems that children preferred objects which are very far away from the earth. Also, very few children used as protagonist a living thing. Only one child used a person (who falls with a parachute) and seven used birds as protagonists. Almost all children used as protagonists non-living things such an artefact (e.g. aeroplane), an object (e.g. ball),

Protagonists could be supported mainly by themselves or by something else. In the last case, protagonists were supported by surface related objects, such as (i) a person (something held) or (ii) another object. The vast majority of the children gave examples without surface related objects although the examples in their textbooks used them (a child up a 'tree' or a flower-pot on a 'balcony'). The surface related objects which support the protagonists could be horizontal surfaces (e.g. flat roof) or vertical surfaces (wall), or containers such as the human hand which can grasp and hold other things.

A description of the position of the protagonist was given by 55 of the children (17 did not). In their examples, children used the ground as the structure related object, directly or indirectly. Many of them said that the protagonist was high above the ground or over the ground; even more of them said just high. However, other children followed an indirect way (they did not mention the ground), saying that the protagonist was in or on another thing such as the air, the sky, or a desk. They did not mention the distance between the protagonist and the ground, probably because the existence of a distance was obvious when they mentioned a place such as the sky which is far from the ground.

Many children named the abstract concept as potential energy in their examples (52 of them named the potential energy while 20 did not). Most of them used the verbal form "x (the protagonist) has potential energy". Also some of them following a similar verbal form with that of the idea said "has energy that is called potential energy". The vast majority of children did not mention in their example the existence of energy (general term) mentioning the specific sort of energy involved, namely potential energy.

Figure 6.7 Children's examples of potential energy

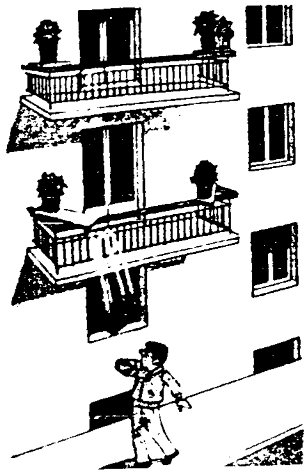


6.3.1.2 Schemes for entities, with and without an idea exemplified

Children were asked to describe first five entities (see below) out of any exemplifying context. Then, they were presented with the following idea and one of the two following examples and were asked to describe the same entities but now in the exemplifying context:

“When things are raised, they have energy, that we call Potential Energy”

A child up a tree has potential energy.



A pot on a balcony has potential energy.

Children were asked to describe in one questionnaire the following five objects :

	(A) example	(B) example
◆ ***Scientific Entity***	potential energy	potential energy
⚹ ***Protagonist***	pot	child
● ***Structure related object***	ground	ground
○ ***Surface related object***	balcony	tree
✕ ***Unrelated object***	air	air

6.3.1.2.1 Interpretation of the Factors

According to the factor scree plot, 3 out of 8 factors have eigenvalues bigger than 0.9. Finally three factors were extracted. The three factors jointly explain 88% of the variance. Factors which are presented in Appendix 6.2 and which are identified in the followings paragraph, are listed in the order of magnitude of percentage of variance contributed by the particular factor in Table 6.2.

Table 6.2 The factors for potential energy

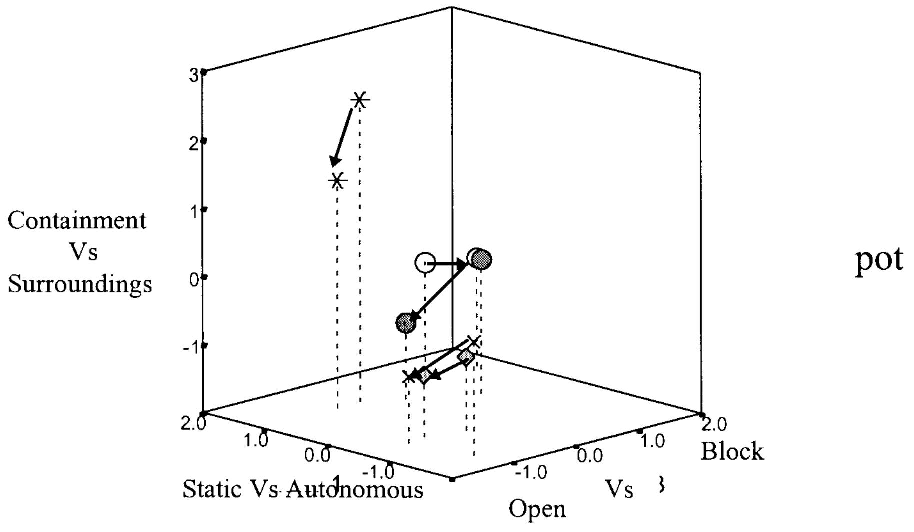
	Factor 1	Factor 2	Factor 3
Autonomy	**-**		
Force	**-**		
Container		**+**	
Contained thing	-	**+**	
Rigidity		+	
Barrier			**+**
Support			**+**
Invisible			-

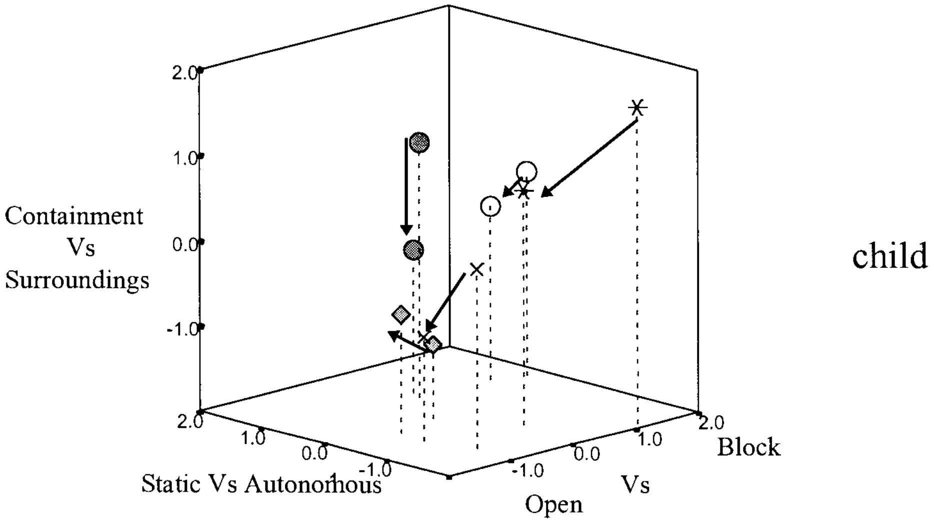
Factor 1 has very high negative loading for "autonomy" and "force" variables. So, factor 1 can be labelled "static" and appears to describe a static object vs. autonomous action dimension. Factor 2 has very high positive loading for "container" and "contained thing". It also has positive loading for "rigidity". It can be labelled "containment" and appears to describe a containment vs. surroundings dimension. Factor 3 has very high positive loading for "barrier" and "support" variables. This factor can be labelled "blocking" and seem to describe a blocked vs. opened (or linked dimension). Appendix 6.3 and 6.4 show plots of factors and the percentages of yes responses for each scheme.

6.3.1.2.2 Analysis of the Potential Energy examples

The movements of the objects' factor scores and percentages of children who used various schemes to describe each object are shown in the following two Figures, Figure 6.8 & 6.9 (see also for the description of the figures that follow, the account given earlier, pages 140 to 142).

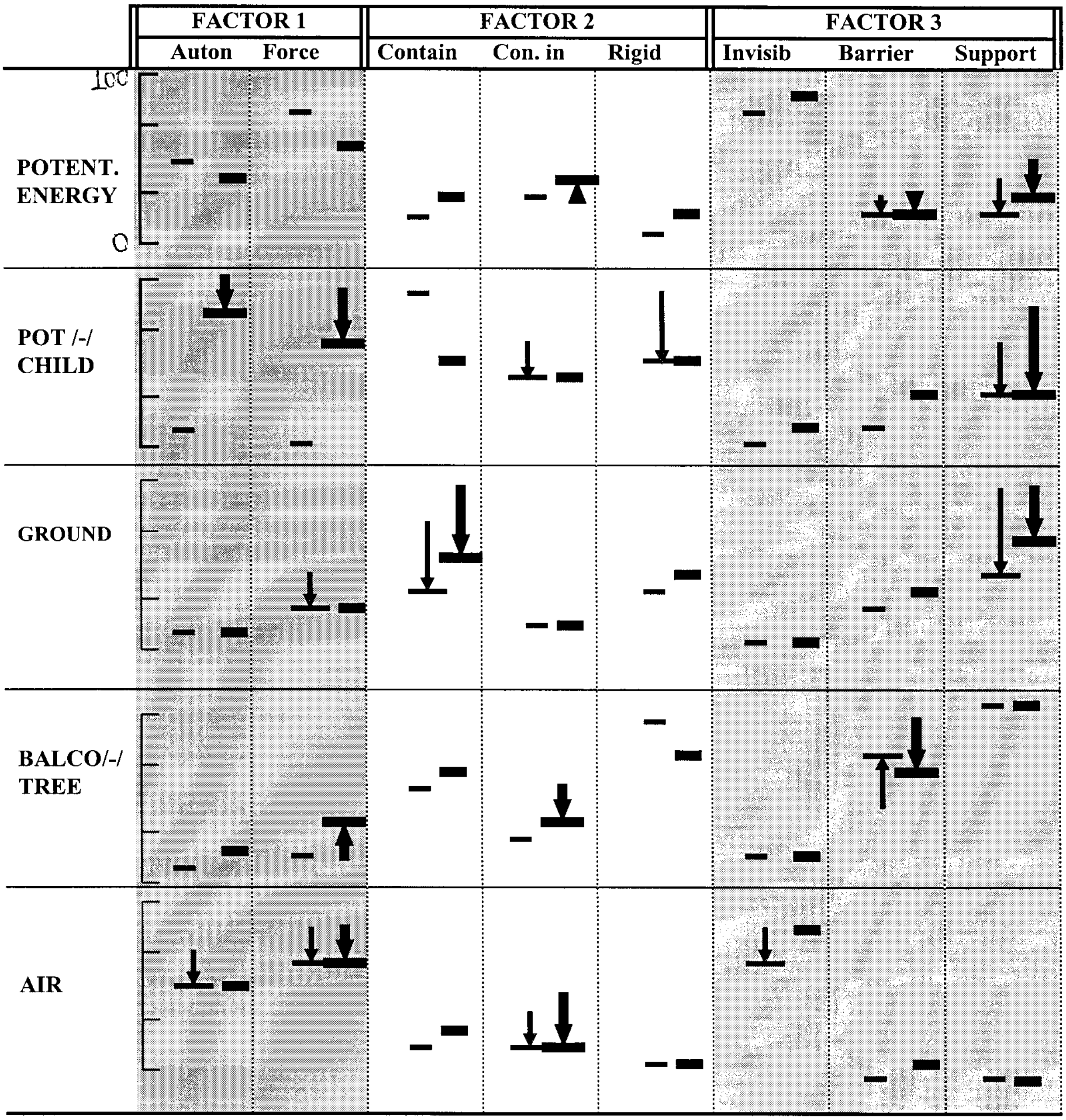
Figure 6.8 Factor scores and their 'movements' for the examples with the pot (top) and the child (bottom)





	(A) example (Top Figure)	(B) example (Bottom Figure)
◈ ***Scientific Entity***	potential energy	potential energy
⚹ ***Protagonist***	pot	child
● ***Structure related object***	ground	ground
○ ***Surface related object***	balcony	tree
× ***Unrelated object***	air	air

Figure 6.9 The percentages of children who used each scheme to describe objects in the examples of potential energy



The factor which explained most of the variance was labelled static/object vs autonomous action. The focus in the idea of potential energy is the description of relations (the distance) between static objects. The second factor describes the containment of the potential energy in some objects while the third factor mentions the existence of some blockers, so as to make it possible to have a distance between some objects and the ground. The objects are described below in terms of schemes, using the factor scores on the above factors to characterize them. The patterns of movements of objects' the factor scores in relation to the three factors seem to be different for the two examples of the particular idea particularly for the protagonists and the surface related objects.

The concept (potential energy) in the examples of this idea is seen as an invisible entity which can make other things move. It is an invisible source of potential movement. There was a bigger tendency in the exemplifying context than in the non-exemplifying context, for the potential energy to be a link and not a blocker. It is notable that although out of context of use in an example, around one fourth of the children said that potential energy can stop other things moving, by contrast, both exemplifying contexts resulted in even fewer children seeing this entity as a barrier or a support. Particularly, in the example with the 'child up a tree', there is a movement of the potential energy, towards 'containment' since more children described the entity as contained in something else. Possibly, this increase happens only for the case of 'a child up a tree' and not for the 'flower-pot on a balcony' because the 'child' is more easily imagined as a source of potential movement. The flower-pot on a balcony is not intended to fall, nor expected to. It should just 'stay there'. It's a decoration, rather than an object.

The protagonists which are used in the two types of questionnaire were very different. The child appeared as 'dynamic' and to 'block' other things while the flower-pot is seen as a 'static' object which is not able to 'block' other things. Both protagonists were described as containment. The examples constrained mainly different aspects of the protagonists which interestingly has as a result to reduce the differences between these two entities. In the exemplifying contexts with the pot, there was a substantial decrease in the number of children who said that the protagonist is a rigid thing, and that it is contained in something. So, there were fewer differences between pot and child on the containment factor. Neither protagonists are seen as contained in other things since they contain the potential energy. Also, they appeared less as blockers in the exemplifying contexts. They do not support anything in the examples and this becomes more obvious since they need something else to support them. However, in the case of a 'child up a tree', about three fourths of the children continued to say after seeing it as an example that the protagonist can present autonomy (even though there was a statistically significant decrease comparing the "yes" responses prior to and in the exemplifying context). The particular example could not constrain and successfully reduce the appearance of the autonomy scheme, which appears to be too strong to be "suppressed".

The Structure-related object in both exemplifying contexts was the 'ground'. Mainly, it was described as a blocker (mainly supporter), and containment (mainly as a container). It is not clearly either a containment or a barrier since it can support something but cannot prevent horizontal movement and has not rigidity (the other schemes that had positive loadings for these factors). In both exemplifying contexts there was a substantial decrease of the number of children who said that it is a support and a container. However, in the case of a 'child up a tree' more than half of the children said in the exemplifying context that it is a support. It seems that the tree which supports the child needs to be supported by the ground while the balcony needs to be supported by the building. The building does not play such a crucial role in the example as the tree. This may be why they did not mention the support of the ground to the building.

The objects which are in contact with the Protagonist are the 'balcony' in questionnaire A and the 'tree' in questionnaire B. The Surface related objects in both examples, turned out to be blockers again becoming more similar than they were out of the exemplifying contexts. 'Balcony' and 'tree' were described mainly as supporters. Going from the non-exemplifying context to the exemplifying context, the tree, starting high as a barrier, decreased in this respect. The balcony started (non-exemplifying context) lower as a barrier, but increased. In fact, these changes brought the two, very close together as barriers. Also, in the case of a 'child up a tree' there was an increase in the number of children who said that the tree can make other things move. It seems that the branch is thought of as able to break and make the child move whereas the balcony can not.

Both exemplifying contexts constrain the schemes for the description of the unrelated object (air) to some extent. However the air, in the exemplifying context, continues to be a dynamic invisible entity with the ability to present autonomous action as in the non-exemplifying context. It is notable that while objects related to the example have their associated schemes constrained when the example is presented, the unrelated object does not to any great extent.

In summary, with the special exemption of the scheme 'force' (in the case of the structure-related objects) discussed above, objects in the two examples either stayed close together or moved closer together (mainly the protagonists and the surface related objects which appeared very different out of the exemplifying context), on all factors, when going to the exemplifying context. Both examples constrain successfully most of the irrelevant schemes for this examples. However, the scheme of autonomy appeared too strong to be "suppressed". In some cases the examples constrained different aspects of two objects, reducing the difference between these entities at the level of their factor description.

6.3.2 Expansion

6.3.2.1 Children's own examples of expansion

All children (73) gave some example of the idea: "Almost all solid things, expand when they are heated. This phenomenon is called expansion". However, two of them gave the following counter examples of this idea: "When a brick is warmed up, it does not expand because it is not made from aluminium, copper, iron etc.", "Concrete does not expand because it is not made of iron". About one fourth of the children gave examples similar to those that are used in their textbooks (8 children had an example with 'railways' and 11 of them with 'cables'). That might happen because children do not see expansion normally, so they only know it through text-book examples.

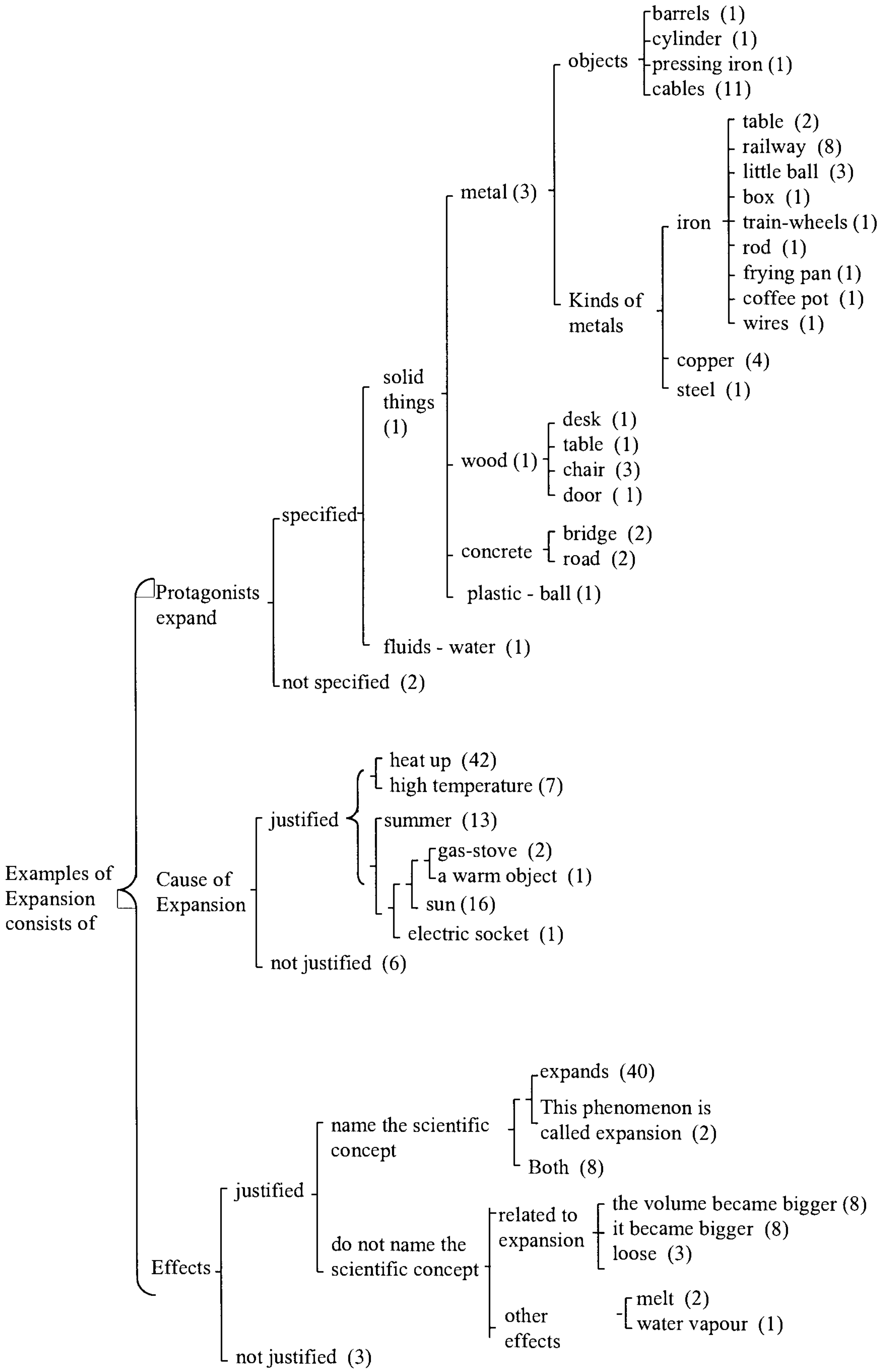
The components of children's examples of expansion fall into the broad categories: (a) a protagonist, (b) the cause of expansion, and (c) the effects of expansion. The network that was constructed from the analysis of children's examples of expansion is shown in Figure 6.10.

All children used a protagonist and only two do not specify a category of things (they just say "things"). The idea that children were given, specifies a category of things as protagonists, "almost all solid things". So, children used as protagonists mainly solid things such as metal, wooden, concrete and plastic objects. However one child used a fluid, water. The most popular protagonists were metals (objects or kinds of metals) and particularly iron objects.

Children's examples of expansion include causes of expansion. Only 6 of the children did not give any cause. The cause of expansion could be a structural related object (mainly the sun), or a particular time characteristic (summer). They used in many cases the description of a process/phenomenon as causes of expansion. Most of the children used heat, or high temperature as the cause of expansion.

Furthermore, almost all the children stated effects of expansion in their examples of the idea (only three did not write any effects). Most of the children named the concept of expansion. They mainly used the expression that "x (the protagonist) expands" or that “the phenomenon is called expansion” or both. Children who did not name the concept used expressions that describe the expansion such as: “the volume became bigger”, “it became bigger”. However only one or two wrote about other effects such as melting or evaporating.

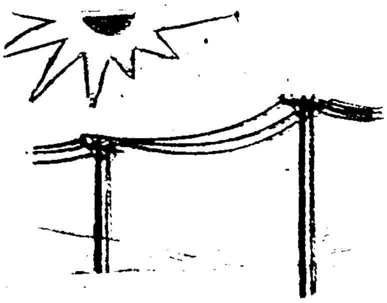
Figure 6.10 Children's examples of expansion



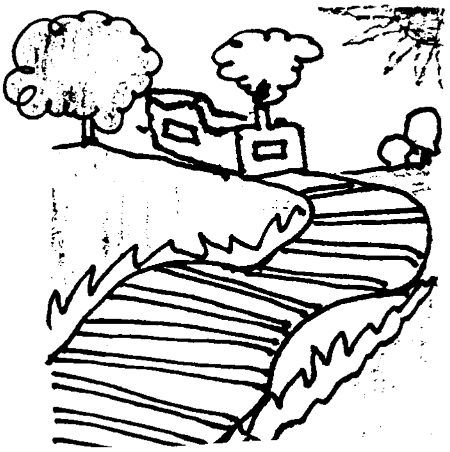
6.3.2.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and one of the two following examples:

> "Almost all solid things expand when they are heated.
> This phenomenon is called expansion"



In the summer the electric wires of the P.C.E are expanded between two pylons because of the high temperature, so they are loose.



In the summer the railways lines, expand because of the high temperature, so they make the line bend up in an arc.

Children were asked to describe in one of the two questionnaires the following five objects:

	(A) example	(B) example
◆ ***Scientific Entity***	expansion	expansion
✳ ***Protagonist***	railway lines	wires
● ***Structure related object***	sun	sun
○ ***Surface related object***	trains	pylons
× ***Unrelated object***	ground	ground

6.3.2.2.1 *Interpretation of the Factors*

The factor scree plot shows that 3 out of 8 factors have eigenvalues bigger than 1. The three factors were retained, and subjected to oblique rotation. The three factors explain 71.7% of the variance. Table 6.3 and Appendix 6.5 presents the results of the analysis, after oblique rotation.

Table 6.3 The factors for expansion

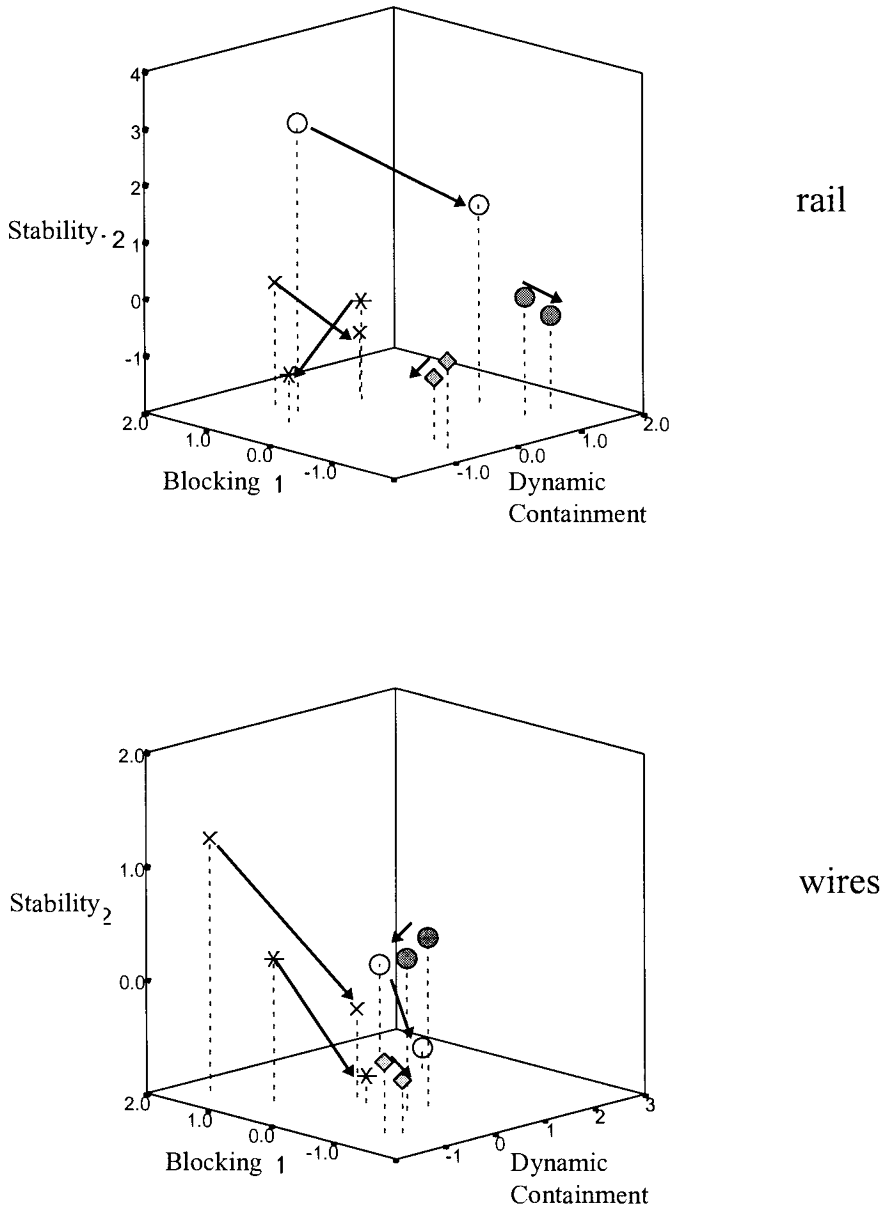
	Factor 1	Factor 2	Factor 3
Support	**+**		
Invisible	**−**		
Barrier	**+**		
Contained thing	+	+	
Autonomy		**+**	
Container		+	
Rigidity			**+**
Force			**−**

Factor 1 has very high positive loadings for "support" and "barrier". Also, it has very high negative loadings for "invisible entity". Factor 1 can perhaps be labelled "Blocking" and appears to be a blocked vs. opened dimension. Factor 2 has the highest positive loading for "autonomy". It also has high positive loadings for "container", and positive loadings for "force" and "contained thing". It may possibly be labelled "Dynamic containment". Factor 3 has very high positive loading for "rigidity" and high negative loading for "force". It might be labelled "Stability" and it may describe a Stability (hardness) vs. flexible dimension. Appendices 6.6 and 6.7 show plots of factors and the percentages of yes responses for each scheme.

6.3.2.2.2 *Analysis of the Expansion examples*

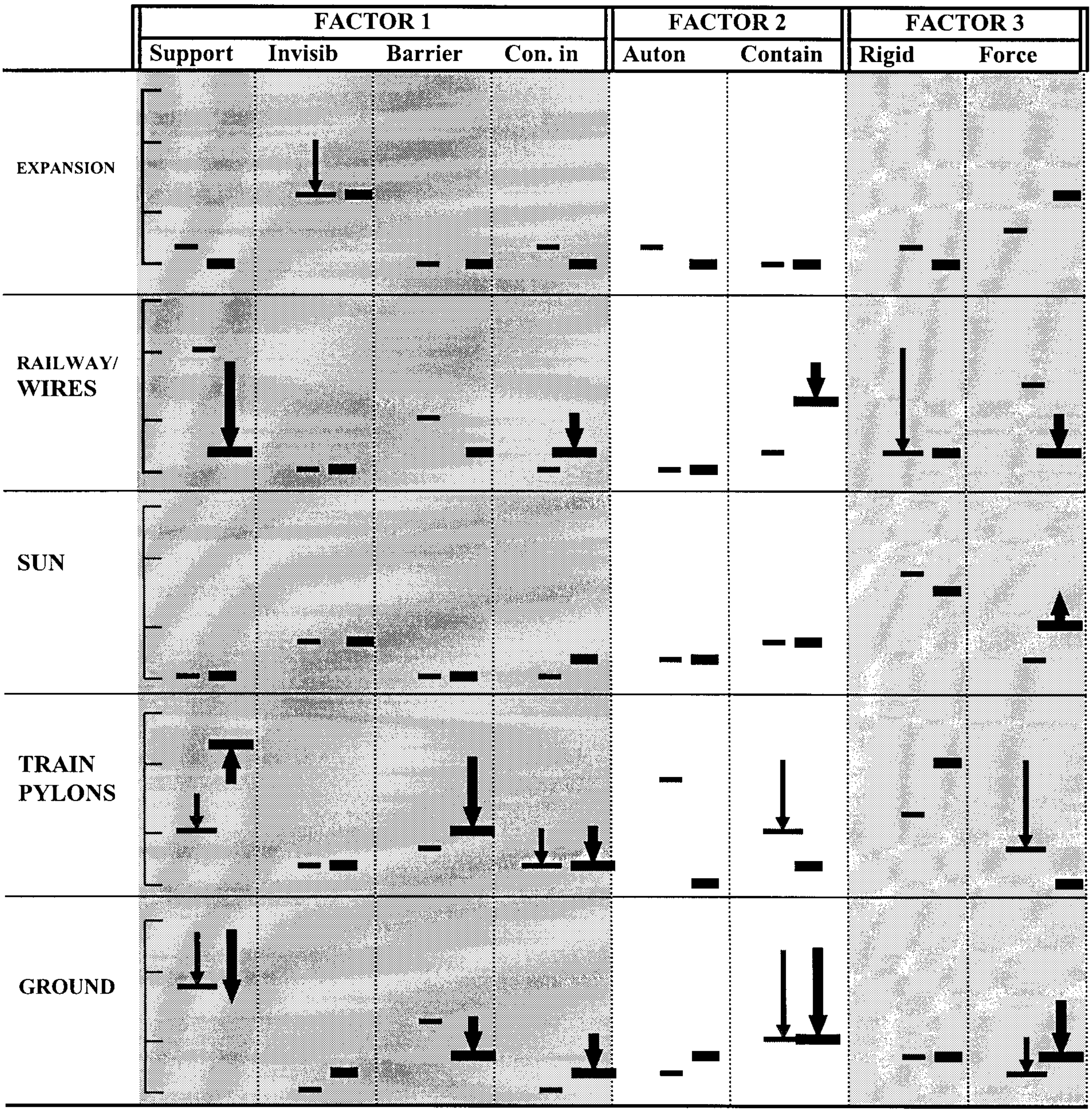
Figure 6.11 shows the factor scores of each object going from the non-exemplifying context to the exemplifying context. Figure 6.12 show how many (in percentages) children described the various objects with each scheme in the exemplifying context and where we had statistical significant differences going from the non-exemplifying context to the exemplifying context.

Figure 6.11 Factor scores and their 'movements' for the examples with the rail (top) and the wires (bottom)



	(A) example	(B) example
	Top Figure	*Bottom Figure*
◆ ***Scientific Entity***	expansion	expansion
✳ ***Protagonist***	railway lines	wires
● ***Structure related object***	sun	sun
○ ***Surface related object***	trains	pylons
× ***Unrelated object***	ground	ground

Figure 6.12 The percentages of children using each scheme to describe objects in the examples of expansion



Both examples appeared to contsrain most of the objects in similar ways. However, in the case of the surface related objects (train and pylons respectively) the patterns of movement of these objects in relation to the factors are very different.

The concept here, ‘expansion’ is not seen as able to block things, and appeared neutral on the dimension of dynamic containment. Also it has not stability. Giving ‘expansion’ in an exemplifying or non-exemplifying context does not seem to make big differences to this entity. It appeared to be an invisible entity mainly prior to using it in an example and to some extent in the exemplifying context. Children seemed to use pragmatic reasoning, since they cannot easily observe the results of expansion in their everyday life. The number of children who said that expansion is an invisible entity in the example with the 'railway' (in which the picture presents a "big" expansion of the railway lines) decreased more than in the other exemplifying context.

The role of protagonist in the two questionnaires was played by the 'railway lines' and by the 'wires' respectively. Both protagonists were seen as good instances of blockers (supporters rather than barriers) out of the exemplifying contexts. In the example with the 'railways', many children continued to say that railways are a support while in the other exemplification context with the 'wires', there was a great decrease in the "yes" responses for the previous scheme, which may be because children think that a part of the railways still support the train which is coming (in the image of the example) while the wires do not support anything in the particular example. Furthermore both protagonists are seen in the examples as less 'stable' things than out of the exemplifying contexts, but for different reasons (decreases happened in different schemes). Children described railways mainly less as rigid things (they can move upwards because of the expansion) and wires as objects that cannot make other things (possibly the electricity) move.

The Structure related objects (sun) appeared as a 'rigid' entity. When it is used in the example with the wires only (not in the other example) the sun appeared as something that can make other things move, presumably because it was the cause of the expansion of wires and so the change of their position.

The Surface related objects which were used in the two exemplifying contexts were very different. The train is a dynamic containment (it is a container and can move when it wants), while pylons are stable blockers. The example with the railway could not constrain to any extent the autonomy of the train. So, in the exemplifying context three fifths of the children said that the train can move when it wants even though they could see in the picture that the railway lines had expanded. In the example with the 'wires' more children described pylons as a support (than out of the exemplifying context) since in this example they supports the wires. A rarely appearing sort of support is when the thing that support other things has a smaller size of surface than the thing that is supported by it. An example of this sort of support appears to be the pylons which support the electric wires. So, pylons in the example with the wires appeared more as supporters in the exemplifying context than in the non-exemplifying context, perhaps because the wires, having expanded, had become more salient and so their need of support is more obvious.

The unrelated object was the ground for both examples. It is mainly a support, a container. In the exemplifying contexts it lost these features. It did not play any role in the examples, and only a very few children described it after the example with some schemes.

So, both examples constrained the schemes that children used in the description of objects - going from the non-exemplifying context to the exemplifying - in a way that made different objects which played similar roles (e.g. protagonists) very similar. However, in the case of the surface related objects, the train and the pylon became more different in the exemplifying context concerning the support scheme. It seems to be a result of the different relations that these objects had with the protagonists. The pylons support the wires in the example while the train is supported by the railways. The appearance of some increases in the exemplifying context show that the examples highlighted some aspects of objects which are well hidden.

6.3.3 Thermal Equilibrium

6.3.3.1 Children's own examples of thermal equilibrium

Almost all of the children gave some example (69 out of 72) of the following idea: "When things come in contact, heat is transmitted always from the warmer to the colder" (see Fig. 6.13). In their examples 16 of them used water as a protagonist which was used as protagonist in the examples of their textbooks. These children described an example similar to the textbook example where we bring into contact two containers with hot and cold water. However, none of them described an example similar to the other example in their textbook where we put a container with cold water inside a bigger container with hot water .

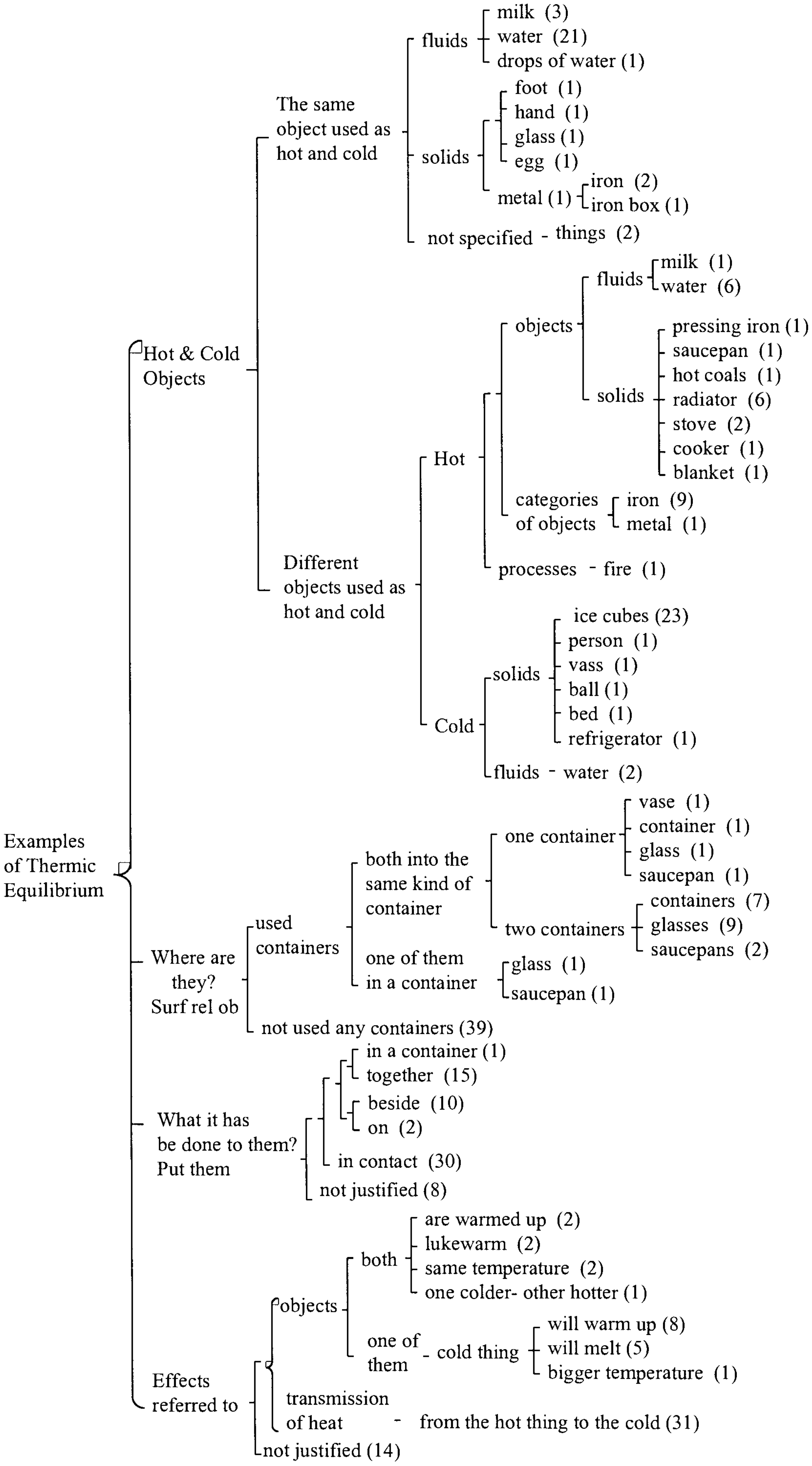
Children used two objects in their examples to show the transmission of heat from the protagonist (hot object) to the structural related object (cold one). The two objects were the same or different. When they were same, fluids were mainly used such as water and milk. However when they were different, solids were mainly used as protagonists as well as structure related objects. Protagonists (hot things) were objects such as a radiator or a category of objects such as a piece of iron. In the case of cold things (structure related things) ice cubes were mainly used.

Thirty nine of the children did not use any container (surface related object) for their protagonist or the structure related object as the examples in their book do. Around half of the children described in their examples some containers of one or both of the protagonists and the structure related object. Few described one of these two objects in a container while the vast majority of them described both objects to be in two similar containers or in the same container. So, most of the children who used surface related objects, described the two objects in containers or a specific kind of container, e.g. glasses.

Almost all described the protagonist as being kept away from the structure related object. So, something had been done to them to allow the transmission of the heat from the hot to the cold one. Children suggested mainly the following three things: thirty wrote that we have to put the containers in contact, fifteen of them wrote that we have to put the substances (water) together and ten argued that we have to put the one container beside the other.

Bringing the hot and the cold things into contact produces an effect. 55 out of 69 children described an effect. In their examples, they described effects which referred to objects or to the process (the transmission of heat). 31 of the children said that heat is transmitted from the hot thing to the cold. When the effect referred to objects children described changes for both objects or just changes referred to the structure related object (it will warm up or it will melt in the case of ice cubes).

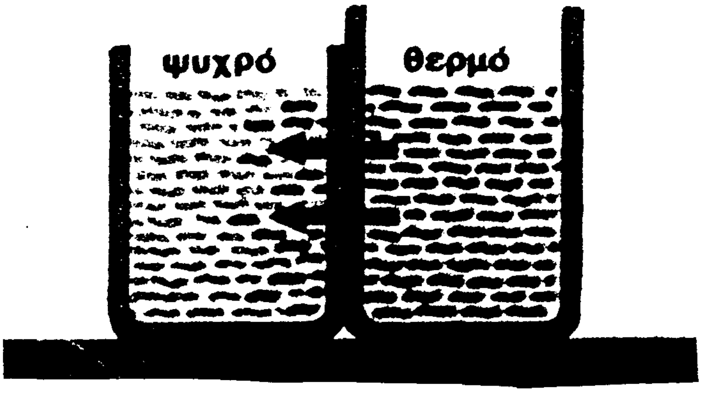
Figure 6.13 Children's own examples of thermal equilibrium



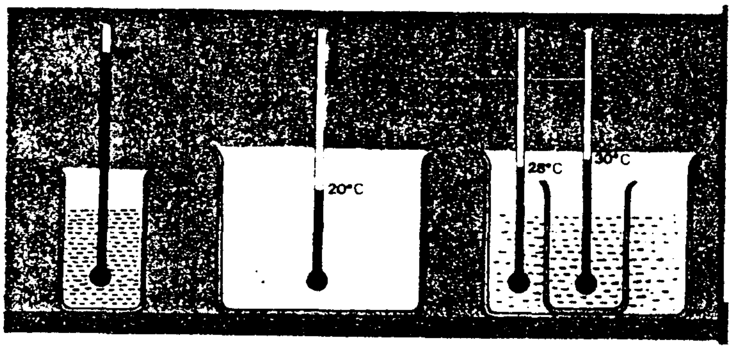
6.3.3.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and one of the two following examples:

> "When things come in contact, heat is transmitted always from the warmer to the colder"



We put two pots with water (one containing hot and the other cold water) in contact. The heat is transmitted from the hot to the cold thing.



We put one metal pot with hot water inside another bigger pot that contains cold water. The heat is transmitted from the hot to the cold thing.

Children were asked to describe in one of the two questionnaires the following five objects:

	(A) example	(B) example
◆ ***Scientific Entity***	heat	heat
✳ ***Protagonist***	hot water	hot water
● ***Structure related object***	cold water	cold water
○ ***Surface related object***	containers	containers
✕ ***Unrelated object***	air	air

6.3.3.2.1 *Interpretation of factors*

The results of the factor analysis indicate that children's responses can be represented by three important factors (see Table 6.4 below, & Appendix 6.8) which explain 94.7% of the variance, one of which -factor 1- is very prominent (explains 60.6% of variance) and the other two factors -factor 2 & factor 3- are minor factors (explain 20.5% and 13.6% of the variance respectively).

Table 6.4 The factors for expansion

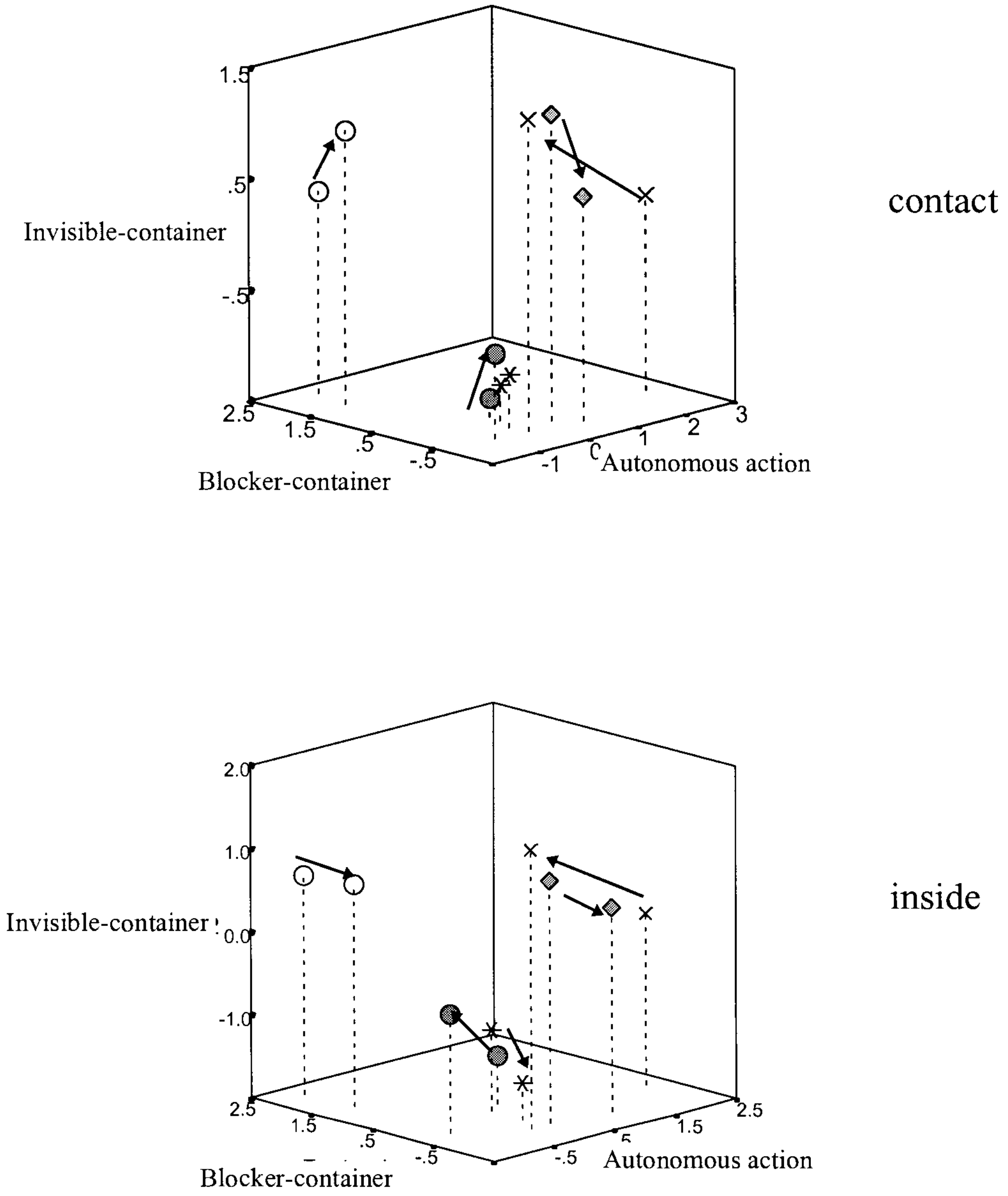
	Factor 1	Factor 2	Factor 3
Support	+		
Rigidity	+		
Container	+		
Barrier	+		
Contained thing		−	
Autonomy			+
Force		-	+
Invisible		+	+

Factor 1 has very high positive loadings on "support", "rigidity", "container", and "barrier”. This factor can be labelled "Blocker-Container". Factor 2 has very high negative loadings for Contained thing and it has negative loading for "force". Also it has high positive loading for invisible entity and positive loading for barrier. Factor 2 can be labelled "Invisible-Container". Factor 3 has very high positive loadings on "autonomy”, “force" and high positive loading on "invisible entity". It can be labelled "Autonomous action by Invisible entities". Appendix 6.9 and 6.10 show plots of factors and the percentages of yes responses for each scheme.

6.3.3.2.2 *Analysis of the equilibrium examples*

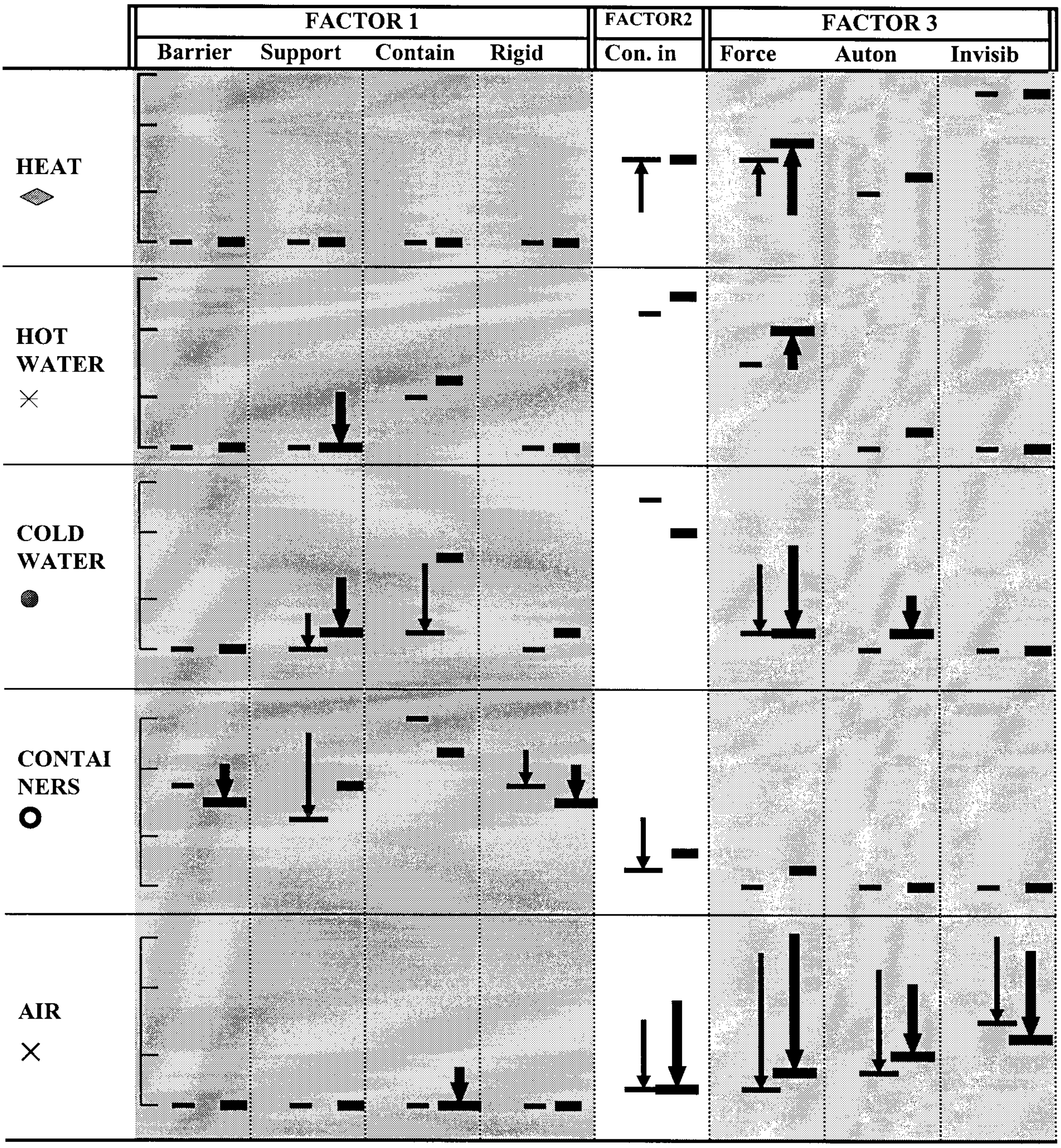
Figure 6.14 shows that the structure of the factor scores for the entities that have a similar role in the two examples of equilibrium was very similar (see also for the description of the figures that follow at the method of analysis section in the introduction). The focus of this study is on the description of whether and how examples constrain the way that children view various entities. So the changes in factor scores rather than their values will be described from Figure 6.15.

Figure 6.14 Factor scores and their 'movements' for the examples with the pots in contact (top) and the one pot inside the other (bottom)



	<u>(A) example</u>	<u>(B) example</u>
	Top Figure	*Bottom Figure*
◆ ***Scientific Entity***	heat	heat
× ***Protagonist***	hot water	hot water
● ***Structure related object***	cold water	cold water
O ***Surface related object***	containers	containers
X ***Unrelated object***	air	air

Figure 6.15 The percentages of children using each scheme to describe objects in the examples of thermal equilibrium



Heat, out of the exemplifying context, appeared as an Invisible-Container, it became neutral as an Invisible-Container when it was used in the context of an example. It happens for different reasons in the two exemplification contexts. On the one hand, more children looking at the 'contact example' described heat as an entity contained in other entities (water), as well as one that can present autonomous action. On the other hand, in the 'inside example' the number of children who said that it can make other things move was increased even more than in the other example. Both increases in 'contained thing' and 'force' variables respectively had as result the decrease of heat's factor score for the Invisible-Container factor since it had negative loadings for these variables.

"Hot water" is not seen as an Invisible-container. Also it is neutral as a Container blocker and as an invisible entity which presents autonomous action. In both example-contexts it lost even more its feature as a container-blocker. In the example with the one container inside another, it lost even more its feature as invisible-container, but in the example with the containers alongside this feature increased. That difference happened because in the exemplifying context with the two pots in contact, the number of children who said that the 'hot water' has a feature of force was more or less the same as prior to its use in an example, while in the other exemplifying context there was an increase in the number of children who attributed the force scheme to the 'hot water'. This increase had as a result the decrease of the factor score for the invisible-container (it has negative loadings for the scheme 'force'). In the exemplifying context with the smaller pot inside the bigger one, the 'hot water' lost significantly its features as support.

Cold water is seen as neutral as a Container-blocker and as an invisible entity which can present autonomous action. The number of the children who said that the "cold water" is a container decreased a lot in the case of the two pots in contact but did not change at all in the exemplifying context with the smaller pot inside a bigger pot. These decreases resulted in the cold water appearing less as a Container-blocker in the examples.

The 'containers' used for liquids (water) are Container-blockers and Surroundings. Also they are not invisible entities which can provide Autonomous action. In the exemplifying context with one pot inside a bigger one, there was a decrease in the number of children who said that the "containers for liquids" are barriers, and rigid things. In the exemplifying context with the two pots in contact, containers for liquid lost even more their features as something that can support other things, as contained things and their rigidity. That had as a result a decrease in the factor scores of the 'containers for liquids' as blocker-containers.

"Air" cannot block other things, but it constitutes a very good example of invisible-container and of an invisible entity which can produce autonomous action. In the exemplifying contexts, there is a decrease in “autonomous action by an invisible entity”, but an increase in it as an invisible container. In the exemplifying contexts, almost none of the children said that air is a support or a barrier. Nor did it constitute an example of a contained thing or of a container. Also, a substantial decrease left only a minority of children saying that "air" has autonomy which can move other things or that it is an invisible entity.

The concept heat appeared in both exemplifying contexts more as an entity that can make other things move. The heat and the hot water to some extent became in the exemplifying contexts dynamic entities from being static entities. It seems that before the examples, the children saw heat as an invisible-container that is around beings on the earth. In both exemplifying contexts, they saw it more as a contained thing in another entity such as the water. It is worth mentioning that similar changes occuring in the two examples at the level of factors can be explained in different ways at the level of schemes as discussed above in the case of heat. So, different examples might constrain the schemes that one can use to describe objects making the entities (that play the same role) similar, but also two examples might constrain different schemes of an entity to make its appearence in the exemplifying context similar at the level of factors.

6.3.4 Inertia

6.3.4.1 Children's own examples of inertia

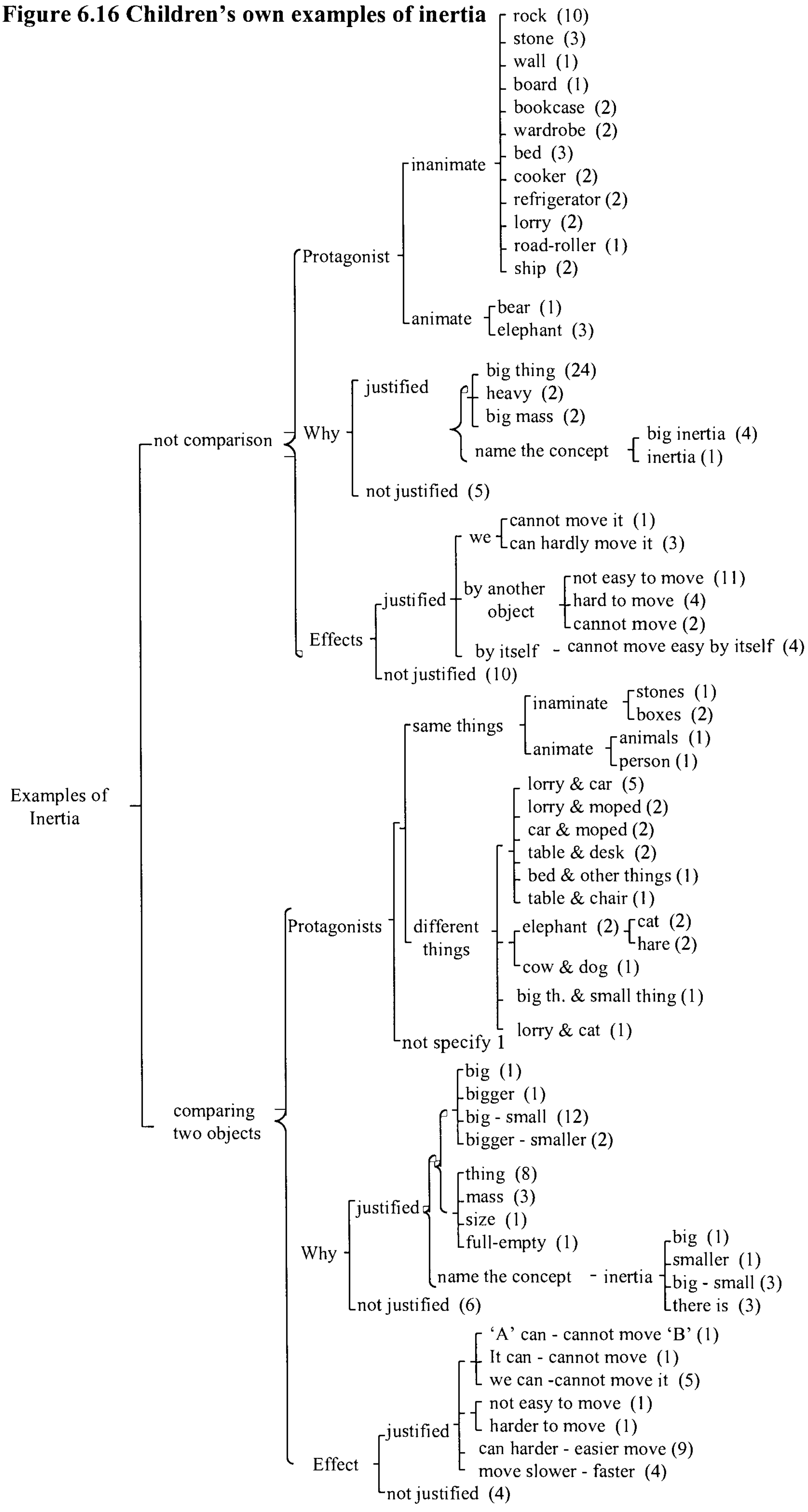
All the children (61) gave some example of the idea: "The bigger the mass things have, the more difficulty they have to move, because they present big inertia" (see Figure 6.16). Five of them described an example similar to one of those used in their textbooks (a lorry will move with greater difficulty and move slower than a car).

The children's examples consist of a protagonist which can or cannot move in a certain way (effect) and a cause that justifies that effect. Almost half the children used in their examples two protagonists describing a comparison between two objects; slightly more used one protagonist. All the children (except one) specified particular objects as protagonists. The children preferred to use inanimate than animate things as protagonists.

In the examples with one protagonist many of the children used as protagonist a rock or a stone. The cause that they are big (24 children) had as effect that they are not easily moved mainly by another object, by us (persons) or by themselves. Very few of the children (5) described inertia itself as a cause, or named it as a concept.

In the examples with two protagonists, the comparisons were between similar or different objects. In the case of similar objects a big and a small object of the same kind was used. In the case of different objects, the children mainly compared a lorry with a car or a moped. Making a comparison between the two objects they said that the big thing can move with a greater difficulty or less speed while the small thing can move more easily or faster, or that the big thing cannot move while the small thing can. There were some children who compared an elephant with smaller animals such as a cat or a hare. As above they also used as the cause of the difference in movement the difference in their size (big-small). Some (more than in the examples with one protagonist) mentioned inertia as a cause and named difference in inertia of these objects.

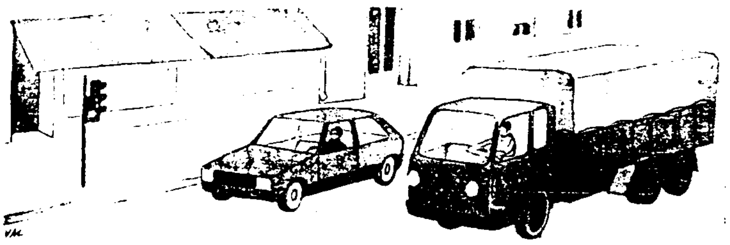
Figure 6.16 Children's own examples of inertia



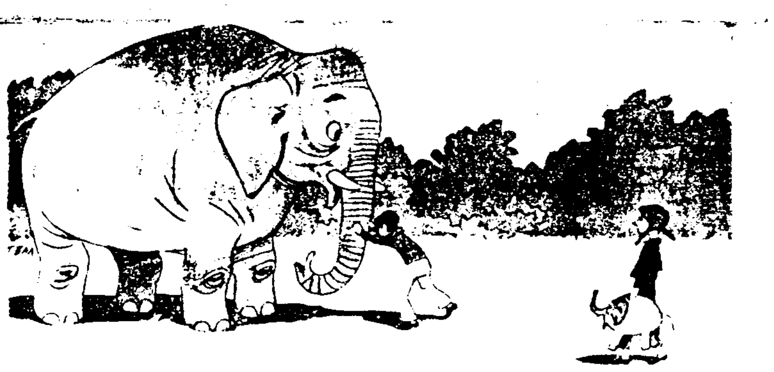
6.3.4.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and one of the two following examples:

> "The bigger the mass things have, the more difficult they have to move, because they present big inertia"



A lorry that has bigger mass than a car will move with greater difficulty and move slower than the car.



A child can easily move a small toy-elephant, but it is much more difficult to make a big elephant move.

Children were asked to describe in one of the two questionnaires the following five entities before and after they were presented with one of the pictures showing the entities together with the idea they exemplify:

	(A) example	(B) example
◆ ***Scientific Entity***	inertia	inertia
✳ ***Protagonist***	lorry	elephant
● ***Structure related object***	car	toy elephant
○ ***Surface related object***	ground	ground
× ***Unrelated object***	air	child

6.3.4.2.1 *Interpretation of the Factors*

The factor scree plot shows that 3 out of eight factors have eigenvalues bigger than 1. The three factors explain 80.6% of the variance. The rotated factor matrices for the oblique solution are provided in Table 6.5 and in Appendix 6.11.

Table 6.5 The factors for inertia

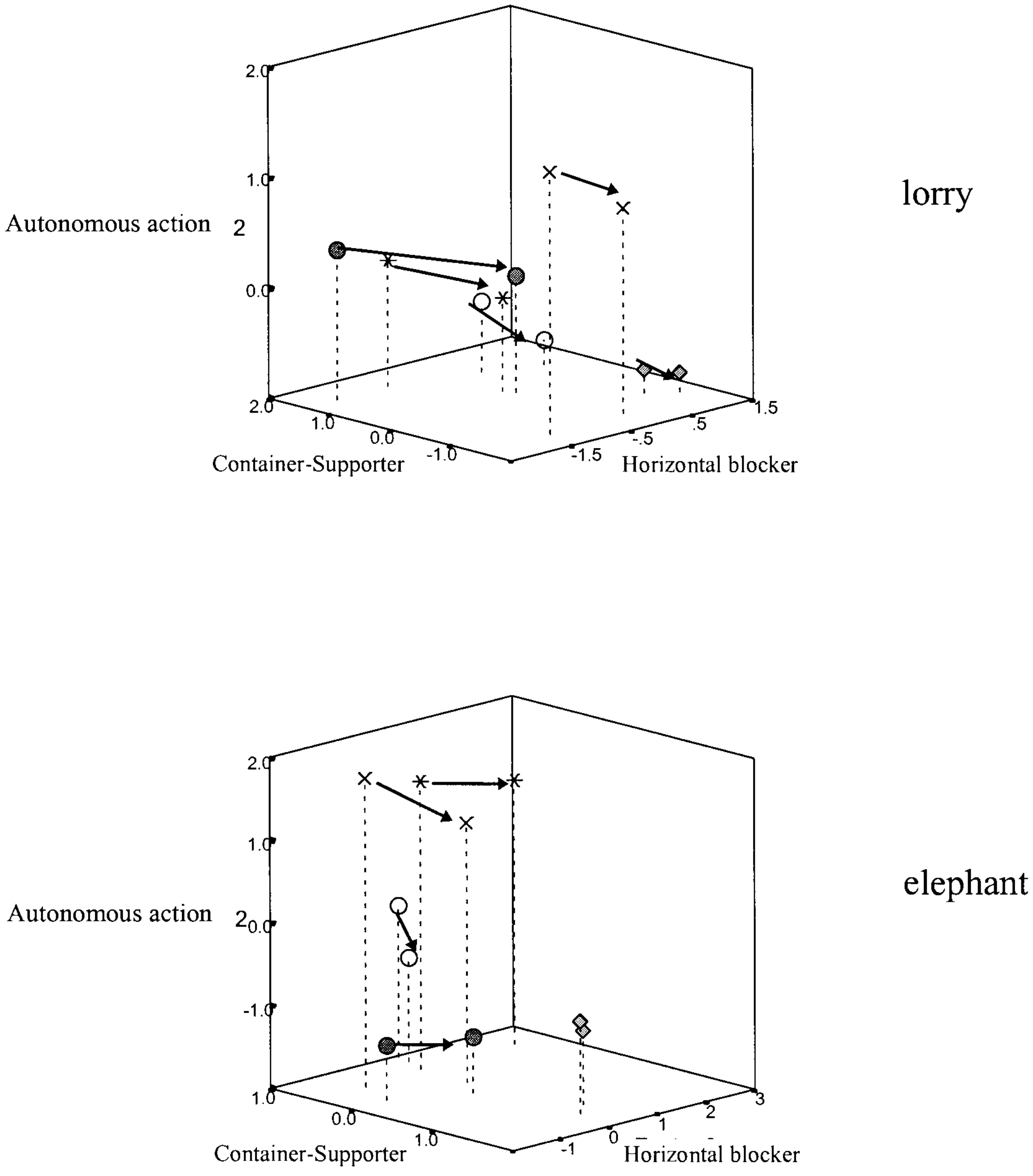
	Factor 1	Factor 2	Factor 3
Invisible	−		
Rigidity	+		
Support	+		
Container	+		
Force		+	
Autonomy		+	
Contained thing			−
Barrier			+

Factor 1 has very high positive loadings on "rigidity", "support" and very high negative loadings on "invisible entity". It also has a high positive loading on "container". It can be labelled "Container-Supporter". Factor 2 has very high positive loadings for "force" and "autonomy". It can be labelled "Autonomous action". Factor 3 has very high positive loading for "barrier" and very high negative loading for "contained thing". It can be labelled "horizontal blocker" . Appendix 6.12 and 6.13 show plots of factors and the percentages of yes responses for each scheme.

6.3.4.2.2 *Analysis of the inertia examples*

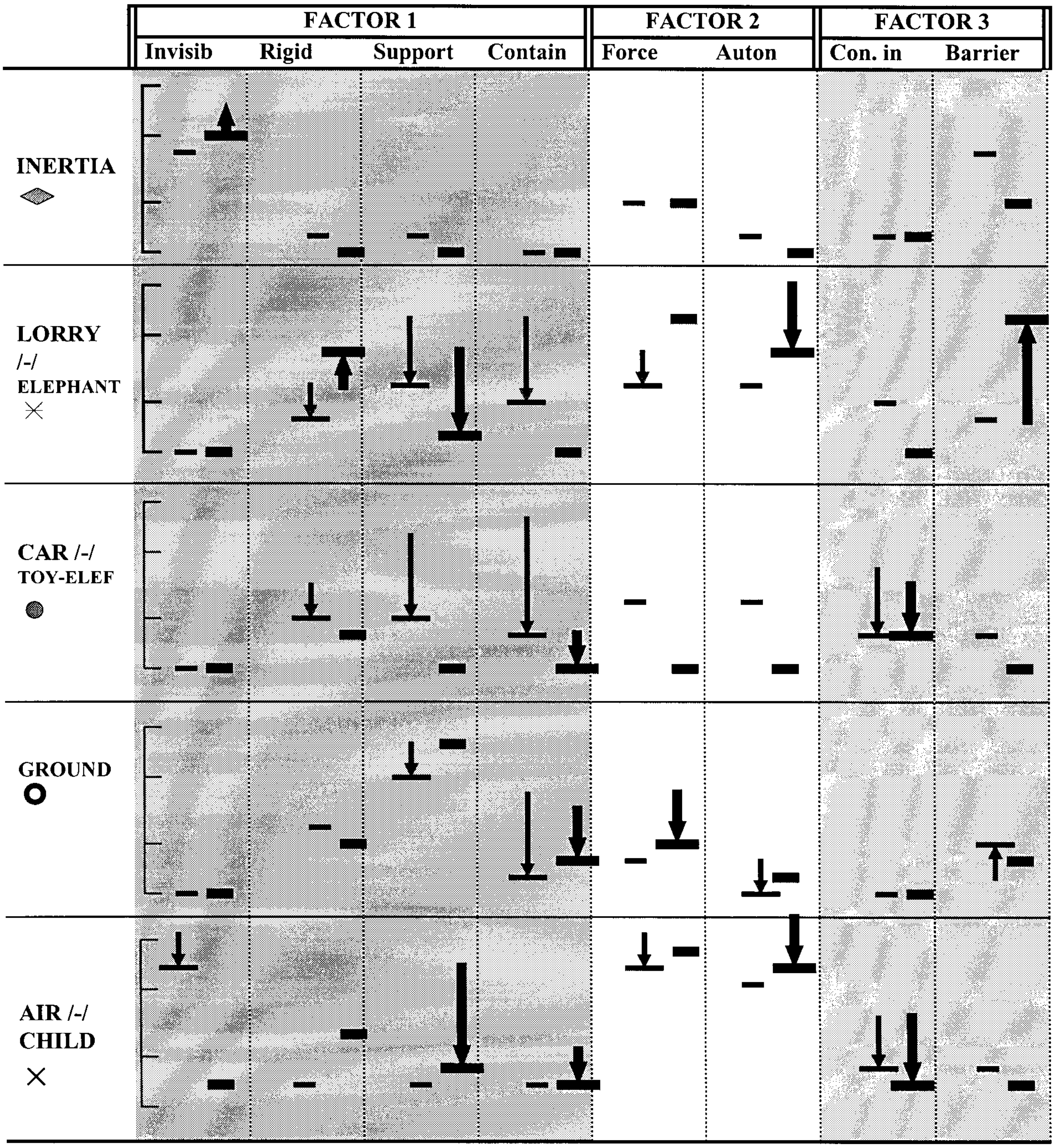
The following figures, (Fig. 6.17 & 6.18) show how the factor scores for each object and the percentages of children who used various shemes to describe objects changed going from the non exemplifying to exemplifying context.

Figure 6.17 Factor scores and their 'movements' for the examples with the lorry (top) and the elephant (bottom)



	<u>(A) example</u>	<u>(B) example</u>
	Top Figure	*Bottom Figure*
◆ ***Scientific Entity***	inertia	inertia
* ***Protagonist***	lorry	elephant
● ***Structure related object***	car	toy elephant
○ ***Surface related object***	ground	ground
× ***Unrelated object***	air	child

Figure 6.18 The percentages of children using each scheme to describe objects in the examples of inertia



In this task "inertia" was the scientific concept. It is seen neither as a Container-Supporter nor as able to present autonomous action. It appeared to some extent as a horizontal blocker. Comparing the exemplifying with the non-exemplifying contexts, there were no big changes in factor scores on inertia for each factor, although in the exemplifying context with the lorry, inertia tended to have a bigger factor score as a horizontal blocker than prior to using it in an example, while in the exemplifying context with the elephant its factor score on this becomes smaller. Also, around half of the children said that inertia is an invisible entity in the non-exemplifying context, with a small increase in this number in the exemplifying context with the lorry. However in the group which had the elephant as an example, most of the children said that inertia is an invisible entity. So, inertia had different behaviour in the two exemplifying contexts mainly in respect of the schemes barrier and invisible entity.

There were two different protagonists in the two exemplifying contexts. The ‘lorry’ which attempts to move by itself (or by a human who was inside the system) and the elephant which a child attempted to move. The lorry is mainly seen as a container which can support other things (high factor score for the factor container-supporter) while the elephant is seen as something that has autonomy and can make other things move (high factor score for the factor autonomous action). In the contexts of use in examples, the elephant became mainly a horizontal rigid blocker while the lorry lost a lot of all its features.

Both examples from the text book were based mainly on comparisons (between lorry and car, and between elephant and toy-elephant). The ‘car’ and the ‘toy-elephant’ were the Structure related objects. The car is seen as a container which can support other things while the toy elephant is seen as a contained thing rather than a container. In the exemplifying context, the car was neutral concerning the factors of Container-Supporter and autonomous action, and had a big decrease as a horizontal barrier, whilst the toy-elephant became more negative as a Container blocker. In the contexts of use in examples, the difference between the elephant and the toy-elephant for the schemes of barrier and rigidity is clear, there was a substantial increase in the number of children who described the elephant as a rigid barrier while only some children used the same schemes for the toy-elephant. In contrast, there is no big difference in the schemes that were used for the description of the car and the lorry

The Surface related object (ground) is mainly a support, a container (container-support). In both exemplifying contexts it appeared less as a container. In the exemplifying context with the lorry, it became less a support and more a barrier. However, in the exemplifying context with the elephant, it became somewhat more a support and less a barrier. The idea used for the concept of inertia focused on the difficulty of making any change in the position of things. Something therefore had to appear as a blocker. In the exemplifying contexts of this idea children describe the elephant (the protagonist) as the horizontal blocker while in the lorry-example inertia (the concept) and to some extent the ground (the Surface related objects) played the role of horizontal blockers.

The unrelated objects for this idea were the air and the child (it is not clear that the child is a good choice as 'unrelated' object. However, it turned out that the behavior of its factor scores shows a pattern very similar to those of other unrelated objects). Both the air and the child are seen as something that can present autonomous action. The air is seen neither as a Container blocker or a horizontal barrier while the child is seen as a container blocker rather than a horizontal barrier. In the context of using them in an example, both lost some of their autonomous action feature. Also the air kept constant its negative factor score as a container blocker and became neutral as horizontal barrier while the child became a horizontal barrier rather than a container blocker. The 'air' and the 'child' lost their features in the examples, presumambly because they were unrelated to the idea.

Both exemplifying contexts do not make children see inertia very differently. The examples constrain most of the schemes that describe objects which play a similar role in the two examples, to make them more similar than they were out of an exemplifying context. The main exemption in that rule is the case with the protagonists: in contrast with the lorry, the elephant is seen more as a rigid thing, going from the non-exemplifying to the exemplifying context. However, these two objects became more similar at the level of the factor scores (and for the factor 1 which includes the scheme of rigidity) going from the non-exemplifying to exemplifying context.

6.3.5 Upthrust

6.3.5.1 Children's own examples of upthrust

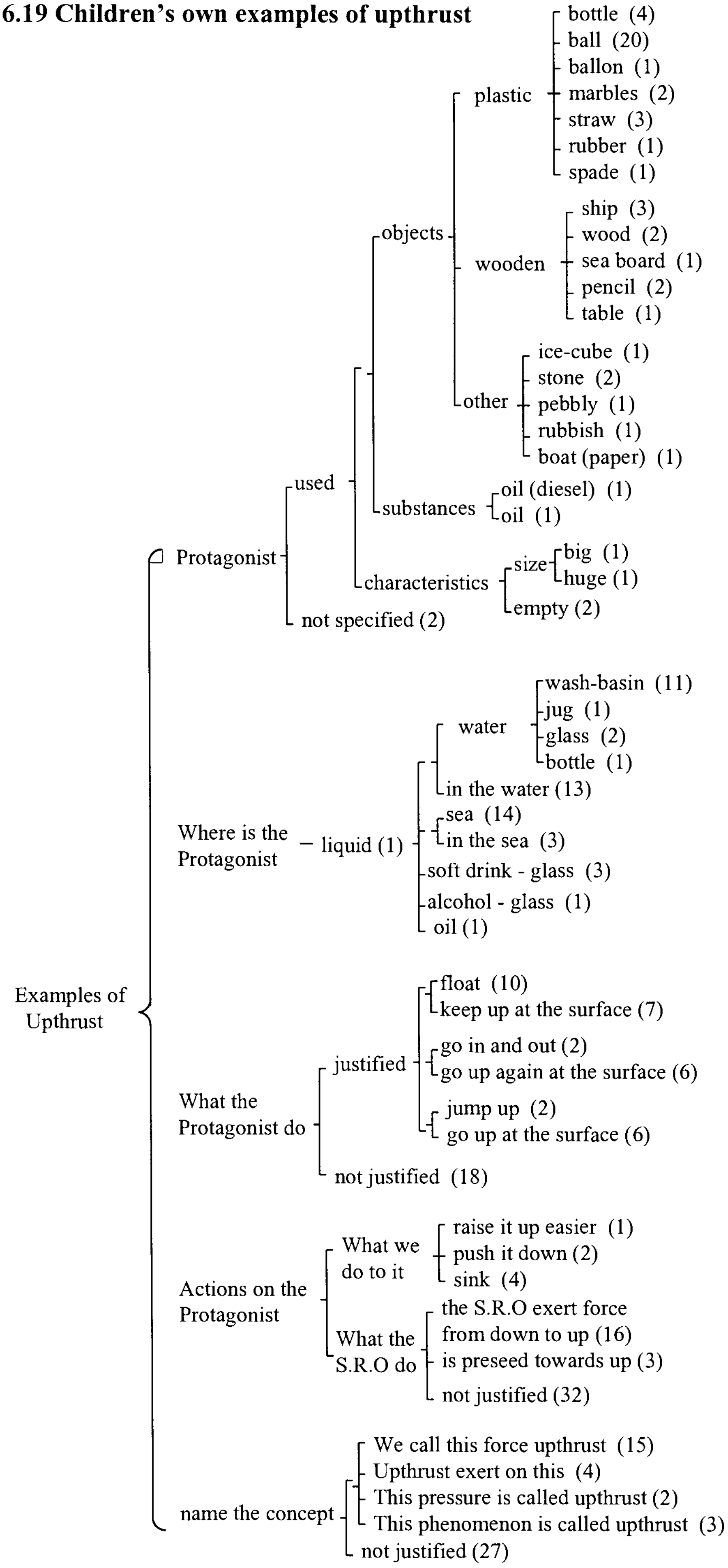
Most of the children (57 out of 63) gave some example of the idea "on a thing that it is in a liquid there is a force acting upwards from the liquid. This force is called upthrust". Twenty of them used in their examples a ball as a protagonist and gave examples similar to (but not the same as) the textbook example where a child attempts to sink a ball in a washbasin with water. However, just one child gave an example similar to the other example in their textbooks where a child can more easily lift a stone in the sea than out of it. Figure 6.19 shows the network that was constructed from the analysis of children's examples of upthrust.

Almost all children gave an example using a specified protagonist. Protagonists were mainly objects or in some cases substances. Objects were made mainly of plastic or wood. These materials can float at the surface of the water and make the existence of the upthrust obvious. Many children used a plastic ball as protagonist.

All children used a liquid, mainly water as a structure related object. The three major categories that were used are the following: thirteen children said that the protagonist is in water, eleven said that it is in a wash basin with water, and fourteen of them that the protagonist is in the sea.

Most of the children justified what the protagonist does in/on the structure related object. It floats or goes up (again) at the surface or the structure related object keeps it up at the surface. So, most of the children defined the position of the protagonist since it was the evidence for the force that the structure related object exerts on it. In contrast with the examples of their text books which used persons as surface related objects, very few children's examples included any surface related object. Only four of them said that we sink the protagonist, two of them that we push it down, and just one that we raise it up more easily. Around half of the children named the scientific concept upthrust in their examples. Most of the children who did not use the name upthrust gave a description of what the structure related object does to the protagonist, that is, it exerts a force from down to up.

Figure 6.19 Children's own examples of upthrust

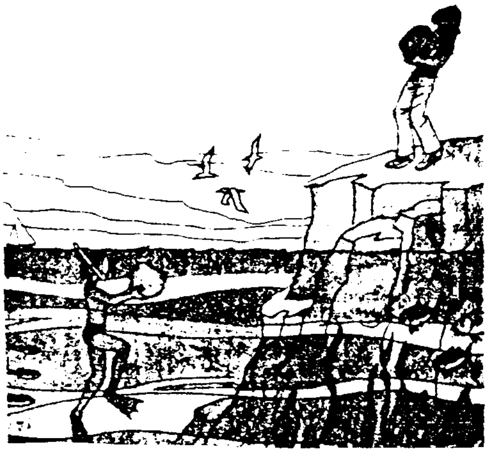


6.3.5.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and one of the two following examples:

"On a thing that is in a liquid there is a force acting upwards from the liquid"

It is very difficult to push down a ball into the water, if you let it free it will come out, because of the upthrust that it gets from the water.



A thing seems lighter in water than out of it, because of the upthrust from the water.

Children were asked to describe in one of the two questionnaires the following five entities before and after they were presented with one of the pictures showing the entities together with the idea they exemplify:

	(A) example	(B) example
◆ ***Scientific Entity***	upthrust	upthrust
⋇ ***Protagonist***	ball	stone
● ***Structure related object***	water	sea
○ ***Surface related object***	child	child
✕ ***Unrelated object***	plastic basin	ground

6.3.5.2.1 Interpretation of the Factors

The factor scree plot shows that 3 out of 8 factors have eigenvalues bigger than 1. Oblique rotation extracted three factors (see Figure 6.10 below and Appendix 6.14) that accounted for 70.1% of the variance.

Table 6.6 The factors for upthrust

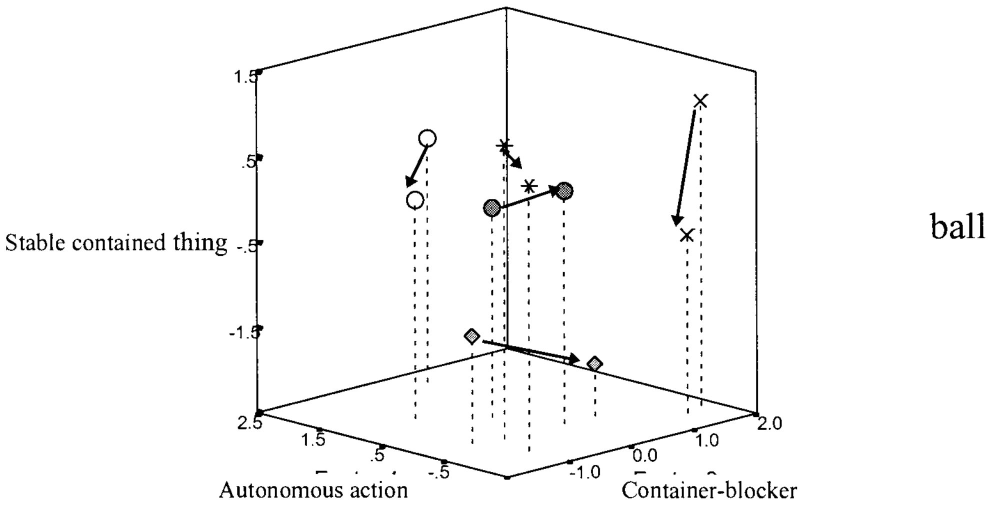
	Factor 1	Factor 2	Factor 3
Force	**+**		
Autonomy	**+**		
Invisible		**−**	
Rigidity		**+**	
Contained thing		**+**	
Support	+		**+**
Barrier			**+**
Container			+

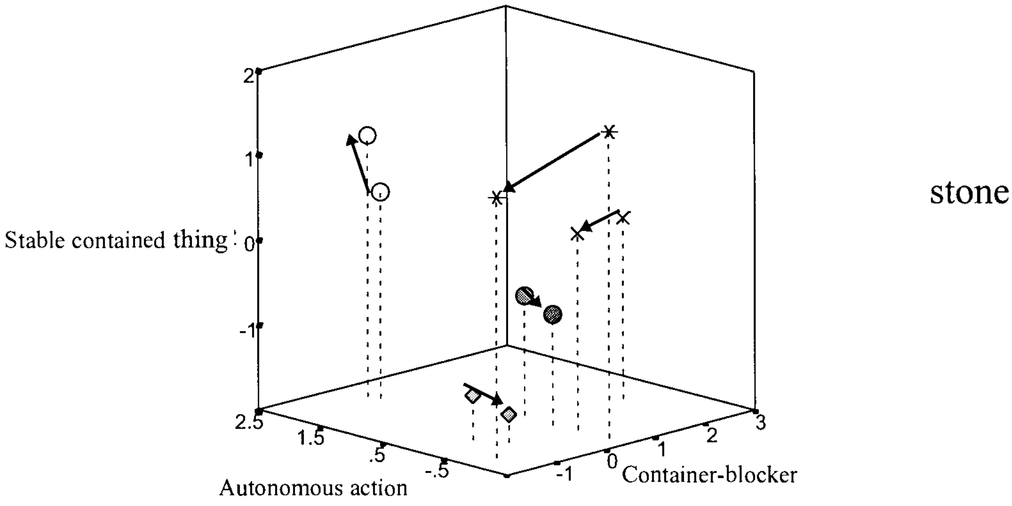
Factor 1 has very high positive loadings for "force" and "autonomy". It can be labelled "Autonomous action". Factor 2 has very high positive loadings for "rigidity" and high positive loading for "contained thing". Also it has high negative loadings for "invisible entity". It can be labelled "Stable Contained thing". Factor 3 has high positive loadings for "support" and "barrier" and positive loading for "container". It can be labelled "Container-blocker". Appendices 6.15 and 6.16 show plots of factors and the percentages of yes responses for each scheme.

6.3.5.2.2 Analysis of the Upthrust examples

Figure 6.20 shows that the factor scores for the entities which have a similar role in the two examples of upthrust were different for many of them: protagonist, structure related objects and unrelated objects (see also for the description of the figures that follow at the method of analysis section in the introduction). However the changes that happened going from the non-exemplifying to exemplifying context and represented in the Figure with the arrows for these entities were similar. Figure 6.21 shows the changes going from the non-exemplifying to exemplifying contexts, in the percentages of children who described the objects using various schemes.

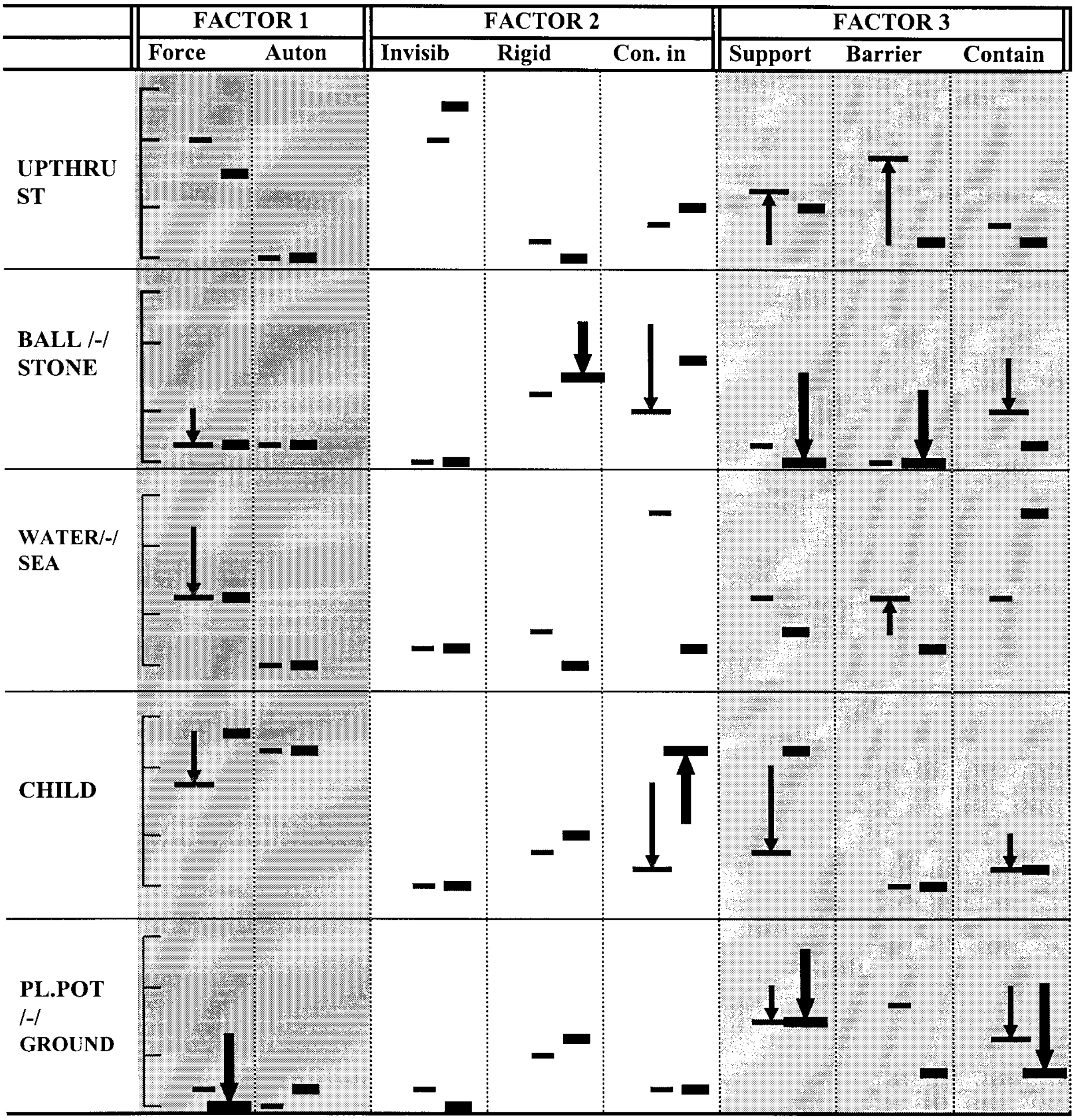
Figure 6.20 Factor scores and their 'movements' for the examples with the ball (top) and the stone (bottom)





	(A) example	(B) example
	Top Figure	*Bottom Figure*
◆ ***Scientific Entity***	upthrust	upthrust
✳ ***Protagonist***	ball	stone
● ***Structure related object***	water	sea
○ ***Surface related object***	child	child
× ***Unrelated object***	plastic basin	ground

Figure 6.21 The percentages of children using each scheme to describe objects in the examples of upthrust



Upthrust is neither a stable contained thing nor a container-blocker and it is negative to some extent for autonomous action. It is seen as an invisible entity. In the exemplifying context with the ball, 'upthrust' appeared as container-blocker (it was described as a barrier) but not in the other context. This perhaps happens because the child in the exemplifying context with the ball attempted to push the ball and something like a barrier rejected this movement, while in the exemplifying context with the stone, the upthrust helps the child to lift the stone up. More children in both exemplifying contexts described it as something that can make other things move and support other things than

than they did prior to using it in an example. Upthrust appeared as a container blocker in the example with the ball (substantial increases in the number of children who said that upthrust is a barrier and support).

The protagonists were the ball and the stone respectively. The ball is seen as a stable object contained in other things which is not a container blocker and does not have autonomous action. In the context of use in an example, the ball appeared less as a stable contained in thing. The stone is a stable contained thing and a container blocker but does not have autonomous actions. In the exemplifying context, it appeared less as a stable contained thing and was no longer a container blocker. In the exemplifying contexts the differences between the ball and the stone are described by the schemes contained thing, and container. The stone is described by children as a contained thing (in the sea) while the ball rather than the stone is described by them as a container (full of air).

Water is seen as being able to present autonomous action to some extent but it is neutral with respect to the other factors. In the exemplifying context, the children thought of it more as a container-blocker (more children said that the water is a barrier) and even more as a stable contained thing; it then appeared no longer as having autonomous action. The sea is seen to some extent as a container-blocker which is neutral in autonomous action and is not a stable contained thing. In the examples, more children said that the sea rather than the water was the container. This may happen because in the picture some part of the ball was not in the water, and it did not appear as a good instance of a container.

The child is seen as something contained in other things and a support in the case of the example with the sea . In both exemplifying contexts it can make other things move and it has autonomy.

Unrelated objects appeared as container-blockers. They were described out of the context of using them as examples, as rigid things, which can support or block things. However in the context of examples, they lost a lot of these features.

Both examples appeared to constrain schemes of objects in a similar way. However, in the case of the surface related objects, more children described in the example with the stone the ‘child’ as a supporter and a contained thing (in the sea) while fewer children in the example with the ball described it using these schemes. It is worth mentioning that some big increases occurred in the number of children going from the non-exemplifying to exemplifying context. In the example with the ball more children described upthrust as support and barrier. The particular example highlighted these schemes of upthrust that are well hidden .

6.3.6 Counter Example-Heat

6.3.6.1 Children's own examples of transmission of heat

30 out of 38 gave a counter example of the idea "a lot of things allow heat to pass through their mass easily". Six of them used as counter example a protagonist similar to the example that is used in their textbook (a glass rod). Five gave as protagonist a thing that does allow heat to pass through their mass such as iron or water.

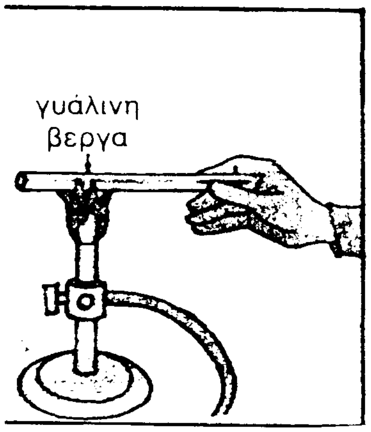
Most of the children wrote as an example just a protagonist without any other component. Children mainly used as protagonists the following:
(a) wood (9) or wooden objects (3) such as a window or a fence,
(b) glass (1) or a glass rod (6), and
(c) plastic (5) or a plastic object such as a ball (1).

However, a small minority of children described the place where we have to put the protagonist to see that it did not allow the heat to pass through it. They suggested putting them on a radiator (2), a fire (3), a fireplace (1) or in the sun (2).

6.3.6.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and example:

"A lot of things allow heat to pass through them easily"



We can touch the edge of a glass tube without getting burnt, because the glass tube doesn't let the heat pass easily through it.

Children were asked to describe in a questionnaire the following five objects:

◆ ***Scientific Entity***	heat
⋇ ***Protagonist***	glass
● ***Structure related object***	gas stove
○ ***Surface related object***	hand
✕ ***Unrelated object***	air

6.3.6.2.1 Interpretation of the Factors

The Factor scree plot shows that 2 out of eight factors have eigenvalues bigger than 1. The two factors explain 78.9% of the variance. The rotated factor matrix for the varimax solution are provided in Table 6.7 and in Appendix 6.17.

Table 6.7 The factors for the transmission of heat

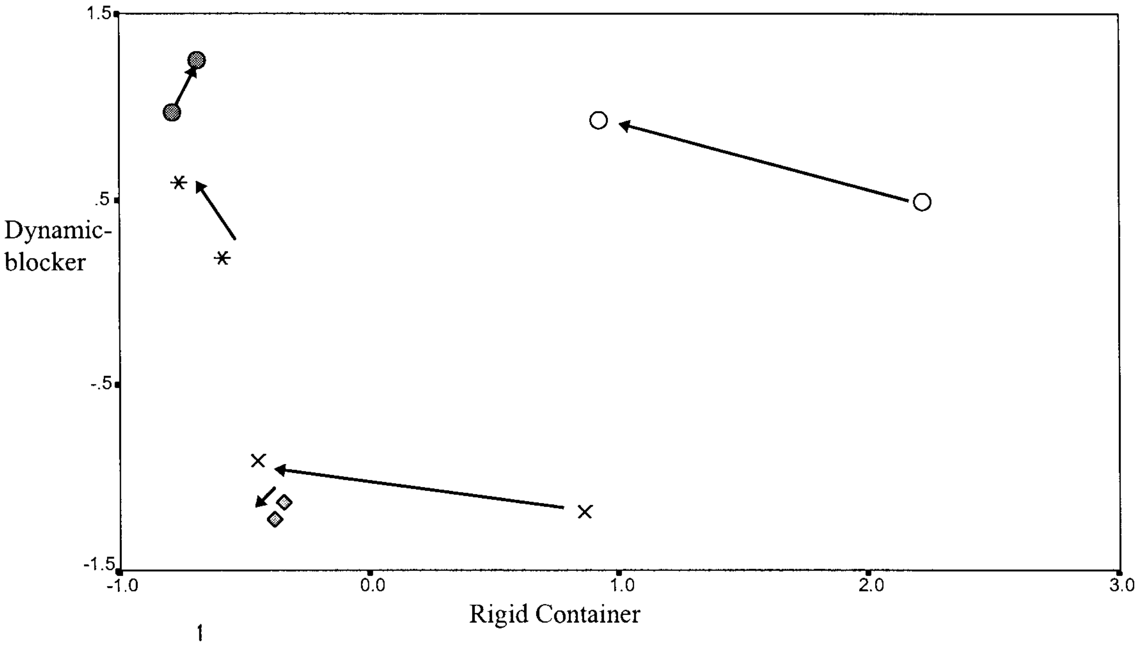
	Factor 1	Factor 2
Autonomy	**+**	
Force	**+**	
Barrier	**+**	
Contained thing	+	
Invisible		**−**
Support		**+**
Container		**+**
Rigidity		**+**

Factor 1, has very high positive loadings for 'barrier', 'force', 'autonomy' and high positive loading for 'support'. It can be labelled 'dynamic blocker'. Factor 2, has very high positive loading for 'container', 'rigidity' and very high negative loading for 'invisible entity'. It can be labelled 'rigid container'.

6.3.6.2.2 Analysis of the counter example about the transmission of heat

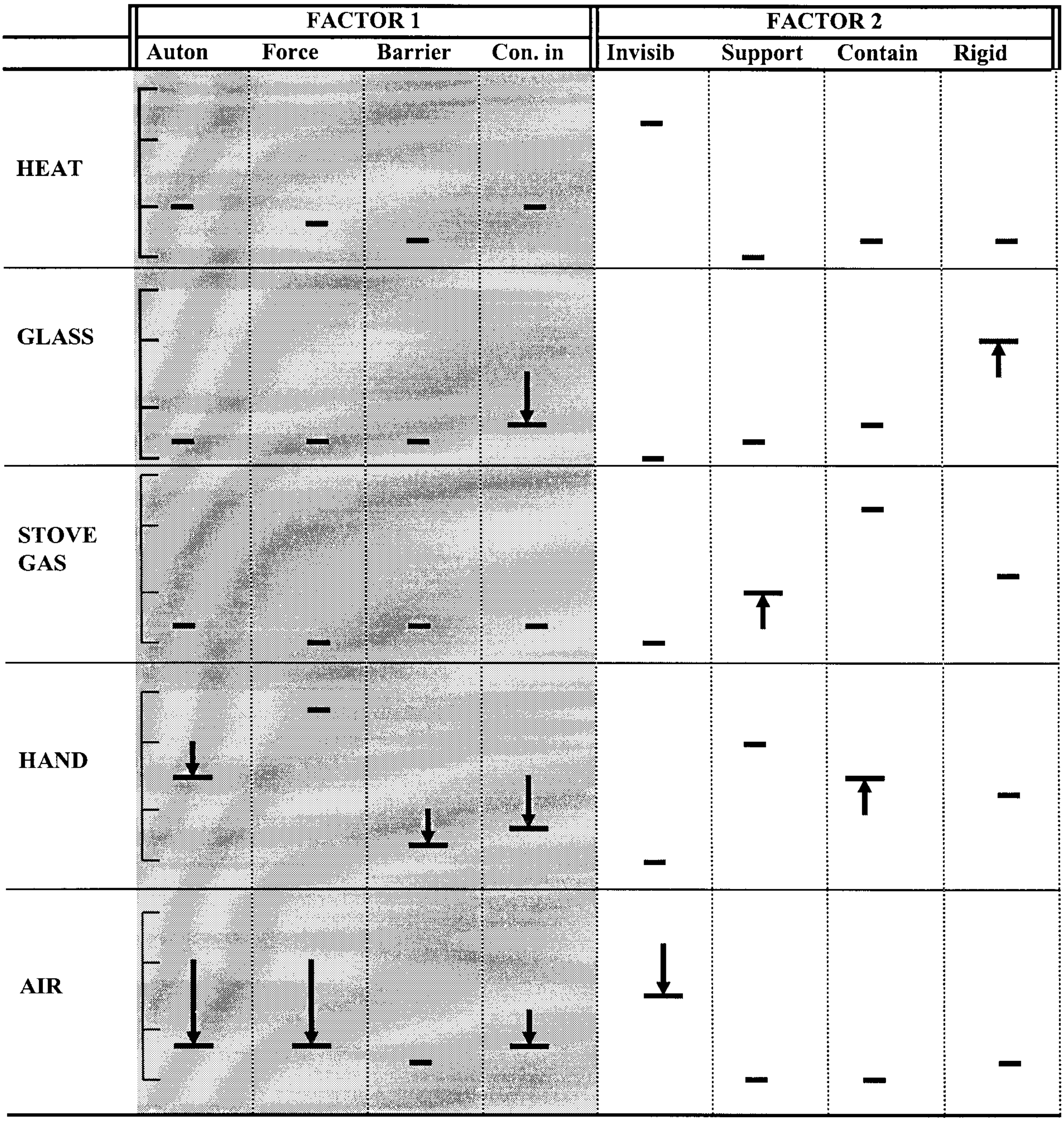
Figure 6.22 shows that the structure of the factor scores for the entities as they were described both in an non-exemplifying and in an exemplifying contexts by children (see also for the description of the figures that follow at the method of analysis section in the introduction). Figure 6.23 shows how many children used the various schemes to describe each entity and which schemes were preferred more or less (only statistically significant difference are represented) by children going from the non-exemplifying to exemplifying context.

Figure 6.22 Factor scores and their 'movements' for the example with the glass



◈ ***Scientific Entity***	heat
✳ ***Protagonist***	glass
● ***Structure related object***	gas stove
○ ***Surface related object***	hand
× ***Unrelated object***	air

Figure 6.23 The percentages of children using each scheme to describe objects in the counter-example of transmission of heat



'Heat' is neither a 'dynamic blocker' nor a 'rigid container' in all contexts. Children used mainly just one scheme to describe 'heat', invisible entity. There were no big changes in children's responses between the non-exemplifying and the exemplifying context.

The protagonist was the glass. 'Glass' is not seen as a 'dynamic blocker' but it is seen to some extent as a 'rigid container'. In the context of use in an example it became more a ‘rigid container’ since there was an increase of the number of the children who described the ‘glass’ as a ‘rigid’ thing.

‘Gas-stove’ is seen as a ‘rigid container’. In the exemplifying context the ‘gas-stove’ became even more a ‘rigid-container’. Many of the children described it as a container, around half described it as a ‘rigid’ thing, and there was a statistically significant increase in the number of the children who said that the gas-stove is a support.

The person’s hand that keeps the glass above the gas-stove is the surface related object. The ‘hand’ is described as a ‘dynamic blocker’ and to some extent as a ‘rigid container’. In the exemplifying context it appeared more as ‘rigid container’ (more children described it as a ‘container’) and lost most of its features as ‘dynamic blocker’.

‘Air’ is to some extent a ‘dynamic blocker’ and it is not a ‘rigid container’. In the exemplifying context it appeared as not a ‘dynamic blocker’. It lost its features as a thing that can make other things move, a contained thing and as a thing that has autonomy.

The counter example did not very much constrain the scientific entity, the protagonist and the structure related object. More changes appeared in the case of the surface related and unrelated objects.

6.3.7 Counter example-Gravity

6.3.7.1 Children's own examples of gravity

32 out of 38 children wrote a counter example of the particular idea "when things go up they must come down (on the ground), because of gravity" (see Fig. 6.20). Most of them thought of the word 'must' as meaning 'immediately' and gave as a counter example a thing that will come down only after some time. Furthermore, only four children gave a counter example similar with that used in their textbooks (a rocket or a satellite).

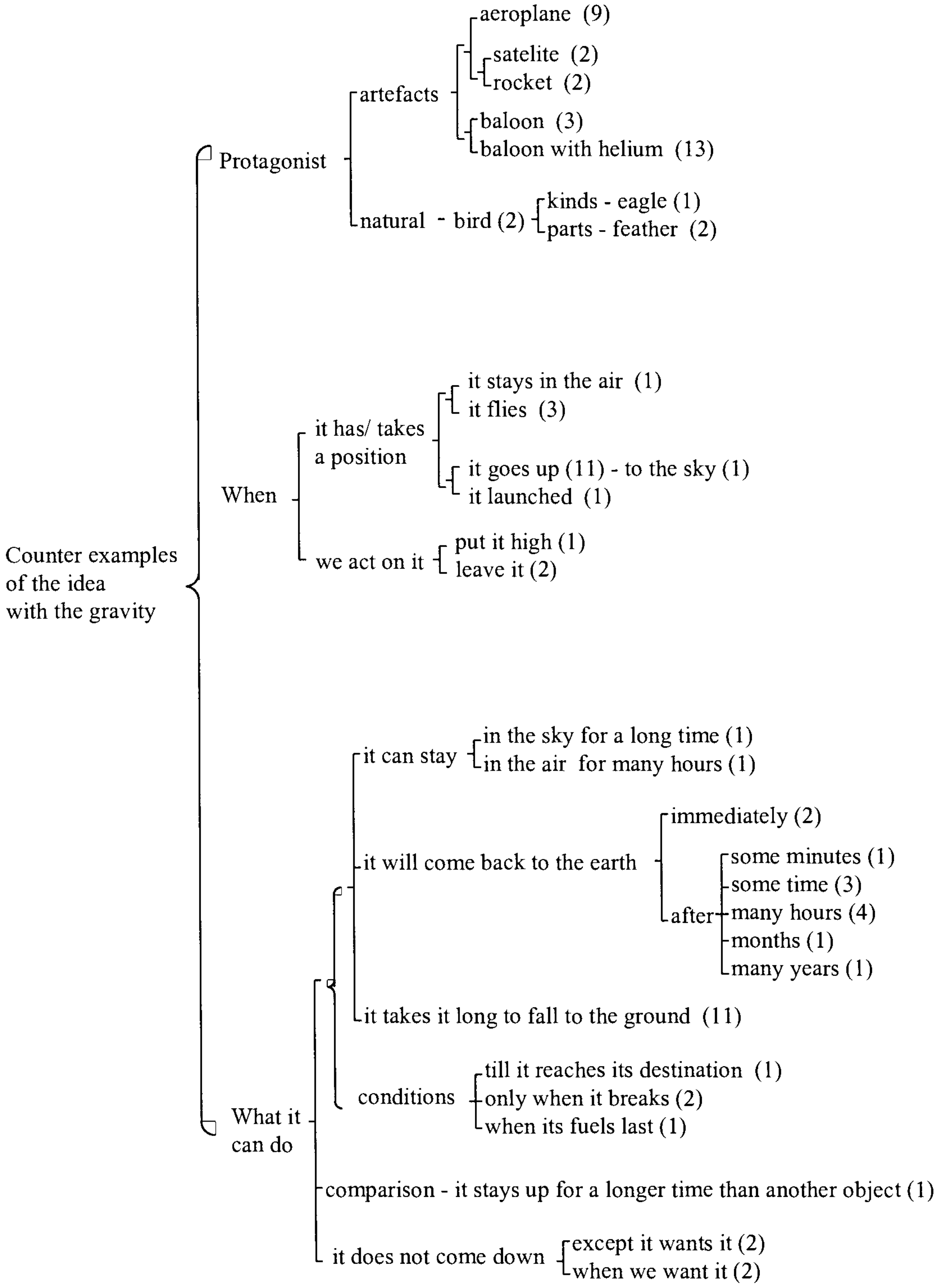
Children's examples consists mainly of three components: (a) a protagonist, (b) the position of the protagonist, and (c) the position of the protagonist after some time.

Protagonists were mainly artefacts or natural kinds. The most popular protagonists were a balloon with helium and the aeroplane. Protagonists in most cases were imagined to be on the ground. Most of the children's counter examples describe an event in which the protagonist has or takes a (new) position far away from the earth.

Quite few children said in their examples that the protagonist does not come down except it wants to, or if we want it to come down.

However, most children gave as an example a thing that will come back to the earth after some time. So, the counter example was related to the time that the protagonist needs to come back. Children used mainly three (quite similar) expressions to describe what the protagonist will do when it is far away from the earth: (a) 'It takes a long time for the protagonist to fall to the ground, or (b) 'it will come back after some time (or hours)', or (c) 'it can stay in the sky or in the air for some time'. A minority of children gave conditions about when the protagonist will come back, such as 'till it reaches its destination', or 'only when it breaks', or 'while its fuels lasts'.

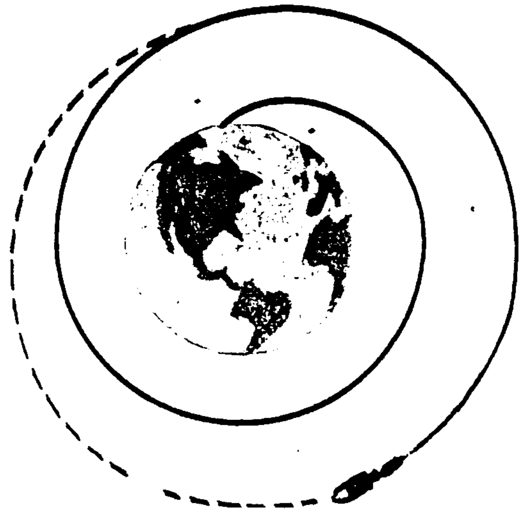
Figure 6.24 Children's own examples of gravity



6.3.7.2 Schemes for entities, with and without an idea exemplified

Children were presented with the following idea and example:

> "When things go up, they must come down (on the ground) because of the gravity"



A rocket launched from the earth with speed more than 40,000 Km per hour. So it beats the earth's attraction and doesn't come back.

Children were asked to describe in a questionnaire the following five objects:

◆ ***Scientific Entity***	gravity
⋇ ***Protagonist***	rocket
● ***Structure related object***	ground
○ ***Surface related object***	people
X ***Unrelated object***	air

6.3.7.2.1 Interpretation of factors

The results of the factor analysis indicate that responses can be represented by two important factors (see Table 6.8 below and Appendix 6.18) . The two factors jointly explain 76% of the variance.

Table 6.8 The factors for gravity

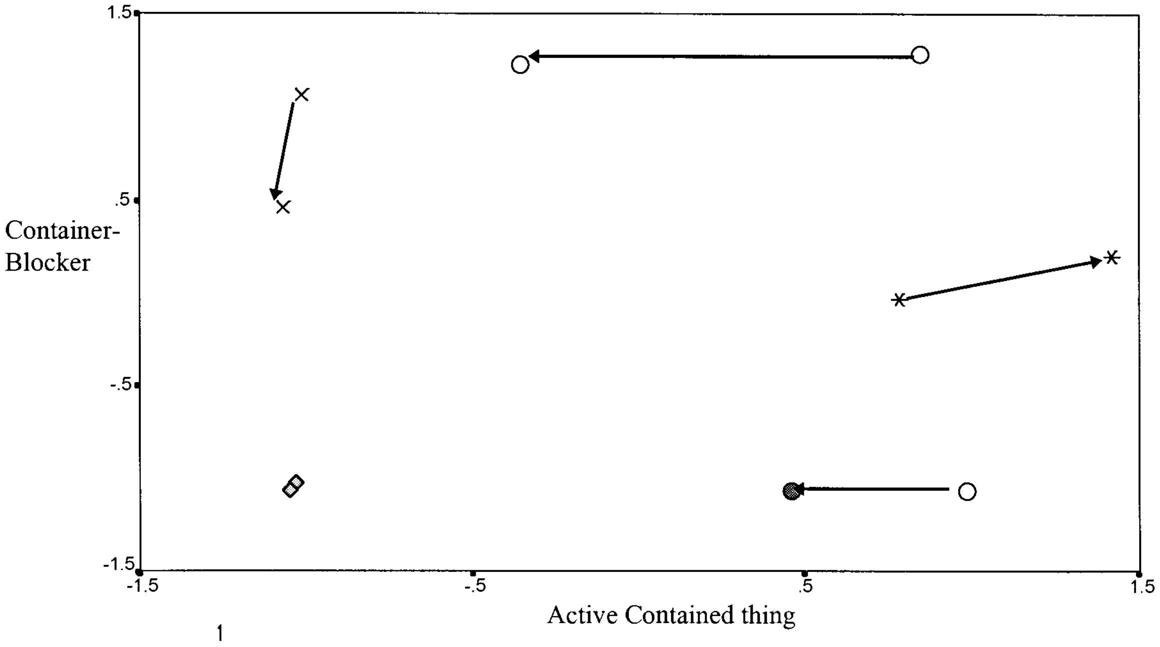
	Factor 1	Factor 2
Invisible	−	
Container	+	
Support	+	
Barrier	+	
Rigidity	+	
Autonomy		+
Contained thing		+
Force		+

Factor 1 has very high positive loadings for "barrier", "support", "container" variables, and very high negative loading for "invisible entity" variable. Also it has high positive loading for "rigidity" variable. It can be labelled "Container-Blocker". Factor 2 has very high positive loadings for "autonomy", "contained thing" and "force" variable. It can be labelled "Active contained thing".

6.3.7.2.2 Analysis of the counter example about the gravity

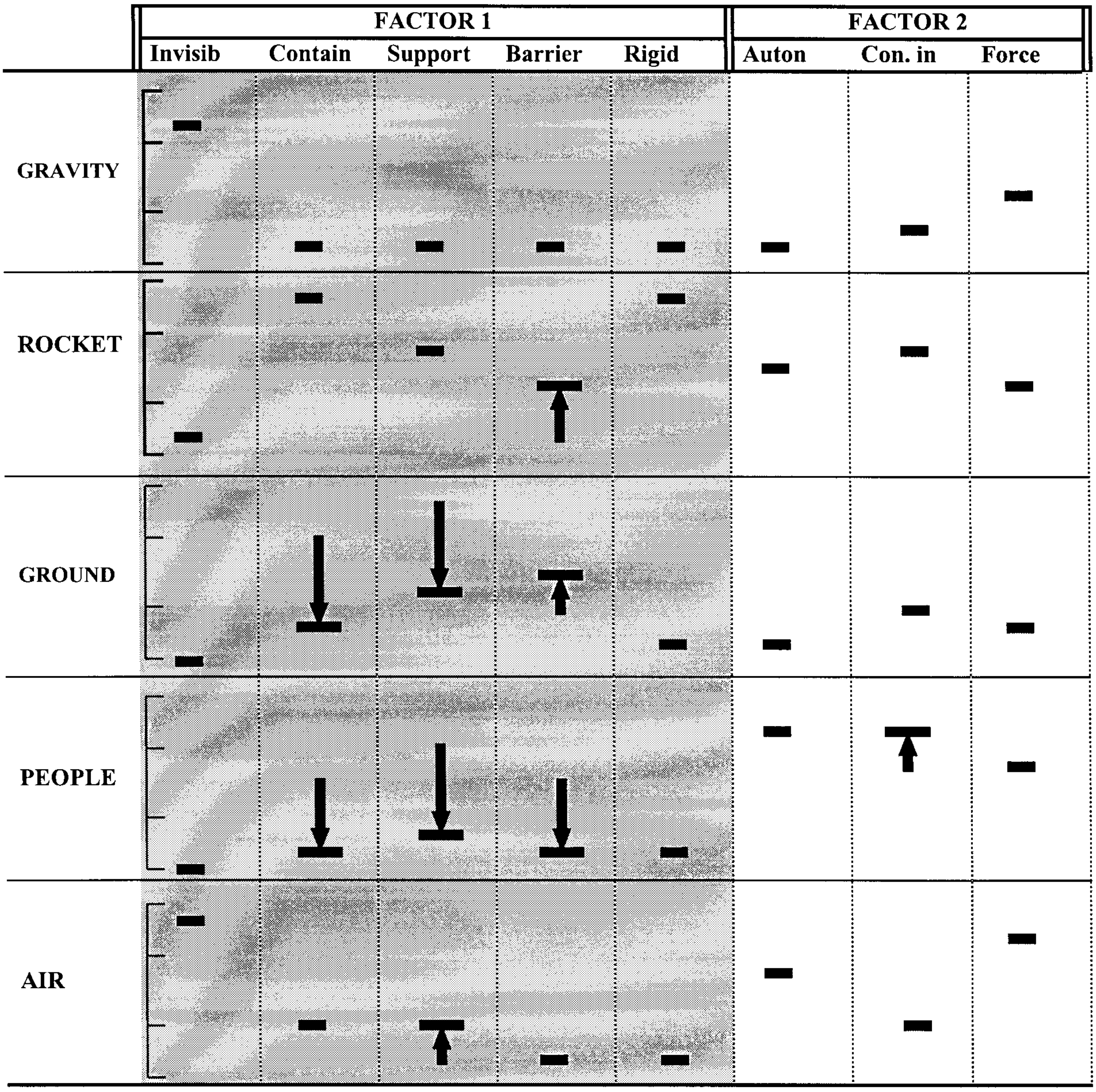
Figure 6.25 shows that the structure of the factor scores for the entities as they are described both in an non-exemplifying and in an exemplifying contexts by children. The next Figure (Fig. 6.26), shows how many children used the various schemes to describe each entity and which schemes were preferred more or less (only statistically significant differences are represented) by children going from the non-exemplifying to exemplifying context.

Figure 6.25 Factor scores and their 'movements' for the example with the rocket



◈ ***Scientific Entity***	gravity
✱ ***Protagonist***	rocket
● ***Structure related object***	ground
○ ***Surface related object***	people
× ***Unrelated object***	air

Figure 6.26 The percentages of children using each scheme to describe objects in the counter-example of gravity



"Gravity" is neither a 'container-blocker' nor an 'active contained thing'. The scientific concept (gravity) was described by students as an invisible entity which is a potential cause of movement. There was no difference in children's responses about 'gravity' between the exemplifying and non-exemplifying context.

The 'Rocket' was used as the protagonist. It appeared as a container-blocker ('container' and 'rigid' thing) which was neutral on the 'active contained thing' factor. In the exemplifying context it appeared even more as a 'container-blocker' (more children described it as a ‘barrier’). There were no other big differences in responses dependent on context.

The ground is a ‘container blocker’ and not an ‘active contained thing’. In the exemplifying context it appeared less frequently as ‘container-blocker’. The ground appeared in the exemplifying context to lose its features as container, support and barrier.

The surface related objects, ‘people’ in the rocket, were seen as ‘container-blockers’ and at the same time as ‘active contained things’, but in the exemplifying context they were imagined as not ‘container-blockers’ since they lost their features as barriers, supports and containers. However, they appeared more as contained things probably because they were in the rocket.

The ‘air’ is seen as an ‘active contained thing’ and not a ‘container-blocker’ appearing less frequently as ‘an active contained thing’ in the exemplifying context.

This counter example (as the previous one) did not make a big change to how children saw the scientific entity and the protagonist in an exemplifying vs non-exemplifying context. It seems that it constrains mainly the surface related and the struture related object.

6.3.8 Analysis of all examples

Factor analysis of the eight variables was performed using a principal components extraction and varimax rotation. Three factors were extracted accounting for 74.6% of the total variance. The factor solution based on the total group is presented in Appendix 6.19.

Factor 1 accounted for 38.1 % of the variance and has very high positive loadings for support, high positive loadings for container and rigidity and very high negative loading for invisible entity. Also it has positive loading for barrier. Factor 2 has very high positive loadings for the force and autonomy variables. Factor 3 has very high positive loadings for contained thing and high negative loading for barrier. Therefore, the first factor was interpreted as "Blocker-Container", the second factor as "Autonomous action" and the third factor as "Contained things".

A multivariate analysis of variance was then used to explore the causes of the changes from the exemplifying to non-exemplifying context. Dependent variables were the factor scores of each of 120 objects in the three factors that were extracted from the factor analysis. The independent variables were: (a) the role of each object in the exemplifying context, (b) participation or not in an exemplifying context, (c) the various ideas, (d) the various examples.

The MANOVA resulted in a higly significant effect of the roles of objects and the exemplifying context, on all the dependent measures (the synthesis of the factors). The various roles of an object had an effect on the score on factor 1 (F=41.48, p=0.000), factor 2 (F=5.38, p=0.001) and factor 3 (F=9.33, p=0.000). The participation of objects in an exemplifying or non-exemplifying context had an effect on factor 1 (F=14.8, p=0.000) and factor 2 (F=7.21, p=0.008) but not on factor 3. There was no interaction between these two independent variables.

Also, the ten objects that were described by children in each questionnaire (five objects in and out of exemplifying context) had a significant effect on factor 3.

6.4 Discussion

6.4.1 Children are able to give examples of ideas

A previous study (Wilson, 1986) with elementary school students suggested that their examples were inconsistent with conventional mathematics definitions. In the current study children were asked to give an example of an idea that was to be found in their science textbooks. The children's responses can be classified into three subcategories which are used frequently in the literature on exemplification: positive examples, negative examples and non-examples (Byrd et.al., 1992)

Almost all of the children were able to give an example of an idea, and the basic example itself was often a positive example. Particularly in the case of the ideas of potential energy and inertia all children gave an example.

For the other ideas, there were still very few children who did not give any example or gave a non-example (that is an example which shows things that are not part of the given idea. 2, 3 and 6 children did not gave an example of the ideas of expansion, thermal equilibrium, and upthrust respectively).

More problems appeared with the children who were asked to give a counter example of an idea. Six (out of 38) did not give a counter example of the idea of gravity while eight (out of 36) did not give a counter example of the idea of transmission of heat (five of them gave an example instead of a counter example). Constructing (or using) counter examples requires an understanding of ideas, recognition of the inconsistency between the idea and the counter example, and deductive reasoning, and this is relatively difficult for students (Lakatos, 1976).

All the ideas that were given to the children were about a scientific concept. Asking children to exemplify the idea we can explore how the concepts are used. Wittgenstein (1953) argues in 'Philosophical Investigations' that concept meaning is closely related to how the concepts are used. The fact that children are able to give examples of ideas is evidence that they have some meaning for the relevant concepts. Furthermore, the variation of children's examples is evidence for the various kinds of uses that a concept can have for them.

Children can make the transformations from abstract ideas to concrete examples and they can establish connections between abstract and various concrete examples. But, ideas do not work in the same way for all children, and through the analysis of children's examples it is possible to identify their different meanings for various concepts.

6.4.2 Children's examples are different from their textbook examples

For some of the ideas the children's examples were very different from their textbook examples, whilst for others, some of the children gave examples similar to these used in their textbooks.

In the case of the idea of potential energy, no child gave an example the same as the examples used in their books. Only five gave an example of the inertia idea similar to those in their textbooks. Furthermore, in the case of the counter examples of two ideas (gravity and transmission of heat) only four of the children gave an example using as protagonist a rocket or a satellite and only six of the children gave an example using as a protagonist a glass (which were the protagonists in the textbook examples).

However, for the other ideas some children did give examples similar to those in their textbooks: (a) one fourth of the children gave one of the two examples that are used for the idea of expansion, (b) one fifth of the children gave an example of thermal equilibrium similar to their textbook example where two containers are in contact, and (c) one third of the children gave as an example of upthrust a ball that floats on the surface of a fluid, which was similar to an example that was used in their textbooks.

The reasons for the existence of a difference in the number of children who gave an example similar to those in their textbooks may have been that:

(a) the children did not want to use textbook examples. Children can use a range of examples for an idea. Textbook examples were not perceived as the best examples of the particular idea by the children. In this case the children use another example which they believe is better than their textbook example. So, they used "an aeroplane high up in the air" as an example of potential energy rather than "a child up a tree" because the aeroplane has more potential energy, and the more potential energy the better the example.

(b) the children could not use textbook examples. It is possible that the children did not remember all the examples well. So, in some cases many of them had to construct their own example.

6.4.3 The roles of objects vary among examples of different ideas

The children gave examples of ideas which almost all had a protagonist. However, there were big variations in the existence of objects which play other roles in the examples, as shown in Table 6.9 (how many children used objects that play each of the four roles in their examples)

Table 6.9 The percentanges of children using objects that play each of the four roles in their examples

Examples	Protagonist	Surf.Rel.Ob	Stru.Rel.Ob	Sci.Concept	No of childr
Pot. Energy	**100%**	**25%**	**18%**	**85%**	*72*
Expansion	**97%**	**0%**	**22%**	**68%**	*73*
Equilibrium	**96%**	**42%**	**96%**	**43%**	*72*
Inertia	**100%**	**0%**	**43%**	**21%**	*61*
Upthrust	**90%**	**11%**	**90%**	**48%**	*63*
Counter Ex.					
Heat	79%	**0%**	**21%**	**0%**	*38*
Gravity	**84%**	0%	**60%**	0%	*38*

In the case of structure-related objects the children seem to think that the ideas of potential energy, expansion and inertia referred to properties which are associated with one object and they usually did not include another structure-related object in their examples. However, the children thought that ideas of thermal equilibrium and upthrust referred to more relational features and added to their examples a structure-related object to focus on a comparison between the features of this object and the protagonist.

Surface-related objects were used in quite few examples of ideas. It seems that objects which can play this role in an example are not so important for children although in all the textbook examples surface related objects could be identified. Surface related objects were identified mainly in the children's examples of the idea about thermal equilibrium (containers for liquids are used) and in their examples of potential energy (some used a blocker to support an object away from the earth).

For most ideas, many children used in their example the name of the scientific concept, particularly with the concepts of potential energy and expansion, and to some extent with inertia. In the last case, they preferred to say that the cause of the fact that an object can be harder to move than another is that it is bigger, without using the name of inertia. It seems that inertia is a hard concept for children.

It is obvious in the previous discussion of the results, that the children gave as a counter-example an object (protagonist) while other entites like surface or structure related objects were not used. It seems that when the children were asked to give a counter-example they suggested objects that might behave in a different way from the particular one that the idea was describing rather than a counter event. So, most of the children used only a protagonist as a counter-example in both questionnaires. Particularly in the first counter example only a very small minority of the children used a structure related object while in the case of the idea with the gravity most of them used a protagonist and focused on its position and on the time that it will takes for the protagonist to come down to the earth.

6.4.4 Comparing the factors for different ideas - Packages of schemes

The children's responses were subjected to factor analyses, together for both groups. Factor analyses were based on the correlations between questions using the percentages of the total number of children who identified one of the eight schemes for a particular object in non-exemplifying and in exemplifying contexts.

Factor analyses were used to identify the underlying (hypothetical) constructs that could explain the covariation among responses in the items of the questionnaire. Factor analyses were used to explore structures of schemes: (a) within each idea, and (b) among the 120 items across all ideas.

The factors that have been extracted for each group of children who took part in the questionnaire for each idea and the proportion of variance explained by them, are shown in Table 6.10.

Table 6.10 The factors extracted for each idea

	Factor 1	Factor 2	Factor 3
Potential Energy	**Static Object** 54.5%	**Containment** 22.4%	**Blocking** 11.8%
Expansion	**Blocking** 39%	**Dynamic Containment** 19.4%	**Stability** 13.3%
Thermal Equilibrium	**Blocker-Container** 60.6%	**Invisible-Container** 20.5%	**Autonomous action** 13.6%
Inertia	**Container-Supporter** 39.4%	**Autonomous action** 23.2%	**Horizontal Blocker** 18%
Upthrust	**Autonomous action** 28.9%	**Stable Contained thing** 25.5%	**Container Blocker** 15.7%
Counter (heat)	**Dynamic Blocker** 42.4%	**Rigid Container** 36.5%	
Counter (gravity)	**Container Blocker** 45.5	**Active Contained thing** 30.3%	
All examples	**Blocker Container** 37.9%	**Autonomous action** 22.7%	**Contained things** 13.8%

The factor structures which emerged for each idea were remarkably similar. There are schemes which appeared together, as a group or package in various factors:

(a) Barrier and support were moderately correlated for most of the ideas and constitute a blocking factor, or a more complicated but related factor. So, in the case of upthrust they appeared together with Container constituting the factor Container-blocker and in the idea of equilibrium they came together with container and rigidity constituing the factor Container-blocker. Also, rigidity was a scheme which usually appeared with support and Barrier and never with force, autonomy and invisible entity. It seems that almost all of the things which are barriers can support other things at the same time and vice versa, even'horizontal sticks' such as pylons was seen by the children as supporters of wires. However in the examples about inertia they belong to two different factors. In this case the concept of inertia appeared in this idea just as a barrier without being at the same time a support. It is clear the difference between the concept of inertia and any object with mass which even in the cases of 'thin' horizontal barriers can be imagined as support.

(b) Autonomy and Force appeared together in all of the ideas and constitute the factor Autonomous action. A thing that can move or stop when it wants, and can also make other things move and vice versa. Invisible Entities usually appeared in the same factor as autonomous action.

It might have been expected that container and contained thing would constitute a group of schemes since almost all of the things which can be imagined as containers can be imagined as contained things, in yet a bigger container. However Container and Contained things appeared together in the same factor only for one idea. It seems that in all examples, things were clearly distinguished into containers and contained things.

In general, the factor structures were very similar across the seven separate analyses, except that the ordinal position of a given factor for the data of one group may not necessarily correspond to its relative position in the data for the other groups. Also, there are some group differences in the factor correlations. For example, container and contained thing variables were moderately correlated for the idea of potential energy but were not correlated for the idea of equilibrium. It seems that when examples highlight one of the two above schemes because of the role the objects have in an example - the pots which were containers in the exemplifying contexts of the idea about thermal equilibrium - it was very difficult for the children to imagine the same objects at the same time as something different -contained for example in our galaxy. Although - from my point of view - one could expect that the schemes container and contained thing to co-exist in exemplifying contexts, it is difficult for children to imagine and describe an object using both schemes, as in the case of horizontal and vertical barriers.

It seems that the factors emerging were: (a) Blocking; an object belongs to this factor only if it can stop other things (horizontally or vertically) and is rigid, (b) Autonomous actions; things that can make other things move and they can move whenever they want are constituents of this factor, and (c) Containment; things classified mainly as containers and not as contained substances or things.

6.4.5 The nature of entities and their behaviour in examples

Appendices shows in detail the changes which were observed for each object, between being considered in the context of an example (not counter examples), and previously not in that context.
6.4, 6.7, 6.10, 6.13, 6.16, 6.17, 6.18

A decrease in frequency of a scheme for an object, when considered in an exemplifying context, means that this possible aspect of the object has been suppressed or constrained by the use in an example. The examples serve to focus only on some schemes. Similarly, an increase in the frequency of a scheme for an object means that this scheme has become more salient, because of the use in an example. With very few exceptions, the entities that played similar roles in the two examples of the same idea, either stayed close together or moved close together, on all factors, going from the non-exemplifying to exemplifying context.

Most of the decreases (36) were observed in 'unrelated' things, for which there were no increases. 'Unrelated' objects did not have any special role in the particular examples. So it was expected that they would have more and bigger decreases. In contrast, the smallest number of decreases (5 decreases) happened in the case of scientific concepts. It is possible that these abstract entities are very difficult to describe by the particular eight schemes, which referred mainly to concrete things. However, the category of scientific concepts had the biggest number of increases (7 increases).

Broadly we predict that for objects relevant to a given example, the frequencies of schemes of objects which play different roles will become more differentiated when the example is given. It becomes clear in the following descriptions that the examples constrain the schemes that one can use to describe an entity in a way that particular schemes can describe objects which play a particular role in an example. For instance, surface related objects are containers or the scientific concepts are contained things on going to an exemplifying context.

In general the entities were described more as supports than as barriers. Barriers and supports were mainly the ‘surface related objects’. It is notable that in this category there were three cases with increases on going to an exemplifying context. The balcony in the example “a pot on a balcony” and the ground in the “lorry-example” increased as barriers while the pylons increased as supports. Furthermore in the exemplifying context, only about half of the children (of those who said ‘yes’ prior to use in an example) said that the protagonists, the structural related objects, and the unrelated ones are supporters, and for almost all of the objects that belong to these categories there was a substantial decrease.

The structure related, the surface related objects and the protagonists were generally seen as ‘containers’. Given an example, the children chose more often the surface related objects rather than the structure related objects and the protagonists as containers. The last two categories were described more as contained things. Thus, contained things were mainly the protagonists, the structure related objects, and in exemplifying contexts, the scientific concepts.

Rigid things were mainly the protagonists and surface related objects. In the exemplifying contexts there was a big difference between them since the objects that were classified as protagonists (the second in frequency category) had a substantial decrease as rigid things.

Out of the context of use in examples, the ‘unrelated’ objects could mainly make other things move and had autonomy. However in the exemplifying contexts, scientific concepts mainly make other things move, with protagonists and unrelated things to follow. Furthermore concerning autonomy, the unrelated objects appeared very close to the surface related objects, the protagonists and the concepts, in the exemplifying contexts.

The scientific concepts appeared mainly as invisible entities. They were not so well known and the example helped children to identify more schemes for the description of these abstract entities. Particularly in the category of concepts, decreases appeared for Potential energy as barrier and support (in both exemplifying contexts), while increases appeared in these schemes for upthrust (ball -example). There was an increase of potential energy (child-example) and heat (inside-example) as contained things. Heat appeared in both exemplifying contexts, mainly as force. Expansion appeared less as invisible entity in the rail-example.

6.4.6 Similarity and dissimilarity in examples

An entity can take part in different examples. In each, the entity plays a particular role. This role is responsible for the schemes that the example will highlight or hide. Looking across the various examples that a particular entity can take part in, there are some schemes which show a similarity and some which show a dissimilarity between the various instances of an entity.

Lets consider the entity "children". If they were not similar then they would not be described by the same schemes across different examples. However, if they were not dissimilar then the child who takes part in the example of potential energy would be the same as the child who takes part in the example of upthrust.

In this study the following three objects were used in more than one example: air, ground, child. Particularly, the ground was used in seven, air in five, and the child in four different questionnaires. The role that each of these objects had in each example has been described previously. In this section a comparison of the use of these objects across the various examples is given. Are there any differences in the patterns of the schemes that describe these objects?

The air played the role of 'unrelated object' in every example. Results from seven groups of children are consistent. The patterns in all the cases in which it appeared did not differ since air did not play any special role.

The ground mainly appeared as a support, and as a container with the ability to make other things move. In four of the exemplifying contexts even fewer children said that it is a barrier, while in the exemplifying contexts with the child up a tree, and the lorry, more children tended to say that it was a barrier. Furthermore, in the case of the railway example there was a statistically significant increase of the ground as a barrier. That may have been because the children thought that the ground continues to be in contact with and give support to the railway lines which bend up in an arc, and so acts as a horizontal barrier.

The "child" was described in the exemplifying contexts by fewer children as a support. However after the upthrust example with a child lifting a stone in water, more children tended to describe the child as a support. Furthermore, although the general pattern was that in the exemplifying contexts, fewer children described the child as a contained thing, there was a statistically significant increase in the number of children who described the 'child' as a contained thing in the sea in the exemplifying context with the stone. Furthermore, most of the examples appeared unable to suppress the scheme of autonomous action that many children used to describe the entity 'child'.

The appearance of similarity and dissimilarity for objects which took part in an example can also be considered at the level of the examples. For instance, both examples, the example with the pot on the balcony and the example with the child up a tree have a similarity, as they are examples of the same idea. In both there were decreases of potential energy as a barrier or support. However they have dissimilarities such as that in the example with the child up a tree, there was an increase in the number of children who said that the potential energy is a contained thing while in the example with the pot there was a decrease.

6.4.7 Constraining schemes

Comparing the children's responses, in and out of the context of use of objects in examples, it appears that examples constrain the schemes children use to describe entities. This is in accordance with Sirridge (1980) who suggests that the meaning of an example can change from one context to another. For example a specific context determines that a tailor's swatch exemplifies a colour and texture and not its size properties.

A way to look at how a context constrains schemes, is to see which objects were identified by most of the children as good instances, before and after using them in an example, and the number of decreases and increases that happened after the children had seen an example.

In Table 6.11 the first two columns show the number of things from all five ideas that were good instances (identified by more than 60% of the children as instances of the particular scheme) for each scheme before and after they had seen the example. The third and the fourth columns show the total number of statistically significant decreases and increases in frequencies of attribution to each scheme, taking all objects and ideas together.

Table 6.11 Number of Decreases and Increases

	Number of Good Instances Before example	Number of Good Instances After example	Number of Decreases	Number of Increases
Barrier	3	3	8	7
Support	21	9	25	4
Container	20	6	22	1
Rigidity	9	7	7	2
Con.Subs	11	8	20	4
Force	18	14	21	5
Autono	13	9	10	0
Invis.Ent	15	12	6	1

Most of the sixty things that the children were asked about prior to using them in examples were identified as supports, as containers and as things that can make other things move. In the exemplifying context, there were many decreases of attribution to the above three schemes. Furthermore, in the exemplifying contexts, most of the good instances had to do with the schemes of force (an object makes other things move) and of invisible entities.

Most of the increases occurred for the barrier scheme. Particularly for this scheme in the examples of inertia and upthrust there were no statistically significant decreases for the objects taking part in the four examples.

The great number of decreases show that the examples constrain the entities in a particular way and each of them exemplifies particular aspects of entities and not all of them. The examples of the ideas that were used in the various questionnaires seem to have highlighted schemes with a dynamic nature such as force and autonomy rather than static ones such as support and container. The preference for the use of dynamic schemes instead static ones in the children's descripions on going to exemplifying context appeared also in the cases of increases. The existence of increases is an indication that exemplifying contexts can highlight schemes which are well hidden. The fact that more children used the scheme barrier in the exemplifying context shows that they used it as a scheme which does not allow other objects to continue their movements. 'Barrier' appeared as a more dynamic scheme than 'support' which keeps things in a position.

6.4.8 The effectiveness of examples

Despite the broad uniformity and consistency of the above results, the examples did not work in the same way for all of the children. In some cases, even though examples constrain the number of the children who described an entity with a particular scheme, there was a substantial number of them who continued to describe this entity with the particular scheme. So, some examples work more effectively than others to constrain schemes.

For instance, in the exemplifying contexts of potential energy, fewer children said that the flower-pot is a support and more children said that the balcony is a barrier and that the potential energy is a source of potential movement. However, the particular examples did not work in the same way for all of the children. Although in the exemplifying contexts, the air lost substantially the ability to make other things move, around half of the children still continued to say that air has autonomy and can move other things. Also, even though the air did not play any role in these examples, almost all of the children continued to say that air was an invisible entity, in both exemplifying contexts.

Also, there were cases where children described the various elements in different ways. So, for half of the children the ground is a rigid thing while for half of them it is not. It can make things move (potential energy and expansion ideas). Some children gave the example of earthquakes which can move things and some others said that if one lets go of something which he/she keeps in his/her hands it would drop to the earth so the earth can move things. In these cases different children imagined in different ways the various elements that take part in examples. The constraining effect of an example will depend on how close children's previous descriptions of entities are with those which the example highlights.

Furthermore there were differences between examples. For instance in the examples of the upthrust idea, in the exemplifying context with the stone in the sea, fewer children said that the upthrust is a barrier while in the exemplifying context with the ball more children said that upthrust is a barrier. So, the examples in these cases might work in two opposite directions highlighting very different schemes of an entity.

6.4.9 "Unexpected" increases

Generally, we might expect decreases in the extent to which elements of an example are seen as related to various schemes, when they are used in an example of a given idea. When presented in relation to no particular idea, it is likely that children can often think of some way in which any element could fit a scheme. Used as an example of an idea, we expect the nature of that idea to constrain (or focus) the perception of elements.

There are however, a number (though not large) of cases in which the number of children who identified an entity as an instance of a particular scheme increased significantly on going to an exemplifying context. These increases are 'unexpected' since prior to the use of objects as an example, the children attempted to describe the same entities with schemes in every possible example. That means that the particular examples highlighted some schemes of entities which were previously to some extent hidden or not important. Table 6.12 shows the entities which presented such 'unexpected" increases for some schemes.

Table 6.12 Increases

Idea	Example with	Increases for	
		Entities	Schemes
Potential energy	pot child child	*balcony* *potential energy* *tree*	**barrier** **contained thing** **force**
Expansion	wires wires	*pylons* *sun*	**support** **force**
Equilibrium	contact contact inside inside	*heat* *heat* *heat* *hot water*	**contained thing** **force** **force** **force**
Inertia	lorry elephant elephant elephant	*ground* *elephant* *elephant* *inertia*	**barrier** **barrier** **rigidity** **invisible entity**
Upthrust	ball ball ball stone	*water* *upthrust* *upthrust* *child*	**barrier** **barrier** **support** **contained thing**
Tranmission of heat	glass glass glass	*glass* *stove gas* *hand*	**rigidity** **support** **container**
Gravity	rocket rocket rocket rocket	*rocket* *ground* *people* *air*	**barrier** **barrier** **contained things** **support**

A description of these increases has been given in the previous parts of discussions for each idea. In summary, increases occurred mainly for the schemes barrier, force and contained things.

A horizontal barrier and a support appear to differ not only as horizontal vs vertical barriers but also considering the objects whose movement they resist. Some entities (balcony, ground, water) that were described as supporters in the non-exemplifying context, were described also as barriers in the exemplifying context. It seems difficult to explain these increases as a result of the children seeing these objects in the example to be a horizontal barrier like a wall. Barriers seem to describe objects which resist movement and make moving things stop, while supporters are mainly objects which keep in position other objects eg. a glass on a table. So, the description of an object with both schemes support and barrier does not mean that the children described an object both as horizontal and vertical barrier but that the children used both schemes to show that these objects in the particular examples not only keep objects in position but can also stop other things that move such as the ground in the case of inertia or the idea with gravity (counter example with rocket).

The children used the scheme 'force' (make other things move) to describe mainly the change in the position of an object when another object pushes it or pulls it. In the exemplifying contexts, objects such as sun, heat, tree appeared to be able to make other things move without pushing or pulling them. The energy from the sun, the energy of the particles because of the heat, the lack of support is seen by the children as causes for the movement of some objects. Examples lead the children to see the scheme 'force' with a broader view.

More children described scientific entities such as potential energy and heat as contained things, when going from the non-exemplifying to exemplifying contexts. The scheme of contained things was used by the children in a broader sense in the exemplifing contexts, including cases of invisible or abstract things. Also, 'people' can be contained things in big containers such as the sea or a rocket.

The appearance of all these increases is an indication that examples do not merely constrain the schemes that can be used in the description of entities but that they may in some cases play another role, extending children's views about the schemes that can be used in the description of particular entities. Examples appeared to work in many ways, as do metaphors or analogies. They highlight or hide some features of entities, and they may suggest new ways of seeing entities.

6.4.10 Good instances of schemes

Some objects were described by more than 60% of the children in the non-exemplifying or/and in the exemplifying context as instances of particular schemes. In this section I will discuss these objects that I call 'good' instances of schemes. This discussion will offer us more broad categories of entities which are good instances of the particular schemes.

The children described objects that resist the horizontal movement of other objects as barriers. Barriers might be inanimate high vertical objects such as a tree or a pylon or animate big objects such as the elephant in the example of inertia which resists the movement of the child. The containers (metallic pots), with the water, are seen as barriers. They resist the movement of the water out of them. Also, a scientific concept, inertia, resists the horizontal movement of the lorry or the elephant and is seen as a barrier.

A thing, in order to be a support, should have a horizontal surface. These surfaces can be the ground or a median between the ground and the thing that is supported. In the last case it might be (a) a solid-rectangular surface such as a balcony, a railway, a hand, the ground (b) the bottom part of a container (e.g. car, lorry, plastic pot, metallic pot), or (c) a horizontal barrier which uses some "branches" to support things (tree, pylons, child, rocket)

Objects that can have other objects inside them can be containers. Containers are animate (child) or inanimate entities. Inanimate entities can be small artificial pots (e.g. the flower pot in the example of potential energy, the metallic and plastic pots that contain water in the examples of thermal equilibrium and upthrust respectively, and the ball in the example of upthrust) or machines (train, car, lorry, rocket) or big natural spaces (sea, ground)

Animate static (elephant) and inanimate static (stone,rocket) things can be rigid. Also, rigid things can be horizontal surfaces (balcony, railway), or containers (pot), or vertical barriers (pylon).

Contained thing can be fluids (cold water, hot water), gases (air) or solid things. Solid things can be in air (child, ball) or in water (stone) or in a big solid container (people in a rocket).

Things which can make other things move can be scientific concepts (potential energy, heat) and animate (child, elephant) or inanimate objects. Inanimate objects such as gases (air) or fluids (cold water, hot water, sea) or machines (train) can make other things move.

Autonomy is possesed by animate entities, humans (child) and animals (elephant). Also inanimate objects such as machines (train, rocket) and gases (air) can move when they want.

Invisible entities are scientific concepts (pot energy, heat, inertia , upthrust, expansion, gravity) or objects (air).

6.5 Conclusions

Children of 11-12 years old can transform abstract concepts and ideas to concrete examples and are able to suggest examples often different from those in their textbooks, which are consistent with simple ideas that are found in their science textbooks. This has a significant implication for teachers, who by analysing children's examples can identify through the way that children use abstract concepts and ideas the meaning that they have for ideas. However, ideas do not work in the same way for all children. Children's examples can be classified in three subcategories: positive examples, negative examples and non examples.

The way examples work can be understood as related to the schematic way their components are perceived by children. A common set of schemes can be used to understand the working of a variety of examples. The results show that:

(a) there are shifts in the way objects are seen (schematically) when they are used as examples of an idea, that is, the use of an instance as an example of an idea constrains the way its elements are understood,

(b) these shifts are intelligible in terms of the nature of the idea being exemplified,

(c) components of examples function in different ways,

(d) unexpected increases can arise when the idea exemplified makes a given schematic understanding especially salient.

There are important implications from the results that show a shift in the way that entities are seen in different contexts. It has considerable significance for teachers and materials designers, since an example can not stand on its own, without a commentary which helps readers to clarify its purpose (Byrd et. al. 1992). Also the analysis of children's examples and their views about textbook examples can give information on the functioning of an idea. That is, the use of a concept or idea can be seen in the exemplifying process.

Furthermore, the various exemplifying contexts did not have the same effect for all children. Some examples work more effectively than others. This implies that textbooks should present many examples for an idea.

Chapter 7:
WHAT MAKES AN INSTANCE A GOOD EXAMPLE OF AN IDEA?

7.1 Introduction

This final study (Study 4) consists of an exploratory study, and a main study. The exploratory study attempts to detect whether children 11-12 years old: (a) are able to establish connections between concrete examples and generalisations, (b) think that some instances are better examples of ideas than others, and (c) can give reasons for their preferences of an instance as a better example than others.

The main study had two phases. Phase 1 (following the exploratory study) which is called "comparing examples" had similar aims and tasks as the exploratory study with some additions: (a) a larger number of children were interviewed, (b) the categories of reasons and empirical schemes that children used in their justifications (mainly comparing examples) were identified in more detail than in the exploratory study, (c) the fit between examples and ideas was explored for various types of these elements (e.g. best examples, counter examples, middle level generalizations etc.).

In Phase 2, which is called "making examples of ideas better or worse" the empirical schemes that appeared in the exploratory study and Phase 1 as more important for a better fit between examples and ideas were tested against a larger variety of ideas and examples and using an even larger number of children. Thus, children were asked whether they could change any of the empirical schemes to make an example better. Also, children were asked whether some changes of these empirical schemes could make an example worse (into a non-example).

7.2 Exploratory study

7.2.1 Aims

The exploratory study consisted of two groups of tasks. The aim of these tasks was to explore whether children 11-12 years old were able to make transformations from concrete examples to ideas and vice versa and to identify children's concrete prototypical empirical schemes, which might emerge through the comparison of different examples of the same idea. Furthermore, the study explored whether some instances are better examples than others and what empirical schemes make an example the "best"- that make it prototypical of an idea? The examples and the ideas used in the exploratory study were found in children's science textbooks which had been used in their previous school year.

7.2.2 Participants

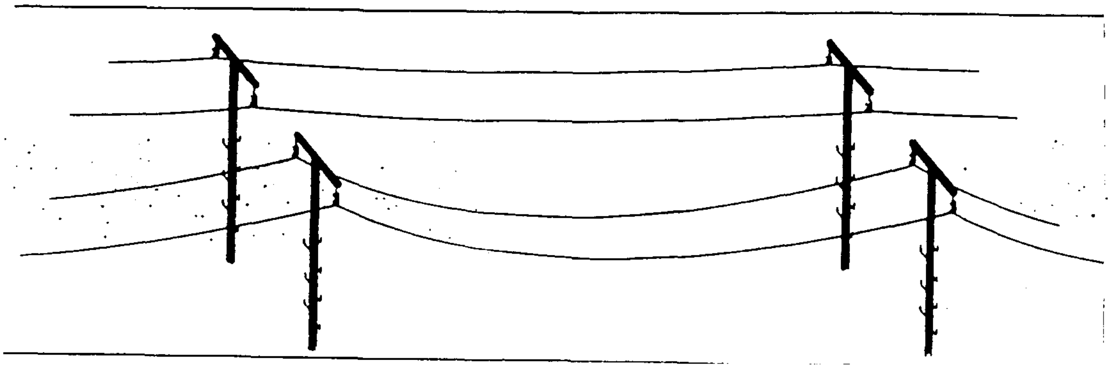
The subjects were 14 children with an average range of age 11 years and 3 months, who volunteered to participate in the study. The study contained 8 tasks, which were divided into two groups (A & B). Eight of the children did one group on the first day and the other group on the next day. A further six children answered only one group of tasks. Each interview took approximately 15 minutes.

7.2.3 From examples to generalization

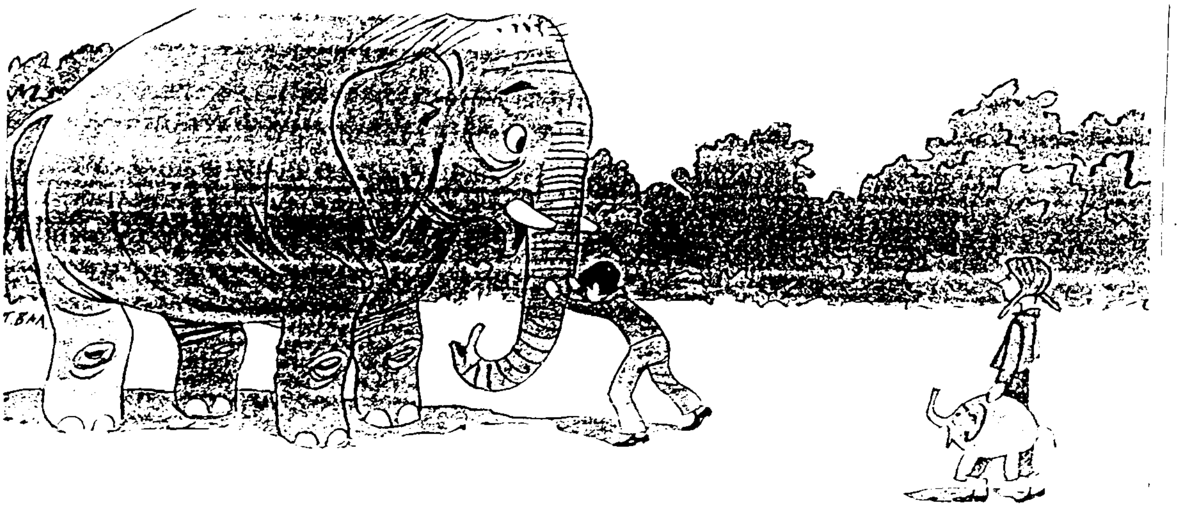
7.2.3.1 Materials

This group (A) consists of four tasks. In the tasks a piece of paper was used, on which a generalization was written. The generalisations were about the following scientific entities: expansion, inertia, hydrostatic pressure and elastic deformity. For each of the generalisations black and white drawings were also used. These drawings were examples of the generalisations (pylons with loose cables, a child who attempts to move an elephant and a child who carries a toy elephant, a barrier which keeps the water in a river, and a spring which a hand pulls and then comes back to its initial state). The generalisations and the drawings were taken from the Greek science textbook. The pictures and the ideas used are presented in Figures 7.1 and 7.2.

Figure 7.1 Exploratory study: From examples to generalizations (pictures and ideas for the 1st and the 2nd task)

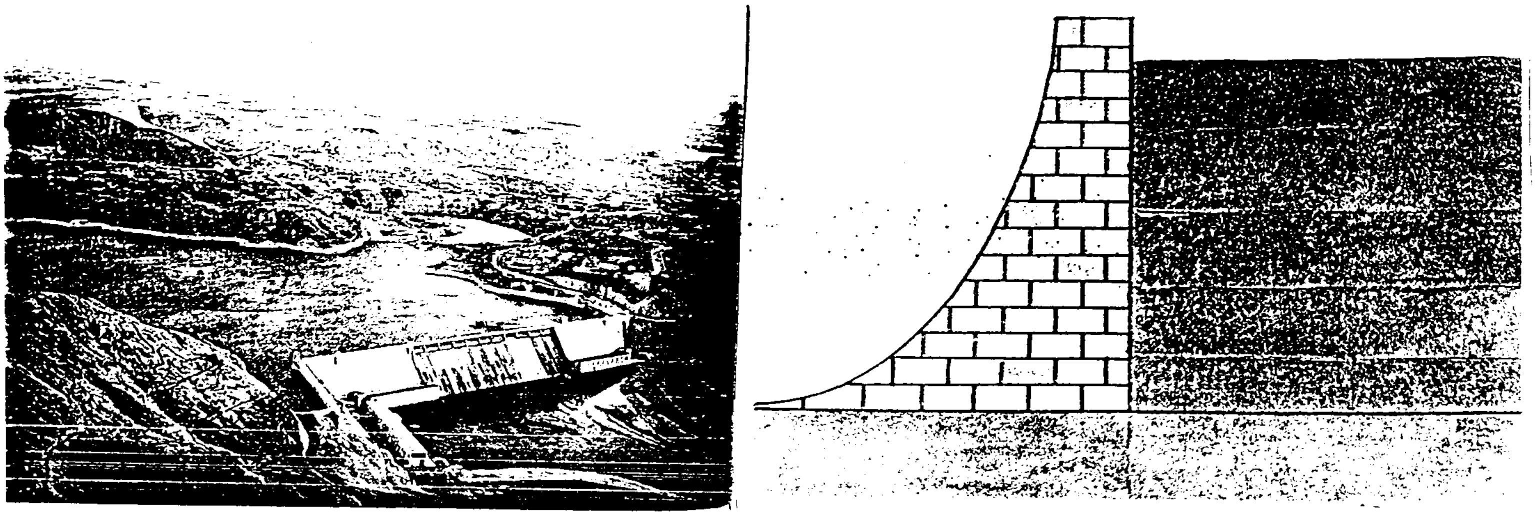


We have already observed during the summer that the electric wires between the two props are loose. Do you think that during the winter the electric wires will still be loose? Solid things through an increase of temperature expand (increase their volume), meanwhile they contract (decrease their volume) through a decrease of temperature.

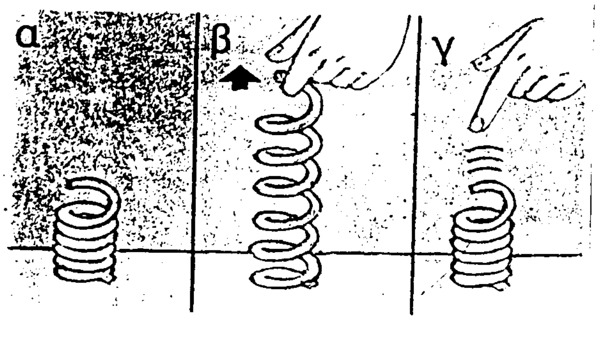


The bigger the mass of the things, the more difficult it is to move them because they present big inertia.

Figure 7.2 Exploratory study: From examples to generalizations (pictures and ideas for the 3rd and the 4th task)



Fluids because hydrostatic pressure produce forces on the surfaces with which they come into contact. The bigger the depth of the fluids the bigger the forces become.



Many solid things undergo deformities because of the influence of forces. Those deformities disappear as soon as the forces stop acting and they are called elastic.

7.2.3.2 Procedure

In these tasks an example-picture (eg. a boy attempts to push an elephant) was given to the children who were asked what this could be an example of. Then the text that was beside the picture in the science text book (eg. The bigger the mass of things, the more difficult it is to move then because they present big inertia) was read and the children were asked whether the picture fitted the text. If there was something wrong (not a good fit) the children were asked to change the picture. Also, they were asked to give another example that they thought fitted better with the generalization and then to compare their example with that of the picture.

7.2.3.3 Results

When the children were asked what the picture was an example of they attempted to give a generalization, looking at the differences between the elements which took part in the story of the specific picture. Therefore, in the picture where a boy tries to push an elephant, the children attempted to give a generalization which could take into account the differences between the different parts of this picture,

> *"maybe it is from the mass that different things have"*

The differences between various things in the textbook examples were usually mentioned by the children when they attempted to create another example of the generalisation. Some children gave as their own example an analogous example through "surface transformation" of the science textbook example that was given to them. In these cases, they kept most of the relations constant, changing only specific parts. Thus, instead of the picture of a boy that tries to push an elephant we have:

> *"the child tries to push a big car, and a child holds a small car in his hand and is able to move it"*

The children based their justifications of the better fit of their examples on the differences between the two examples. So, comparing two, “a child that tries to push an elephant” with his own example, "a child that tries to push a big car" a child said:

> *"the differences are in the different parts of the elephant and the car. The car instead of legs has wheels. Also the car has an engine instead of elephants' belly and things that the elephant has inside in order to move"*

An example was judged better than another because of the more salient differences between parts. An elephant was better for the idea of inertia than a car because:

> *"it is more bulky... So, this is the reason that the elephant is better, because it is more bulky.*

It seems that children prefer examples that show big observable features related to what is exemplified. The electric wires are better examples of the expansion and contraction of solid things than "a bullet over a small gas flame..." (child's own example) because:

> *"it is more clear that the wires are different during the summer and during the winter...We could see that there too (in the second case) but with a smaller difference...This example (wires) is more illuminating.*

Also a barrier is a better example of hydrostatic pressure than "a glass of water" (child's own example) because:

> *"at the barrier it seems in a more clear way that it becomes bigger at the bottom... it happens the same (in the glass) but the tilting is smaller comparing to that the barrier makes. Also, there is much more water in the barriers than in the glass"*

Although in this case the children mentioned that both of the parts which interact (barrier, water) make one example better than another, they usually focused only on one of the parts and suggested the change of one part make a better example.

In the above cases, "salience" leads to an important difference in ease of "reading" the example but it does not make a difference to it as an example. That is, both cases can be used as examples of the same idea, but one is more salient.

One of the reasons that children chose an example as better than another had to do with daily real life experiences (whether the instance is a part of their everyday life). Also, children often used spatial "empirical schemes" such as down-up, fat-thin from everyday reasoning in their justifications and examples.

In some cases children preferred to use non-living things rather than living things. So, "a child that tries to push a load" would be a better example of inertia than a child that tries to push an elephant because:

> *"The load would be a bit easier for children to understand, because with the elephant we cannot understand who pushes the other thing"*

A 'better' example is one which has stronger or more stable characteristics of the relevant empirical schemes. For example, a barrier is 'better' if it is harder to break:

> *"the oil is lighter than water and it would be more difficult for it to break the barrier"*

7.2.4 From generalizations to examples

7.2.4.1 Materials

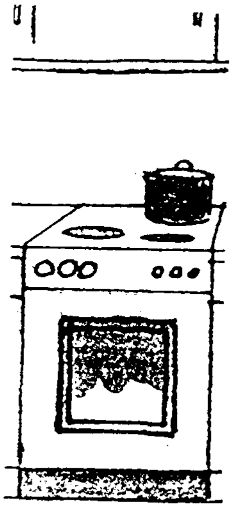
The second group of tasks (B) consisted of four tasks. A piece of paper on which a generalization had been written (eg. "Everything that moves has got energy, and this energy is called kinetic") and one black and white picture (eg. a man who runs) were used for each task. The generalisations that were used in these tasks were about the following scientific entitites: thermal equilibrium, kinetic energy, gravity and potential energy. The pictures that were used as examples of the generalisations were found in the Greek science textbook for 11 year old children (a pan on a cooker, a child who runs, a ball in the air, and a boy up a tree, respectively). The pictures and the ideas used are presented in the Figures 7.3, 7.4 and 7.5.

7.2.4.2 Procedure

In these tasks the order of presentation was reversed, compared with the tasks (A). The children were initially presented with a generalization and were asked to give an example of the generalisation, and explain why they believed that it is a good example. Then, they were presented with a further example (taken from a science textbook) of that generalization and were asked to compare the two examples.

Figure 7.3 Exploratory study: From generalizations to examples (ideas and pictures for the 1st and the 2nd task)

When two things are in contact heat is transmitted always from the warmer thing to the colder one. After some time the temperature of the things is the same and we say that they are in thermal equilibrium.



Everything that moves has got energy, and this energy is called kinetic.

Figure 7.4 Exploratory study: From generalizations to examples (ideas and pictures for the 3rd task)

"What goes up must come down".

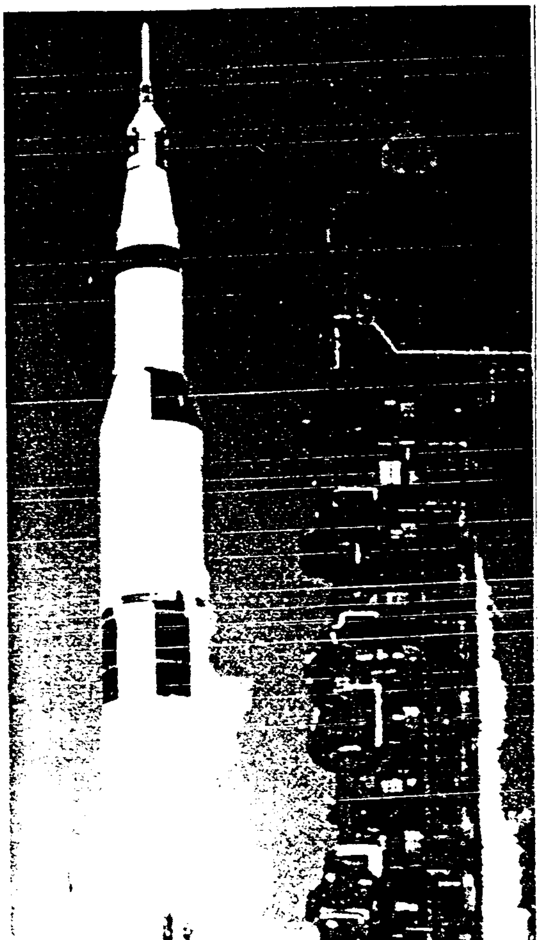


Figure 7.5 Exploratory study: From generalizations to examples (ideas and pictures for 4th task)

When things are raised they have got energy, that we call potential energy.

7.2.4.3 Results

The children were able to compare their own example of a generalization with the textbook example for that generalization, focusing on the differences or the similarities of the parts that constituted these examples.

For the children, an example is different from another one, when it is constituted from different parts and subparts. A child that runs is a different example of kinetic energy from "a car that moves" because:

> *"the child has got a heart instead of an engine that the car has..., the child's body is different from that of the car and instead of legs it has wheels"*

Also, it is notable that the children differentiated examples in which a part is able to do something by itself from examples in which a part needs a contribution from something else. So, a child who runs - has the power of autonomous action - is a different example from "a car that moves" because:

> *"the child has its own energy while this does not happen for the car"*

On the other hand, an example is the same (it is not better) than another one, if its parts are made of the same material. Therefore, an example of thermal equilibrium could be "if we put two iron plates, where one is hot and the other is cold, and we link them" as well as "if we put a cold pan on the hot-plate of an electric cooker" because:

> *"that pan and the hot plate are the same things, we have the same temperature transmission, because we have this material that the hot-plate is made of, something like iron..."*

An example is mainly judged better than another one because :

a. it is a usual phenomenon of everyday life.

> *"we see-know (in our everyday life) what happens in this... So, this is why we explain the phenomenon with that example "*

b. it shows big differences. An "aeroplane" is a better example of potential energy than a child up on a tree.

> *"because the higher it is from the earth the bigger potential energy it has"*

c. the nature of its parts. A "car that moves" is better example of kinetic energy than "a child that runs" because:

"it is difficult for someone to believe that there is energy in a boy"

Also, children seem to prefer examples which include stable (mainly solid) things. A child up on a tree, is a better example of potential energy than "a cloud" because:

"the tree cannot disappear but the cloud can disappear when it is raining"

d. the parts are "enough" for the whole process that the example describes. A cold pan over a cooker is a better example of thermal equilibrium than "to warm a metal with a gas-stove and put it in touch with a cold metal" because:

"the heat is transmitted from the cooker while in the second case we should have the gas-stove and many other things"

7.2.5 Overview of the Exploratory study

In the exploratory study, the children constructed generalisations, examples and made comparisons between examples which were based mainly on the differences in what the things that take part in them are made of. Results show that the children identified some instances as better examples of ideas than others. In summary, “good” examples are the ones where the relevant features are salient (often large), are more easily noticed, are stable, have autonomy, and are not too complex. Also an example is “better” if it is familiar.

7.3 Main study, phase 1: Comparing examples

7.3.1 Introduction

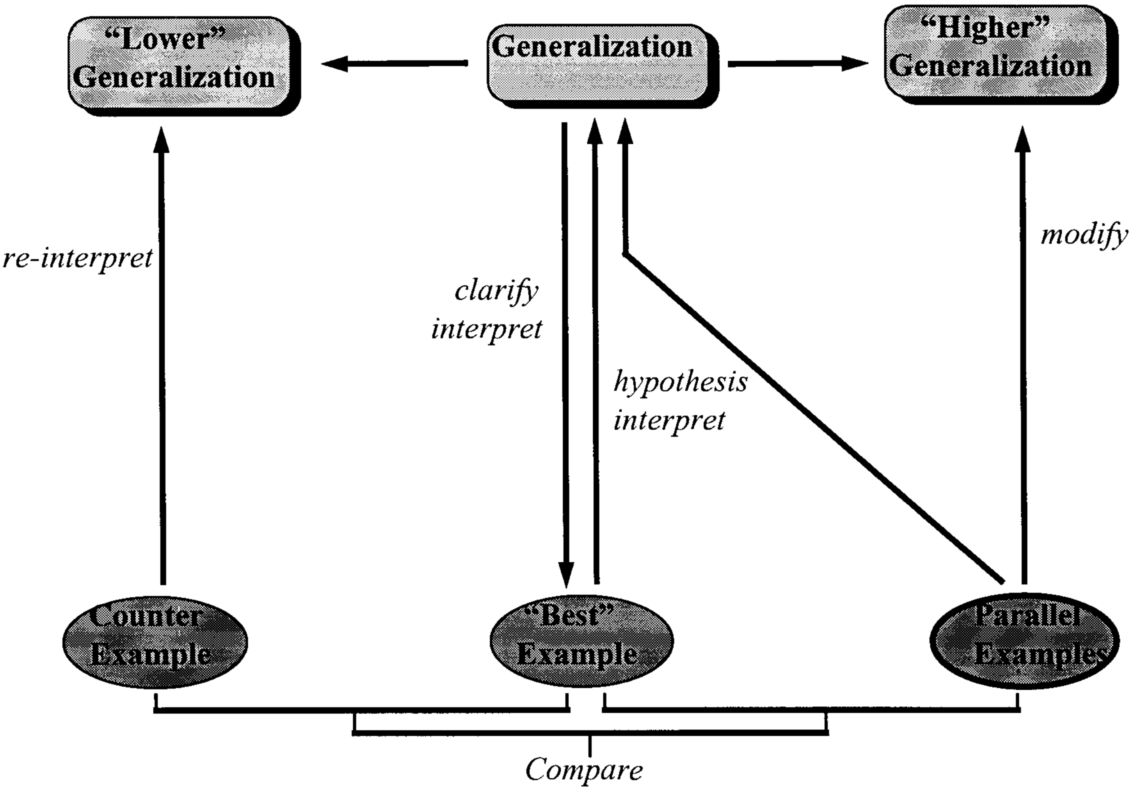
Empirical schemes are common abstractions of events. A scheme can represent more than one concrete thing. Empirical schemes are not these concrete things. They have the form of "bridges" that connect some concrete things (see study 1 in chapter 4). Through these bridges people are able to reason about one event using their knowledge about another. These bridges have a form and a content. In reasoning, people manipulate these imagined things - mental representations - not the concrete things themselves.

An example is not a good example of a generalization when it does not fit with the empirical schemes associated with the generalization. The nature of fitting can be described by a definite number of empirical schemes, and the addition or removal of some empirical schemes can lead to a higher or a lower generalization. The principle is that the fit is good when several anticipated empirical schemes are satisfied and poor when some are and others are not.

In this research, ideas (generalizations) and examples are considered at different levels of abstraction and specification (see theoretical discussion in chapter 2, and fig. 2.1). In order to make ideas (eg. things which are in thermal contact come to the same temperature) more concrete, so as to clarify or interpret them, an example may be used. The example might be the "best" example of the specific generalization (eg. two metal plates - one cold and one cold - that we bring into contact). On the other hand, people also use an example and hypothesize about it to produce a generalization.

Furthermore, comparing a best (prototypical) example with "parallel" examples (eg. the sun makes stones hot) one might modify the generalization to a "higher" one (eg. hot things often make things hot) in which both the best and the parallel example fit well (see figure 7.6). On the other hand, comparing the best example with a counter example (eg. two wooden plates - one hot and one cold - that we bring in contact) one may re-interpret the generalization as a "lower" one (eg. some things only allow transmission of the heat from one thing to another with difficulty). This analysis was used to classify the tasks, using generalizations, examples and counter examples.

Figure 7.6 A variation of examples and generalizations



The aims of the analysis of the tasks in phase 1 were:

a) to show that there is a variation of examples and generalisations that might follow the proposed schema in figure 21 (A generalization has a best example. The addition of parallel examples can lead to "higher" more general generalizations, while the addition of counter examples can lead to "Lower" generalizations).

b) to identify empirical schemes that are "responsible" for this variation.

The above diagram in relation to the aims led to the construction of three tasks:

(A) Fitting a generalization to examples

(B) Matching generalizations to examples and production of examples

(C) Constructing a generalization from examples

7.3.2 Participants

Forty children of mean age 11 years and 4 months participated in these tasks. All the children attended the last class of a public primary school in Athens. The children came from a middle class background.

7.3.3 Fitting a generalization to examples

7.3.3.1 Aims

In this task the children were presented with a generalization (middle level) and three examples (best, parallel and counter example). The aim of this task was to explore the way that children:

(a) think of an instance as a better example of an idea than another instance

(b) modify a generalization into a higher generalization or lower generalization in order to fit with the "parallel" and "counter" example.

(c) interpret the differences that they observe in various examples at the level of generalizations.

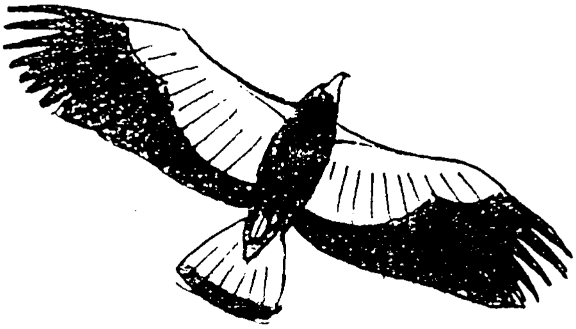
7.3.3.2 Materials

The materials used for this example were a piece of paper where a (more or less) scientific idea was written (e.g. what goes up must come down) and three pictures to serve as examples of each idea. In one of these pictures, some children played football and the ball was in the air; in the other a bird was flying, and in the last, a rocket was being launched (see figure 7.7)

7.3.3.3 Procedure

Firstly, I told the children that I was going to read them an idea that I had found in a science text book. The idea was "What goes up must come down". After hearing the idea, the children were asked to describe what they could see in the three pictures, and to decide and explain, which picture was the best example of the idea. At the end, they were asked to modify the idea in order to make it fit with the other two examples.

Figure 7.7 Phase 1: Fitting a generalisation to examples (pictures)



7.3.3.4 Results

7.3.3.4.1 Which is the best example?

All the children (40) suggested that the example with the ball was the best example of the initial idea "What goes up must come down". The analysis that follows, is based on children's arguments to support their judgments that the eagle example and the rocket example do not fit so well with the generalization. Thirteen of the children argued that a rocket does not come down, while only four of the children argued that an eagle does not come down. Particularly, the empirical schemes which were responsible for the poor fit of the examples with the idea could be classified into the categories discussed below.

7.3.3.4.2 Which empirical schemes are responsible for a good fit between examples and ideas?

1. Rapidity of change

An eagle can fly for a long time (6 children, 15%). That is, it can stay up without coming down for a longer time - "for many hours"(C.25) - than a ball. "Some things when they go up they can stay there, flying for a long time" (C.14). The smaller time a thing needs to come down the better an example of the initial idea it is. Also, the rocket "can stay up for a longer time" (8 children, 20%). That happens because "the rockets have fuel and they can stay more time up in the air" (C.22). Furthermore, the rocket "cannot come down immediately" because it has to reach its destination" (C.13).

The initial idea includes two actions (go up and come down) which are connected with an implication of the form: If the first action happens then the second action must happen as well. In that case the particular task shows that the less time needed between these two actions, the better the example will be.

Considering the role of the time, I hypothesized that the example of a stone thrown in the air would be better than that of a ball thrown in the air. I tested this hypothesis with 13 of these children. Eight (8) of them argued that the stone-example is better because the stone will come down more quickly than the ball. Two of them said that the two examples are the same, while 3 of them argued that the ball-example is better because a stone thrown up can hit somebody.

2. Autonomy of action

The most popular justification that the children used to explain why they chose the ball as more prototypical example than the eagle, was that the eagle is a living thing while the ball is not (14 children, 35%). This difference suggests that the eagle as a living thing can be viewed as an autonomous actor. Thus, it can do things that are in contrast with the initial idea. The rocket which is controlled by humans is treated in a similar way (but not so frequently) as the eagle (8 children, 20%). The justification is based on the power of autonomous action. In addition to autonomy of action living things have the power to decide, to want and act accordingly; that is they have autonomy “control”.

Eleven of the children (27.5%) argued that the eagle example does not fit so well with the idea "whatever goes up must come down" because the eagle can come down whenever it wants. That is the eagle has the power of autonomous action. It can control its actions. The presence of the scheme of autonomous action makes the particular example not fit with the idea well.

So, "when the eagle goes up it can stay up as much time as it wants"(C.21). Furthermore, because of its ability to fly, "it can go everywhere it wants"(C.33). Six of these children (15%) reasoned that the eagle can do anything it wants because it has the ability to fly. In a similar way a rocket can come down whenever it wants because it has engines (3 children).

"When the bird goes up, it can decide whether to stay there or to come down"(C.39). In some cases the children reffered to animals' consciousness. That is, "the eagle is a living thing and understands that it can go up without coming down". Also, "the eagle is not a non living thing that you can control, it can do anything it wants, it can go up or come down without any help"(C.35). That is, the consciousness dimension is based on the autonomy of the bird. There is a conscious control of its power for autonomous actions.

The above examples suggest that the eagle's desires (wants) have their origins not in unconscious processes (e.g. being hungry, tired etc.) but in conscious processes (e.g. understanding). The whole idea of making decisions and particularly the extreme case of consciousness of living things gives an indication of how the empirical schemes of two examples can differ in abstract qualities.

Also, "the rocket is a non-living thing but people make decisions for it"(C.28). "In order for a rocket to come down, people who are there must decide," (C.18) (5 children). One of the decisions can be that "the pilot stops the engines"(C.27)

3. Necessity

The eagle-example and rocket-example do not fit so well with the initial generalization, because of the inherent natures of the eagle and the rocket. The necessity category can be described in three forms:

(a) General reference to nature of the object

"The eagle because of its nature can fly"(C.4)

"A rocket when it has passed a specific distance can not come down" (C.3)

"When the rocket goes up, only some parts of it fall down. It has been designed in this way" (C.35)

(b) Specific elements that are responsible for this nature

"Birds have wings and they can fly without falling down"(C.1)

"It (the rocket) has engines and come down whenever it wants"

(c) Specification of the nature of object and its implications

Consciousness, is controlled by humans or other animals (see in the previous category for examples).

4. Support

A bird can be temporarily supported by its wings and so it does not come down. "The bird flies when moves its wings, but when it stops moving them, it will fall down" (C.3)

An eagle does not fit so well with the initial idea because of a temporary (movement of wings) or more permanent support. In the last case "When the eagle goes up it can stay continuously up a tree"(C.34) or in "a nest" (C.11). Also, a rocket does not come down because it "can stay up, on the moon"(C.11) or on another "planet" (C.32). Furthermore, it can "get into an orbit around the earth" (C.15) or "around the moon"(C.21).

5. Features of the route (actual time and space-location)

This category includes the particular features of the route. It is notable that an “asymmetry” between the routes of different examples make them different. Assymetries appeared in the actual time that the eagle or the rocket needs to go up and come down: "the eagle goes slowly up and come slowly down" (C.31) while “the rocket goes quickly up and comes slowly down”(C.31). These asymmetries can make one example a better example than the others. Thus the example with the ball is better than the one with the eagle "because the eagle cannot go up-down so quickly"(C.17).

7.3.4 Matching generalizations to examples and production of examples

7.3.4.1 Aims

The aims of this task were to:

(a) explore whether children using their empirical schemes could match a "best" example with a middle level generalization

(b) see whether children are able to produce examples which fitted well with various levels of specification of a generalization

(c) identify the boundaries that exist between different levels of generalization and how they could be seen through the different empirical schemes that children used, in the production of different examples.

7.3.4.2 Materials

The materials used for this task were a pair of pictures and one piece of paper with three ideas of science. In the one picture the children could see two metal plates, one cold and one hot. In the other picture these plates were in contact (see figure 7.8). The ideas written on the paper were:

a. Hot things frequently make things hot.

b. Things which are in contact reach the same temperature.

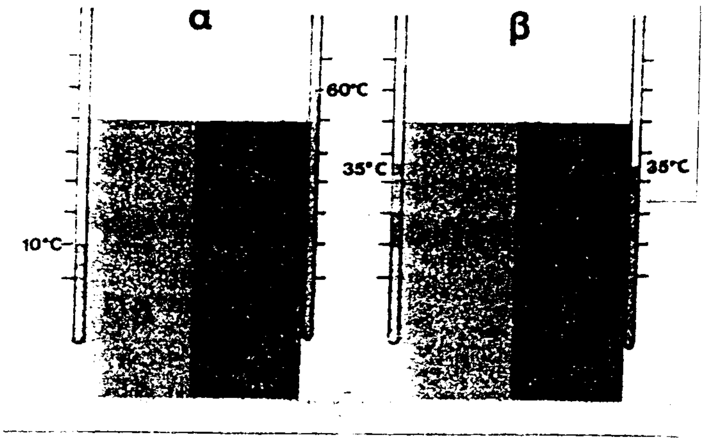
c. Some things in contact allow with great difficulty the transportation of heat from one thing to another.

All the above three ideas are about the transmission of heat. The first one is more general than the second because it includes cases where there is no contact between things (e.g. the sun makes hot the sea). The example with the plates fits better with the second generalization. The third one includes only these things that are in contact but do allow with difficulty the transmission of heat (e.g. glass). It is a "low-level" generalization while the first one is a "high-level" generalization in relation to the second generalization (see above for figure 7.7).

7.3.4.3 Procedure

The children were presented with the pair of pictures and were asked which of the three ideas fitted best with the example (pictures). They were then asked to give other examples that fitted with the other two ideas.

Figure 7.8 Phase 1:Matching generalisations to examples and production of examples (picture)



7.3.4.4 Results

7.3.4.4.1 Which is the best-fitting generalization?

Most of the children (32 out of 40) suggested that the example with the two metal plates in contact, fitted better with the (middle level) idea "things that are in contact reach the same temperature". They chose this idea as better for the interpretation of the example, instead of the higher generalization "warm things frequently make the other things warm", and the lower generalization "some things allow, with great difficulty, the transportation of heat from one thing to another".

Some of them justified their choice saying that the example did not fit well with the higher generalization because this idea "does not mention that the two things must be in contact (C.36) or "if (these things) were not in touch the heat is not transported" (C.18). Furthermore the example did not fit well with the lower generalization because in the particular example "the heat will be transmitted easily" (C.18).

In these cases, the children recognized the expected specific properties (contact, easy transportation) of the example, and looked for them in the text of the generalization. The analysis that follows is based on the children's justifications. It attempts to identify the various empirical schemes that appeared in the children's justifications.

7.3.4.4.2 When might an example be "bad" for a generalization?

1. Interaction

(a) The "leader" of the interaction

A high level generalization has to be modified, specialized, and interpreted so as to fit well with the example. The example does not fit well with the higher generalization because "cold things can make other things cold" (C.12, 22, 24). In the particular example, two opposite states or properties of things - hot, cold - interact and produce a new state. The principle which might be responsible for this answer is the following: When two things appear to have two opposite states or properties which can interact and modify their states or produce a new state, it is expected that both of them will "lead" to this new state. As warm things have heat and can make other things warm, in the same way, cold things have something that can make other things cold.

(b) Quantity

Furthermore, the example did not fit well with the higher generalization because "the other thing - the cold one - could be very cold, so the heat of the other thing could be not enough to make it (the cold one) hot" (C.13).

Therefore, the new state of things depends on how big or small are the properties of these things.

(c) Initial state

The higher generalization distinguishes the state between "hot things" and "other things". Thus, the example did not fit well with this idea because in the particular example "both of these things have temperature" (C.23) or because both of them are warm things" (C.39).

The initial state of the things that interacted was considered by the children. In the particular task the problem appeared because the correspondence between terms such as hot, cold and the values of the temperature were not clear.

2. Rapidity of change

The example did not fit well with the lower generalization because in this example "the temperature changes immediately" (C.12), and "the heat passes quickly" (C.13), so "in some time the heat becomes the same" (C.22). So, the small amounts of time that is needed for the transmission of heat means that this transmission happens more easily, that is "quicker means easier".

7.3.4.4.3 How can an instance be a "good" example of an idea?

1. Higher generalization

A good example for this generalization is an example in which a source of heat makes other things which are not in contact with the hot thing, warm. This example can mention (a) in general the things that become warm:

"The radiator became hot then all the class will become hot" (C.2)

"the sun makes other things warm" (C.13)

"the stove makes the other things hot" (C.17,31)

"if we light the lighter it will heat" (C.11)

(b) specific things:

"The sun makes people feel warm" (C.3),

"The sun makes the windows warm" (C.18)

In the above examples, we can distinguish two different groups of things, the source pole and the receiver pole. These two poles are at a distance from one another and the things that are between them (mainly the air) allow the source pole to cause an effect on the receiver pole. The higher generalization can be interpreted as "things act on other things". The above examples strongly specify the source pole, copy the act (make warm), and weakly specify the receiver pole (other things). So, the important thing here is the identification of the "actor". Finally the "actor" acts on "patients" which in many cases might be so numerous that it is not important to specify them.

Another variation of this scheme which connects causes and effects can be seen in the following examples :

"Hot lake, (or sea, C.8) then it makes the fish hot" (C.4)

"Hot weather, then our bodies become hot" (C.23)

"the cooker make the food hot" (C.27)

In these examples the receiver pole is inside the source pole. In general, the properties of a thing that belongs (is inside) in a system, are the same as those of the system.

Furthermore, the mixing of two things with the same nature is different from their contact. so in this higher idea good examples can be:

"a casserole with hot food....."(C28)

"a bowl with hot water .... " (C.39)

2. Lower generalization

What makes transmission of heat difficult can be described by the following categories of empirical schemes:

(a) "Barrier"

> *"When the sun drops behind a wall, it is difficult to make the bed which is behind the wall hot" (C.6)*
>
> *"when we put something into the freezer, it becomes ice while the freezer does not allow the heat from outside to come inside easily" (C.4).*

The transmission of heat is difficult when there is a "barrier" between source and receiver such as a wall. In some cases the receiver pole can be used as a "border" or a container.

(b) Quality - the nature of the material

> *"The freezer inside is made of plastic in order not to allow the cold temperature to go out" (C.9)*

The children suggested as receiver poles various materials such as aluminum, wood, cement, plastic which do not allow the transmission of heat easily. So a good example for the lower generalization is one in which the nature of the material that constitutes the receiver pole or the material of the barrier has the special ability to "stop" the transmission. All of the children believed that glass belongs in this category.

(c) Distance

> *"when our body is cold and we are far from the radiator it is difficult to become hot" (C.23)*
>
> *"Two glass bowls far away one from the other" (C.25).*

Another reason that can "cut" the easy connection between source and receiver pole is a distance between them. It appears to me that there is a strong relation between space (distance) time and goals. The construction of many empirical schemes is based on this relation between the above empirical schemes.

7.3.5 Constructing a generalization from examples

7.3.5.1 Aims

In this task, the children were presented with three pictures of examples and were asked to construct a generalization which could describe what they observe in all these pictures. I attempted to see whether the variation of the generalizations that the children produced could be described as belonging to high, middle, or low levels of generalization. In other words, to see if the variation of the level of the generalization that they constructed depended on the picture-examples which they would focus on in order to construct the generalization. I was also interested in what changes are required for different types of examples (parallel, counter), to fit well with each of the three levels of generalizations.

The aims of this task were:

(a) to identify common empirical schemes in various examples

(b) to see how children interpret (and include) these empirical schemes in producing a generalization

(c) to identify which of the concrete empirical schemes were common in these examples

(d) to explore the modifications that these distinct empirical schemes in various examples underwent, in order for all the examples to become good examples of the same generalization.

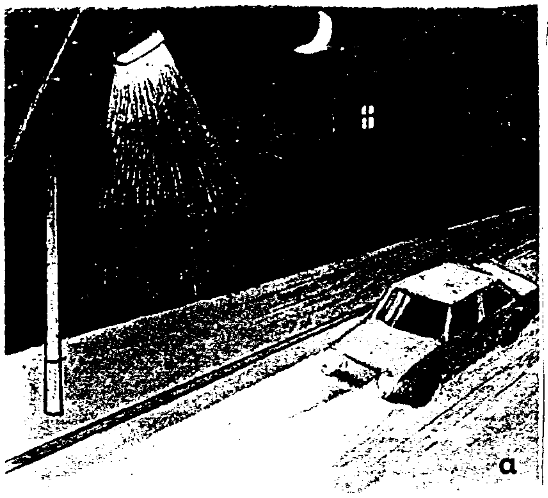
7.3.5.2 Materials

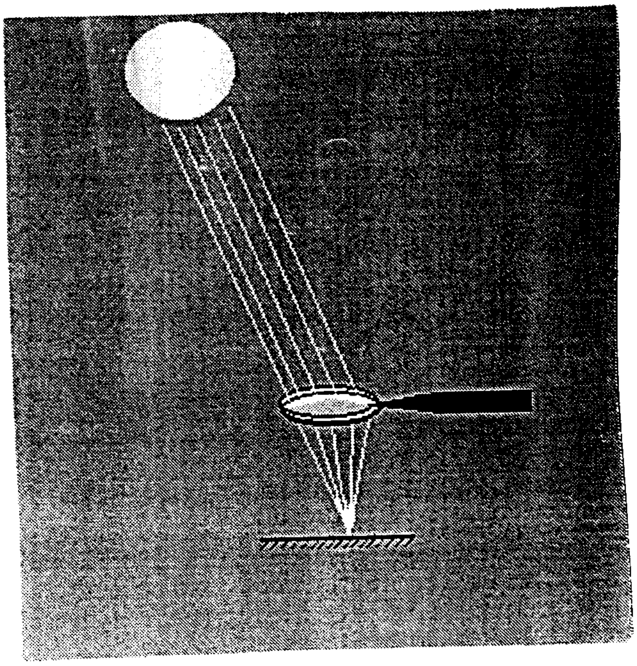
The materials used for this task were three pictures and a blank piece of paper. In one picture, they could see a car at night with its lights on, in the second a torch that makes a child's shadow, and in the third a magnifying glass (see figure 7.9).

7.3.5.3 Procedure

The children were presented with the three pictures and asked to describe what they could see in the pictures. Then, they were asked which science idea these picture could be examples of. Having obtained such an idea I asked if all these pictures fitted equally well with that idea. If they thought that there were some problems in the fitting of examples to idea, I asked them to tell me how to change the pictures in order to fit them better to the generalization.

Figure 7.9 Phase 1: Constructing a generalization from examples (pictures)





7.3.5.4 Results

7.3.5.4.1 What sort of generalizations did children construct?

The children constructed their own generalizations at various levels. These generalizations indicate counter examples (lower generalizations), match with one example only out of the three pictures (middle level generalizations) or can stand as generalizations for more than one example (higher generalizations).

1. Lower generalization

"Light can pass through some things" (C.12). In this generalization the word "some" indicates the existence of counter examples, that is, this lower generalization allows the existence of counter examples. Light cannot pass through all things.

2. Middle level generalization

This type of generalization arose from just one (out of three) picture example. "With the light we can see during the night, with electricity" (C.13). In this case the child had as best example (and at the same time it was the example from which this generalization had arisen) the car-picture. Therefore, big changes were required in order for the other two examples to fit with this generalization. For example, in the case of the magnifyng glass he kept the sun, and asked to put a cardboard in a window with a small hole. Thus, we can see in this dark room because of the light.

3. Higher generalization

a. Include all (the three) picture-examples

"The light comes from a specific source " (C.12).

In this case the child tried to recognize the existence of sources of the light in each example, although in two of them the sources were not observable. The existence of a source seems necessary for the presence of the effects (existence of light).

b. Include two parallel examples

"The rays of light are refracted, become bigger" (the parallel beam) (C.25)

The child said that this generalization fits with the examples with the torch and the car but does not fit with the example with the magnifying glass. He said that the magnifying glass concentrates light on to the ground while the torch and the car headlamps refract light in a bigger area.

7.3.5.4.2 What is responsible for the variation of generalisations?

1. Negative versus Positive Generalizations

Consider for example:

> *"Artificial light helps us much in our life" (C.20)*
> *versus "Without light we cannot live" (C.22) and*
> *"With light we can see in the night, with electric" (C.13)*
> *versus "Without light we cannot see" (C.14)*

Children gave the above generalizations. In these the first in each case is a positive statements and refers to the contribution that the presence of an entity has in our life. The second in each case refers to a hypothetical absence of an entity (light) which is related with the absence of an effect (cannot live/see). This case of negative generalizations is very interesting, because the absence of something is not easily shown in examples. There are many more entities that could be hypothesized as absent in an example from this than those that are present.

2. Powerful empirical schemes

The producer of the generalization "light can pass through some things" (C.18) chose as the best example the magnifying glass picture. He recognized as "problematic" the picture with the shadow and asked to change it, putting a glass instead of the boy in front of the wall. Although the picture with the shadow could fit well with the above generalization, (considering that "some" means "not all"), the child did not accept the good fit of this example with the generalization because he thought of the scheme ‘pass’ as more important-powerful.

3. Explicit use of empirical schemes

Also, in the case of the car, the child recognized that it was a good example of the generalization. However, the child said that we have to put a man into the car (it is not explicit) and then we can say that the light passes through the front glass to the man.

Another example of this dimension is the child who constructed the following generalization, "The light comes from a particular source"(C.18). He suggested as a better example for this idea the picture with the magnifying glass and the sun. The other two examples fitted well with the idea but they were not so good because "the sun can light itself while the car and the torch need batteries (which are also explicit).

7.3.5.4.3 What are the origins of generalisations?

The generalizations that are constructed by children have their roots in (a) commonsense knowledge and in (b) scientific knowledge. The presentation of some major dimensions which lead to the construction of empirical schemes in the above categories follows.

1. Commonsense Knowledge

(a) Social Aspects

There were many children who based the construction of their generalization on social aspects.

> *"Without light we cannot live" (C.22).*

This child used social aspects also when he tried to change the other two examples. In the case with the magnifying glass he suggested removing the magnifying glass and putting a factory instead.

> *"...It means that without the sun we could not have any energy.... the factory using some particular machines will take the energy from the sun, and it will provide it to us" (C.22)*

Also, in the other example he suggested putting a child who needed the light.

> *"A child who had gone to his house and cut off his electricity supply,... he did not know what he should do and he might have started shouting help,... so some neighbors would help him" (C.22)*

(b)Goals

> *"With light we can see" (C.33)*
>
> *"We use light for a particular aim" (C.32)*

In this case, the child following an emphasis on goals, was asked to modify the pictures with the magnifying glass (in order to fit better with the above generalization) adding a firebrand (torch). "We can kindle the firebrand and use it for the Olympic games"(C.32) Furthermore, the picture with the child was rather forcibly adapted to fit well: because "we use it to see the child's shadow"(C.32)

(c) Necessity

"Without light we cannot see" (C.14). Light has a strong relation with some of our abilities. This relation which indicates for example that the action "see" cannot appear without "light" is known to the children from their experience and they state this relation even though they do not know why it happens.

2. Scientific views

"In these two pictures the light passes through diverging lenses" (C.34)

"The rays of light are refracted, become bigger" (the parallel beam) (C.25)

In the above cases the children with their generalization identify different effects on the light when it passes through different objects. Probably it is an indication of the existence of different lenses.

7.3.6 Overview of Phase 1

The results demonstrated that there is a variation of examples and generalisations that can be described by the following principles: A generalization has best examples. The addition of parallel examples can lead to "higher" more general generalizations, while the addition of counter examples can lead to "Lower" generalizations.

Some examples have a better fit than other examples with an idea. The presence (or absence) of particular empirical schemes influences the fit between examples and generalisations. Some of the main reasons which were identified (in children's justifications) as responsible for a good fit between examples and ideas, are the following:

- Speed (rapidity of change). The principle is, the less time needed between two actions, the better the example is.
- Autonomous action. Some objects can control their actions, that is they are able to present autonomous actions. In the particular idea 'When things go up they must come down', examples which consists of an object which can be described by the scheme of autonomous actions are not good examples of this idea.
- Necessity. The fit between examples and ideas is influenced by the inherent nature of the objects. So, the nature of an object is to some extent responsible for the way that it appears in the example.
- Support-Barrier. Objects which can be supported by themselves or by another object can 'reject' the movement that they would have because of gravity. Also,

movement in a horizontal axis can be prevented by a barrier or a container. The scheme of support in the vertical or horizontal axes plays an important role in the fit between examples and ideas.

- Space-location. The position of an object in space and its relations (e.g. the distance between two objects) with other objects that take part in an example of an idea play an important role in the fit between examples and ideas.
- Quantity. The size (big-small) and the weight (heavy-light) of objects that take part in an example influence the fit between examples and ideas.
- Shape. Each object has a shape and it can influence the particular movement of an object. Thus, the shape can be responsible for a contrary movement to the vertical movement which an object tend to have because of the the gravity.
- Existence. The presence (or absence) of an object in an instance can have as result a better (or worse) fit between this example and an idea.

The above reasons emerged from children's justifications and were used in the construction of the questionnaire used in phase 2. In phase 2 the aim was to explore the role that changes of these categories of reasons have on the fit between various examples and ideas.

7.4 Main study, phase 2: Making examples of ideas better or worse

7.4.1 Introduction

Examples of ideas consist of specific objects which have particular relations. In this study I explored how changes in the dimensions of the existence of objects, their attributes (such as shape, size, weight) and their relations (such as time, space) can highlight or hide features which make them better or worse examples.

7.4.2 Methods

7.4.2.1 Participants & Materials

The participants were the same children that participated in study 3. Thus, 407 children ranging in age from 11 to 12.28 years with a mean of 11.56 years old participated in the study. Twelve questionnaires were used (see the previous chapter for the description of these questionnaires).

7.4.2.2 Procedure

In this part of the questionnaire (see Figure 7.10 and Appendix 7.1) the focus was now on what makes an example better or worse. To do this the children were presented with an idea and an example of the idea. They were asked to choose some changes that can be made to five objects (they were components of the example and played particular roles such as protagonists, structure related objects etc. - see previous chapter for a detailed presentation of their roles) in order to make the example better or worse. The changes referred to dimensions of time, space, existence, weight, shape and size (they could make each object act more quickly, be away, not exist, be heavier, change its shape, be bigger).

Figure 7.10 The questionnaire

An example for the idea "When things are raised, they have energy, that we call Potential Energy" is <u>a boy up a tree</u> (see picture on the previous page). The child, the tree, the ground, and the potential energy take part in this example. How could you change them to make the above example a **better example**?

Make it...→	bigger	not to exist	heavier	to do something quicker	to change its shape	to be further away
the child	☐	☐	☐	☐	☐	☐
the tree	☐	☐	☐	☐	☐	☐
the air	☐	☐	☐	☐	☐	☐
the ground	☐	☐	☐	☐	☐	☐
the P.energy	☐	☐	☐	☐	☐	☐

How could you change them to make it a **worse example***?*

Make it...→	bigger	not to exist	heavier	to do something quicker	to change its shape	to be further away
the child	☐	☐	☐	☐	☐	☐
the tree	☐	☐	☐	☐	☐	☐
the air	☐	☐	☐	☐	☐	☐
the ground	☐	☐	☐	☐	☐	☐
the P.energy	☐	☐	☐	☐	☐	☐

7.4.2.3 Method of analysis

The research questions of this study and the way the data were analysed are presented below:

(a) Are there differences in the frequency of choice of each feature for the five objects? In this case whether the differences among the five objects influenced the number of “yes” responses given to a particular change of feature by the children could be tested. If there are differences, this means that for a given feature, objects differ in whether they need to be changed to make the example better (or worse). The Cochran Q Test for k related subjects was used. It provides a method for testing whether the frequencies of each feature (e.g. make it bigger) differ significantly among the five objects.

(b) Are there differences in the frequency of choice of features for each object? The Cochran Q Test for k related subjects was used to test whether for a given object, the features differ among themselves with respect to how often they are chosen.

These two questions are obviously related: a high frequency for a feature and a given object will re-appear as a high frequency for an object and a given feature. Therefore, the results are presented together as a matrix (see figures in the analysis of each idea), identifying combinations of features and objects which are salient in both analyses.

(c) Are there differences in frequencies of choices of features for the objects with the same role (e.g. scientific concept, protagonist) in different examples of the same idea? The chi-square test was used to determine the significance of differences between the two independent groups of children who gave answers for the two different examples of the same idea.

At the beginning, the results of the analyses of the above questions will be discussed for each idea (both examples) separately. Then there will be a summary discussion of the common and different things that appeared across the different ideas. At the end, issues about the importance and the information that an analysis like this can give to researchers will be discussed.

The presence or the absence of significant differences will be shown in tables such as Tables 7.1 & 7.2 (which apply to the case of potential energy) while the actual level of significance can be seen in the tables in Appendices. In these tables (such as Table 7.1 & 7.2) there are symbols * against all the features (e.g. bigger etc) for each object (e.g. 'air') for which the frequencies -"Fe"- were unusually high. Thus the * symbols should be read horizontally (e.g. for pot, first example, the features bigger, heavier and further away are frequent in table 1). Also, there are symbols + resulting from looking at the same data the other way, asking which objects -"Ob"- are chosen frequently for a given feature. Thus, these should be read downwards. For example, for the feature 'bigger' the objects pot, child, tree and potential energy were frequently chosen (see table 7.1).

Furthermore, the box around two (*) and two (+) symbols means that in both examples of the particular idea there was a high frequency of children who chose the particular feature among the other features for a given object and the particular object among the other objects for a given feature. In contrast, the shaded boxes mean that there was a difference between the two examples in the number of children who chose the particular feature for the given object.

7.4.3 Results

7.4.3.1 Potential energy

Idea: *'When things are raised, they have energy, that we call potential energy'*

Examples:

(a) *'a child up a tree has potential energy', and*

(b) 'a pot on a balcony has potential energy'

There are differences in the frequency of 'yes' responses according to: (a) the type of object and (b) the sort of feature since the significance level of the Cochran Q test is less than 0.05 in almost all cases (37 out of 44, see Appendix 7.2).

The cases of non-significant differences are worth discussing briefly:

(a) The feature of existence, being chosen hardly ever for any object, could show no difference when children attempted to make better the example with the child up a tree.

(b) When the children suggested changes to make the example worse there were no differences for the feature 'quicker' in both examples, the features 'heavier' and 'shape' in the pot example, and the feature 'further away' in the child example. In the last three features there were no statistically significant differences among the five objects since all of them appeared with a similar frequency (about a quarter of the children chose them, with a range of 10%).

(c) Differences in frequency of choice of feature for each object were absent only in two cases, when the children suggested changes in features of the air and the ground to make the example worse.

The presentation of results in tables 7.1 & 7.2 (see in method of analysis for the interpretation of symbols in these tables) is based on the features for each object that a different number of children appeared to chose them in relation to other features, and the objects for each feature that their frequency in children's 'yes' responses differ significantly from other objects. It seems that in both examples the children follow the principle "more is better" which in the particular example translates "bigger is better" or "the more potential energy the better the example".

Table 7.1 Making the examples of Potential Energy better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Irrelev.	air							*	+				
	air							*	+				
Protag.	pot	*	+			*	+					*	+
	child	*	+			*	+				+	*	+
Surfac.	balcony	*	+							*	+		
	tree	*	+								+		
Struct.	ground											*	+
	ground											*	+
S.Conc.	pot.ener	*	+					*	+				
	pot.ener	*	+										

Table 7.2 Making the examples of Potential Energy worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Irrelev.	air		+										
	air			*									
Protag.	pot			*	+					*	+		
	child			*	+	*	+			*	+		
Surfac.	balcony	*	+	*	+					*	+	*	+
	tree	*	+	*	+					*	+		
Struct.	ground		+								+		
	ground			*	+					*	+		
S.Conc.	pot.ener			*	+			*					
	pot.ener			*									

Key to abbreviations

Fe : Feature	* : statistically significant features
Ob : Object	+ : statistically significant objects

☐ : high frequency for features and objects in both examples

▨ : differences between the two examples

There are different ways to use the principle "more is better". To make something bigger is one dominant way to make both text-book examples better. The quantity of the scientific concept should increase. Potential energy has to be 'bigger'. The increase of potential energy could be the result of some other increases. So, the surface related objects (balcony and tree) and the protagonists (pot & child) have to be bigger. Making bigger in a vertical axis the surface related objects (mainly the tree), has as a result the removal of the protagonists 'further away' and that could lead to increase the quantity of potential energy. It seems that children think that making bigger the store of potential energy - the protagonists - has as a result the increase of the scientific concept (potential energy). Also, the protagonist (pot & child) should be heavier.

Furthermore, removing some objects 'further away' from other objects would have as a result the increase of potential energy. So, if the protagonists and the structural related objects are 'further away' from each other the example will be better.

A different approach to make the example (with the pot) better was the following: children saw potential energy as a potential source of movement, and a better example should show this movement. The irrelevant object could make something quicker (to make the protagonist fall down from the surface related object). In this case the quicker (less time) the better.

There were some statistically significant differences in the changes between the two examples. More children in the case of the example 'a pot up a balcony' said that the scientific concept has to make something quicker than in the case with the child up a tree. The potential energy as a source of potential movement seems to be able to make the pot (inanimate) move quicker than the child (animate). More children said that the tree should be bigger than said the balcony should be bigger. A bigger tree equals a higher tree with more potential energy for the child while a bigger balcony equals a wider balcony which does not make any change in the potential energy. In addition the structure related object has to be further away in the case of the example with the child rather than the example with the pot. The tree can more easily be imagined to become bigger-higher than can the balcony. Also the distance between the child up a tree and the ground is not shown in the picture as big as the distance between the balcony and the ground. So, more children asked to move the ground 'further away' in the case of the example with the child than that with the pot, even though they only saw one of the two cases.

Both examples could be made worse if various objects, mainly the protagonists, did not exist. An example will be worse when its essential components do not exist, because the example does not then exist. Also, the example could be made worse by changing the shape of protagonists, structure and surface related objects. That happens because after changing the appearance of these objects their identity is not so recognisable. In other words, the example loses again its components, they do not exist, and the example become worse.

There is evidence that the children sometimes chose the same features but for different reasons. So, some children said that by making the child in the picture heavier the example could be made worse since the tree branch will break and the child will fall down and then there will be no example. In this case, the example becomes dynamic (with the addition of movement) and loses the 'duration' that it had as a static phenomenon. Also, the balcony and the tree could be bigger, to make the example worse (as well as better, as above). One or two of the children justified this choice saying that a bigger tree will have stronger branches which will not break to provide as evidence of the existence of potential energy the fall of the child. In a similar way, if the balcony is bigger-wider the pot will not fall and so we would not have any evidence for the existence of potential energy.

There were some differences in the frequencies of the changes between the children of the two different groups. More children in the case of the example 'a child up a tree' suggested making the tree and the child not to exist than did this for the balcony and the pot in the example with the 'pot on a balcony'. Also, more children said that the child had to be heavier, than said the pot had to be. By making the child heavier, they would expect to break the tree branch. However, a heavy pot cannot break the balcony. More children said that the balcony has to be removed ‘further away’ than the tree.

7.4.3.2 Expansion

Idea: *'Almost all solid things, expand when they are heated. This phenomenon is called expansion'*

Examples:

(a) 'In the summer the electric wires of the Δ.E.H (Public Company of Electricity) are expanded between two pylons because of the high temperature, so they are loose' and

(b) 'in the summer the railways lines expand because of the high temperature, so the lines bend up in an arc'

The Cochran Q test showed that there are statistically significant differences in the frequency of 'yes' responses considering the type of object and the sort of feature (34 out of 44, see Appendix 7.3)

Tables 7.3 & 7.4 show the symbol (*) for a given feature the objects with significantly bigger frequencies among others, and the symbol (+) for an object the features with significant bigger frequencies among other features.

In both examples of this idea the bigger the protagonists, the structure related objects, and the scientific concepts are, the better the example is. Making the expansion bigger the example becomes better. A way to make the expansion bigger is to make the sun bigger. A bigger effect needs a bigger cause. Also, by making the rail or the wires bigger they will not fit in a straight horizontal line. The curve due to the expansion will be bigger and the example will be better. So, the shape of the protagonists has to change more.

Table 7.3 Making the examples of Expansion better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	rail	*	+							*	+		
	wires	*	+							*	+	*	+
Irrelev.	ground												
	ground									*			
Struct.	sun	*	+									*	+
	sun	*	+					*	+				
Surfac.	train					*	+	*	+				
	pylons	*								*	+	*	+
S.Conc.	expansi.	*	+										
	expansi.	*	+										

Table 7.4 Making the examples of Expansion worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	rail			*	+					*	+	*	+
	wires			*	+					*	+	*	+
Irrelev.	ground												
	ground			*						*	+	*	
Struct.	sun			*	+					*	+	*	+
	sun			*	+					*	+	*	+
Surfac.	train					*		*	+				
	pylons			*						*		*	+
S.Conc.	expansi.			*	+								
	expansi.			*	+					*		*	

Key for abbreviations see page 257.

The train has to be quicker to cover in less time its distance from the curve, because then the 'size-power' of the expansion to stop the train, will be more observable. The train also should be heavier, possibly in order to stop at the front of the curve and not (having the ability as a light thing) to pass over the curve. In agreement with that, very few children asked to make things ‘heavier’ when they attempted to make both examples worse.

Very few of the children who attempted to make better or worse the example with the electric wires in summer, asked to make any object ‘heavier’ making it better. In the example with the wires, children made the example better suggesting that the sun has to make something happen more quickly. It could make the wires expand quicker. There is a statistically significant difference between the two examples. Children did not suggest the same thing in the example with the railway lines because the railway lines were seen as more rigid things that could not change so easily. However, in the example with the train children said that the sun should be ‘further away’. Possibly that happened because in the picture, the sun was very close to the ground, and this may have been seen as conflicting with reality. Very few children asked to remove things (‘not exist’) when they attempted to make both examples better.

In contrast, both examples could be worse if some of the objects did not exist or they were further away or they changed their shape. The protagonists, the structure related objects and the scientific concept which had to be bigger in order for the example to be better, had to be removed in order for the example to be worse. Furthermore, the protagonists and the structure related objects should be removed further away or change their shape, to make the examples worse since there would not be any indication of expansion. Changing the shape of the sun by making it smaller, or removing the cause, the sun, ('further away') the effect would be smaller and the example worse.

The children suggested making the train do something quicker. This was used both to make the example not only better but also worse. In this case the example becomes worse because it loses its duration.

The feature 'further away', was chosen for all objects by many of the children when they attempted to make the example with the wires worse, but there were no statistically significant differences among the objects. Particularly, in the example with the wires more children said that the ground and the surface related objects had not to exist or be removed than did so in the example with the railway. This difference was statistically significant. In contrast only a very small minority of children suggested making any object 'bigger' and 'quicker'. The train did not play an important role in the example like the pylons which keep the wires, so its removal is not so important. In a similar way, it seems that the ground is not so important in the example with the railways.

More children said that the pylons rather than the train should be moved further away. The children did not think that moving the train far away would make so important a change to the example as would the movement of pylons which held the wires.

7.4.3.3 Equilibrium

Idea: *'When things come in contact, the heat is transmitted always from the warmer to the colder'*

Examples:

(a) 'We put two pots with water (the one containing hot and the other cold water) in contact. The heat is transmitted from the hot to the cold thing' and

(b) 'we put one metal pot with hot water inside another bigger pot that contains cold water. The heat is transmitted from the hot to the cold one'

In 34 out of 44 sets of data (see Appendix 7.4) the probabilities of 'yes' responses differ according to the type of the object or feature. The cases that had no significant differences are worth discussing briefly.

The children said that one can make the examples better, by making the transmission of heat happen 'quicker'. So, as expected 'quicker' was a feature which was chosen hardly ever for any object by the children when they attempted to make both examples worse. A feature that can help to make both examples worse is moving the containers which are in contact (or a container inside a bigger one) 'further away'or to remove ('not exist') them. In agreement with that, in both examples very few children asked to put any object 'further away' or remove them (in the example with the smaller pot inside a bigger one), when they attempted to make the examples better. Only a small minority of children asked to make any object 'heavier' in order to make the example with the smaller pot inside a bigger one, worse.

In some cases the children hardly ever chose any of the features for a given object. So, very few of the children asked to make any change to the 'air' when they attempted to make both examples better, and to make any change to the cold water in order to make the example with the smaller pot inside a bigger one, better or worse.

Tables 7.5 & 7.6 show the features which presented significantly bigger frequencies among others and the objects which presented significantly bigger frequencies among other objects.

Table 7.5 Making the examples of Equilibrium better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Irrelev.	air												
	air												
Struct.	cold w.			*	+								
	cold w.												
Surfac.	m.pot	*	+							*	+		
	m.pot	*	+							*	+		
Protag.	hot wa.	*	+			*	+	*	+				
	hot wa.	*	+			*	+						
S.Conc.	heat	*	+					*	+				
	heat	*	+					*	+				

Key for abbreviations see page 257.

Table 7.6 Making the examples of Equilibrium worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Irrelev.	air			*									
	air			*									
Struct.	cold w.	*	+	*		*	+						+
	cold w.		+										
Surfac.	m.pot			*	+					*	+	*	+
	m.pot			*	+					*	+	*	+
Protag.	hot wa.			*	+							*	+
	hot wa.			*	+							*	+
S.Conc.	heat			*	+							*	
	heat			*	+								

Key for abbreviations see page 257.

Both examples are seen as better if the protagonist, the scientific concept and the surface related objects become bigger. The more heat the better the example is. Other ways for having more heat are to have more hot water or to make the pots bigger. It is possible that the change 'more hot water' is described by children as making hot water heavier, or make it bigger. Also, pots should change their shape if they have to be bigger. It seems that another way for children to make the example better is to make the proportion hot water: cold water bigger. In this case some children suggested the extreme view that the cold water should 'not exist'.

The hot water and particularly the heat should increase the temperature of the cold water quicker, to make the example better. So, the less the time needed for a cause to produce an effect, the better the example is. There were no statistically significant differences in changes for making the example better, between the two examples.

Examples could be made worse if something happens that will prevent contact between the hot and the cold thing. It could happen if some objects do not exist or are moved 'further away'. So, children made the examples worse choosing the feature 'not exist' for various objects and particularly the protagonist, scientific concept and surface related objects (which children asked to made bigger to make better the examples). Also the protagonists and the surface related objects should move 'further away' since without contact the example will be worse.

In contrast with the children's attempts to make the example better, they tried to make it worse by making the proportion hot water: cold water smaller. So, in the contact-example the cold water should be bigger and heavier. The children made these changes in one of the two examples (significant differences in the case of feature heavier) probably because in the case of the example putting the smaller pot inside the bigger one, the cold water (in the bigger pot) seemed more than the hot water.

7.4.3.4 Inertia

> Idea: *'The bigger the mass things have, the more difficultit is to move them, because they present big inertia'*
>
> Examples:
>
> *(a) 'a lorry that has bigger mass than a car will move with greater difficulty and move slower than the car' and*
>
> *(b) 'a child can easily move a small toy-elephant, but it is much more difficult to make a big elephant move'*

In most cases there were significant differences in the frequency of 'yes' responses considering the type of object and the sort of feature (33 out of 44, see Appendix 7.5)

However, there are some cases where the differences among objects for a given feature were not significant because only a very small number of children chose the particular feature in any object. This happens when they attempted to make both examples better or worse choosing the feature 'not exist' or the feature 'shape' in the example with the elephant. For the feature 'bigger' there were no significant differences among the objects when the children attempted to make the example better since many asked to make all the objects bigger.

There were some cases where there were no differences in the various features that were chosen for a given object. So, very few children asked to make any changes to the objects 'toy elephant', 'inertia' and to the 'child', 'elephant' when they attempted to make the example with the elephant better or worse respectively. Also only a small minority of children asked to make any changes to the 'air' in order to make the example with the lorry better.

Tables 7.7 & 7.8 show the features and the objects which presented significantly bigger frequencies among other features or objects respectively.

Table 7.7 Making the examples of Inertia better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Struct.	car							*	+		+	*	+
	toy el.												+
Irrelev.	air												
	child	*	+					*	+				
Protag.	lorry	*	+			*	+	*	+		+		+
	elepha	*	+			*	+						+
Surfac.	ground	*								*	+		
	ground									*			
S.Conc.	inertia	*											
	inertia												

Key for abbreviations see page 257.

Table 7.8 Making the examples of Inertia worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Struct.	car	*	+			*	+			*	+		
	toy el.	*	+			*	+						
Irrelev.	air		+						+				
	child		+				+		+				
Protag.	lorry						+	*	+	*	+	*	+
	elepha										+		
Surfac.	ground		+							*	+		
	ground									*	+		
S.Conc.	inertia			*									
	inertia			*									

Key for abbreviations see page 257.

It is notable that in both examples, children did not choose any change in the scientific concept (inertia) to make the example better. Children thought that both examples of inertia could be better if they made the protagonists (lorry and elephant) bigger and heavier. The bigger (and heavier) protagonist the more inertia (and the better the example).

Another way children used to make the example better was the creation of bigger differences in the comparison between the protagonists and the structure related objects. So, in the example with the lorry, the car should be quicker, to have bigger differences in the time that it needed to move from the lorry. The children wanted to make the differences bigger sufficiently that some of them chose the extreme change to put the structure related objects 'further away'.

Some children attempted to make the example with the lorry better by choosing the lorry and the car to be quicker. Also, the child in the example with the elephant can be bigger and make something quicker.

In this idea, only very few children attempted to make the example worse by choosing the feature 'not exist' for any object. Children attempted to make the examples worse, by making the difference between the structure related objects and the protagonists smaller. Children chose the car or the toy elephant to be bigger and heavier. Then the comparison will not present any differences and the example will be worse.

Children thought that the example could be better or worse, making the lorry quicker in the example with the lorry. It would be worse because the lorry will be moved in the same time with the car and there will not be differences between the lorry and the car. Also, in both examples changing the shape of the ground would have as a result the examples to be worse.

There were some significant differences between the examples. More children said that the lorry should be quicker and further away than said the elephant should be. Also more children said that the car rather than the toy-elephant should change its shape.

7.4.3.5 Upthrust

Idea: *'On a thing that it is a liquid there is a force acting upwards from the liquid. This force is called upthrust'*

Examples:

(a) 'It is very difficult to push down a ball into the water, if you let it free it will come out, because of the upthrust that it gets from the water' and

(b) 'a thing seems lighter in water than out of it, because of the upthrust the things gets from the water.

There are significant differences in the frequency of yes responses considering the sort of object or feature (33 out of 44, see Appendix 7.6). Tables 7.9 & 7.10 show the features and objects with significantly bigger frequencies among other features or objects respectively

Table 7.9 Making the examples of Upthrust better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	ball					*	+						
	stone									*	+		
Surfac.	child	*	+					*	+				
	child	*	+					*	+				
Struct.	water												
	sea												
Irrelev.	wash basin	*	+							*	+		
	ground												
S.Conc.	upthrust												
	upthrust												

Key for abbreviations see page 257.

Table 7.10 Making the examples of Upthrust worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	ball	*	+			*	+			*	+	*	
	stone			*		*	+			*			
Surfac.	child			*								*	
	child			*						*		*	+
Struct.	water			*									
	sea			*								*	
Irrelev.	wash basin			*						*	+		
	ground			*						*			+
S.Conc.	upthrust			*									
	upthrust			*						*			

Key for abbreviations see page 257.

The children used the feature of the rapidity of change (‘quicker’) when they attempted to make the examples better rather than worse. Both examples could be better if the surface related objects (child in both cases) moved the protagonists in less time. The children suggested that ‘child’ should be quicker and to make it quicker it needs to be bigger. They thought that the upthrust could be a sort of force that resisted the movement of the protagonist (ball in the water) or helped it (stone in the sea) but they suggested more 'powerful' surface related objects to show better that this force exists (this is the reason that bigger children are needed). Also the ball should be heavier to 'win' more easily against the resistance of upthrust while the stone should change its shape (significant difference with the ball) and be smaller to make its movement to the surface of the sea easier. Furthermore, the wash basin should change its shape and should be bigger, since a bigger bowl is needed to put the whole ball inside the water. In summary, the examples could be better if the effect happens in less time.

For the objects 'water' and 'sea' there were no significant differences in frequency of choice of features for each object when the children attempted to make both examples better. A very small minority of the children asked to move any object 'further away' or remove ('not exist') it, making both examples better.

In contrast, examples could be worse if some of the objects did not exist. Many children attempted to make the example with the stone worse, choosing the feature 'not exist' for the various objects. In this case, there were no differences among the objects. Also, the 'child' should be further away. Also the shape of the wash basin should change and be small enough, so the ball could not be inside the water. Making the ball and the stone heavier the upthrust will not be obvious as before.

The features 'bigger' and 'changing shape' were hardly ever chosen for any object by children when they attempted to make the example with the stone better or worse respectively.

7.4.3.6 Counter examples

7.4.3.6.1 Gravity

Idea: *'When things go up, they must come down (to the ground) because of gravity'*

Counter example: *'A rocket was launched from the earth with speed more than 40.000 Km/h. So it beats the earth's attraction and doesn't come back'*

The Cochran Q test showed that there are statistically significant differences in the frequency of 'yes' responses considering the type of object and the sort of feature (18 out of 22, see Appendix 7.7). Table 7.11 & 7.12 show for a given feature the objects with significantly bigger features among others, and for an object the features with significant bigger features among other features.

The cases of non-significant differences appeared only when the children attempted to make the example worse:

- There were no significant differences in frequency of choice of feature for each object only in two cases, when they suggested changes in features of the 'gravity' and 'people', to make the example worse.
- In some cases the children very rarely chose any of the objects for a given feature. So, they did not choose any object for the features 'quicker' and 'away', when they attempted to make the example worse.

Table 7.11 Making the example with the rocket better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	rocket	*	+				+	*	+	*	+	*	+
Irrelev.	air			*	+								
Struct.	ground	*										*	+
Surfac.	people							*					
S. Conc	gravity			*	+								

Key for abbreviations see page 257.

Table 7.12 Making the example with the rocket worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	rocket			*	+	*	+			*	+	*	
Irrelev.	air			*				*					
Struct.	ground			*	+					*	+		
Surfac.	people		+				+				+		
S. Conc	gravity												

Key for abbreviations see page 257.

The counter example could be better if some object such as the unrelated object (air) and the scientific concept (gravity) were removed. Also the example could be worse if the protagonist (rocket) and the structure related object (ground) were removed. So, the scientific concept which should be made bigger in the positive examples to make them better, in counter examples should not exist.

The counter example could be made better, by changing most of the features of the protagonist. It should be bigger and go up quicker since the less time needed to go up the better the example,

Also, the rocket should be more away from the ground. If it is further away it has more possibilities not (or to delay) to come down. In this case, many children said that the ground should also be further away.

Furthermore, the children sometimes chose the same features for making the example better or worse. So, by changing the shape of the rocket the example could be made worse since a rocket with a rectangular shape cannot go up. However, by changing the shape of the rocket the example could also be made better if the rocket had a more aerodynamic shape.

The counter example could be made worse by changing the rest of the features of the protagonist. So, by making the rocket heavier it will be more difficult for it to go up. Also many children said that it should not exist.

7.4.3.6.2 Transmission of heat

Idea: *'A lot of things allow heat to pass through their mass easily'*

Counter example: *'We can touch the edge of a glass tube without getting burnt, because the glass tube doesn't let the heat pass easily through its mass'*

In 14 out of 22 sets of data (see Appendix 7.8) the probabilities of 'yes' responses differ according to the type of the object or the feature. Table 7.13 & 7.14 show the features and the objects which presented significantly bigger frequencies among other features or objects respectively.The rapidity of change seems not to play any important role for children in this particular example.Very few children asked to make any object do something 'quicker' when they attempted to make the example better or worse.

Table 7.13 Making the example with the glass better

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	glass	*	+				+			*	+		
Irrelev.	air			*	+			*					
Struct.	gasstove							*		*	+		
Surfac.	hand							*				*	
S. Conc	heat	*	+					*					

Key for abbreviations see page 257.

Table 7.14 Making the example with the glass worse

		Bigger		N. Exist		Heavier		Quicker		Shape		Away	
		Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob	Fe	Ob
Protag.	glass		+	*						*	+	*	+
Irrelev.	air												
Struct.	gasstove												+
Surfac.	hand		+								+		+
S. Conc	heat			*									

Key for abbreviations see page 257.

The counter example could be made better if we changed the shape of the glass and made it bigger. If the glass becomes bigger the transmission of heat from one edge to the other will need more time. Also we have to change the shape of the gas stove to make the heat 'bigger'. The feature 'further away' was hardly ever chosen for any object by children when they attempted to make the example better. On the other hand, the example will be worse if we put the glass, the hand and the gas stove further away. Also we have to change the shape of the glass (by making it smaller). The result will be that there will be no transmission of heat and so no counter example of the idea.

7.4.4 Overview of Phase 2

In both examples of all ideas, when the children attempted to make them better or worse, there were significant differences in the frequency of 'yes' responses given to a particular change of feature of an object considering the type of object and feature. Thus, the differences among the various objects influenced the number of 'yes' responses given to a particular change of feature by the children, and the differences among the various features influenced the number of 'yes' responses given to a particular object.

In all examples, change of existence was hardly ever chosen for any object, when children attempted to make the examples better. The children made the examples better, following mainly the principle "more is better". They used this principle in various ways:

(a) The more (bigger) the scientific concept the better the example (ideas of potential energy, expansion, equilibrium). The increase of scientific concept could be the result of some other increases:
  - The bigger or heavier the protagonists the bigger the concept is (in all ideas)
  - The bigger the surface related objects the bigger the concept is (ideas of potential energy, equilibrium, upthrust)
  - The bigger the structure related objects the bigger the concept is (idea of expansion)

(b) The greater the distance the better the example is (idea of potential energy).

(c) Changing the shape (e.g. bigger) of objects the example could be better (ideas of expansion, equilibrium.

In the case of time, it seems that in most cases "quicker is better". The smaller the time needed by the cause to produce the effect the better the example (ideas of potential energy, equilibrium, upthrust).

Generally, to make examples worse, the things that play an important role in the example were removed. An example can be worse if :

- certain objects do not exist (the same objects -ones playing important roles in the example - which children made bigger when they attempted to make a better example)
- the objects are moved further away
- objects change their shape, and we cannot recognise them

- the cause is changed so as to have smaller effects (see sun in expansion). The smaller the effects the worse the example is
- the example loses its 'duration', changing a static phenomenon to dynamic

In some examples particular changes can have as a result either making the example better or making it worse (e.g. make the child heavier in the example with the child up a tree, make the train go quicker in the example of expansion).

There were some differences in the frequencies of the changes between the two examples of an idea. This happens mainly for three reasons: the nature of the objects, the importance of their role in the example, the constraints of reality.

In some cases, two objects which had a similar role in the examples, had such big differences in their nature that the particular role they played in the example could not constrain them in a specific way. For instance, the tree and the balcony are surface related objects in the two different examples of potential energy. Although these objects play a similar role in two examples of the same idea (they support the protagonist) they have differences in their nature. That is, the tree can be bigger vertically while the balcony cannot, which do not allow the examples to constrain the schemes of these objects in the same way. Also, even though two objects could have the same role in two examples, the importance of their role was not the same (the train and the pylons were the surface related objects in the examples of expansion, but they had different functions). Furthermore, reality often defines limits to the changes that are suggested by the children (e.g. the child should be heavier since it could break the branch of the tree while the pot did not need to be heavier since it could not break the balcony).

7.5 General conclusions of the study

Children 11-12 years old are able to establish connections between concrete examples and generalisations. Examples do not fit equally well to a generalisation. Children think of some instances as better examples of ideas than others. A generalisation can have a best example. The addition of parallel examples can lead to ‘higher’ more broad generalisations, while the addition of counter examples can lead to 'lower' less broad generalisations.

Children in their comparisons between examples referred mainly to:

(a) Objects' attributes such as quantities (size, weight, shape), qualities (e.g.having or not autonomous action) and necessity (the inherent nature of the objects)

(b) Objects' relations such as the time between two actions, the space location of various objects (distance and the empirical schemes of support and border)

(c) Objects' existence

The fit between examples and ideas is good when empirical schemes such as 'support', 'border', 'autonomous action', or several such anticipated empirical schemes are satisfied, and poor when some are and others are not. Also, an instance is a 'good' example when its relevant features are salient, familiar, stable and it is not too complex. Children asked for similar changes for objects which played similar roles in examples. But some of the objects which had a similar role to the examples, had big differences in their nature that appeared very different in examples.

There is consistency in children's responses when they attempted to make the examples better or worse. Children made the examples better, following mainly the principle "more is better". They used this principle in various ways. However, in the case of time, it seems that in most cases "quicker is better". The smaller the time needed by the cause to produce the effect the better the example is. It is possibly the same principle as 'more is better' if we interpret this as 'rapidity' and not as 'duration'. In order to make the examples worse, the things that play an important role in the example were mainly removed, or moved further away, or changed their shape. On the other hand the feature 'not exist' was rarely used by children when they attempted to make the counter-examples better.

Chapter 8:

CONCLUSIONS AND FUTURE WORK

8.1 Introduction

The broad conclusions that may be drawn from this research are summarized in this final chapter of the thesis. The chapter includes: a summary of the most important findings, implications of the unifying framework of the description of schemes for science education, an indication of where future work should be done and the main limitations of the current thesis.

8.2 Summary of the findings

Researchers in different fields have had various goals behind their accounts of what mental representations are used in human reasoning. Philosophers attempt to describe the fundamental relation between knowledge and reality, and the origins of knowledge. The goal of psychologists is to explain how mental representations are responsible for observed aspects of human thinking. Artificial intelligence researchers describe human mental representations in a way that will enable computers to perform tasks which require the use of intelligence.

I respect all these goals, but in the current thesis my major aim is to describe the mental representations that children use in response to various tasks related to science education. The current research drew on two main traditions (originated by Piaget and Johnson-Laird respectively) in the area of mental representations, describing the tools for thought ('empirical schemes') and exploring the content of thinking. A way of describing many of the studies which belong to both traditions is that they all suggest reasoning as based on schemes which are repeatable patterns in action. The current thesis includes a series of studies that are based on the previous claim to describe various areas of children's reasoning such as analogy, exemplification and transformation. Thus, the general starting point of the current thesis is that children, in understanding the physical world, make imaginative transformations using empirical schemes. A brief presentation of the main findings follows.

Children's reasoning is based on empirical schemes

In the second chapter of this thesis, I argued that an approach to children's reasoning as a multi-leveled system is essential in charting a balanced view of their mental representations. Children can use various levels of mental representations to make imaginative transformations. To understand these levels consider, for example, ways that a child can think when trying to transform a feature of an aeroplane such as the "aerodynamic shape":

a. Propositional level (the transformation can be based on the proposition "the aerodynamic shape")

b. Empirical level (using the "aerodynamic" empirical schema which is a common abstraction of our bodily experience and observations such as the posture we adopt when walking in a strong wind, or the movement of fast cars versus lorries)

c. Mental image level (the transformation based on picture images of a particular bird and a particular aeroplane)

It is suggested here that the differences which appeared in various attempts to describe the mental representations system can be seen as a result of two dimensions: (a) abstraction, (b) organization. This research does not argue that children do not use one or more of these levels. However, it gives evidence that in the tasks of the particular research children mainly use the empirical level, which may be the basic level of thinking.

Empirical schemes that the children appeared to use in their transformations lie at a middle level, - the empirical level - between the two ends of the continuum concrete to abstract. Empirical schemes organize children's mental representations at a more abstract level than that which they use to form mental images. On the other hand they are more concrete than verbal propositions. The empirical scheme 'aerodynamic shape' that the children kept constant while transforming the eagle into an aeroplane and vice versa cannot be an image that fits perfectly with both objects since there are differences between them (e.g. size, width, even the shape).

The empirical scheme is not so concrete as a picture of an F-16 aeroplane because then it would fit only to this particular type of aeroplane and the children could not keep it constant when they attempted to transform it into another object. On the other hand, it is not so abstract as the verbal proposition 'aerodynamic shape' which suppresses and represents visual and enactment features in another mode (verbal). Propositions can capture some of the features of empirical schemes since they can also show an abstraction, but they cannot capture the analog nature of images and they cannot describe schematic transformations. The empirical schemes are the result of "empirical abstraction". That is, children abstract information from objects and events. This leads to knowledge about particulars; children think about and with particular instances-examples. These findings are consistent with the results of the project "Empirical Abstraction" (Bliss & Ogborn 1997) which described schemes as re-usable building blocks being neither too generic nor too specific. The final report of this project, in which I participated, is included here as Appendix 2.1.

Empirical schemes are organised in packages

The children's transformations can be explained by the use of schemes in a continuum between the poles specific-generic. Schemes appear to be neither too specific nor too generic. Empirical schemes such as "aerodynamic", "wings", "fly", "movement" were used by children. The children used the following general operations on them: add, remove, modify, and keep constant.

In contrast with diSessa (1988) this research shows that children's knowledge can be characterized to some extent by organized structures. That was evident in various ways:
a. the children used generic schemes in their transformations;
b. identification of groups of schemes in the Analogy task;
c. groups of schemes which varied together in the schematic description of examples.

All the above suggest that children's knowledge consists of patterns such as those described by Johnson ('image schemata') rather than being fragmentary.

The analysis of the children's analogies for a simple electric circuit provides evidence for the existence of at least a partially organised system of schemes. The children generated their own analogies, generally drawing on groups of schemes. Schemes which were commonly evoked are the following: flow, path, container, open/close, barrier, link, forward and continuous movement. The presence of some elements of analogies predict the presence or absence of others. Types of structure were identified at the level of pairs (e.g. a "source container" is a sufficient condition for the "flow") and of groups of schemes (e.g. "flow" comes from a "source container" and an "action on a dynamic link" can admit flow to pass with a "forward movement" from one edge to another one). Also, types of structure were identified at the level of the "whole analogy" dimensions 'cause vs. effect' and 'dynamic vs. static'.

Clusters of schemes that vary together could be identified, going from non-exemplified context to an exemplified one (study 3). Different packages appeared. For example, 'blocking' which contains the schemes barrier, support, rigidity, container or the package of 'autonomous action' which contains the schemes autonomy, force, invisible entities. In general, the packages (factor structures) which emerged, were very similar across the analyses of different examples.

Empirical schemes are matters of imagination

The children used their imagination to modify existing knowledge patterns. They used the empirical schemes to generate novel meanings and transformations. The first study with the transformation tasks gave evidence for the children's use - and for the importance of this role- of empirical schemes in their reasoning. The children easily made the imaginative transformations between objects which belong to the same ontological category. However, they faced serious problems when they attempted to transform objects which belong to different ontological categories.

These difficult cross-ontological transformations became easier when the objects had common functional schemes. The children kept constant in their transformations the empirical schemes which contain structural features that are common to many different objects, events, etc. That is, empirical schemes are common abstractions of a broad number of physical experiences or phenomena, such as the movement of objects, the ability of some objects to fly, and the aerodynamic shape. The children based their transformations on this feature of common abstraction and used empirical schemes as 'bridges' even between different ontological categories.

In a similar way, the children based the transformations between analogical examples (or events) on functional schemes. The children attempted to make transformations in analogical examples by focusing on actions (using 'functional schemes') and on schemes that describe them, rather than on parts and relations. Most of the children made their transformations between analogical examples which are found in school text books, giving a variation of transformation-matching. They did not worry about the transformation of all parts and relations, but their focus was on keeping the similar actions or functions and common schemes stable.

Thus, in transformation tasks there were indications that children can transform one entity into another using schemes. They distinguished essential features of a scheme which they kept constant during transformation, from “accidental” features, which they changed. The children’s transformations can be classified in the following categories: “keeping constant”, “add”, “modify”, “remove”. They kept constant (mainly in the case of objects with common fuctional schemes) mainly schemes that are related with similar functions of objects rather than with surface similarity (e.g. similar position). So, they kept constant functions of objects, the parts of objects that are responsible for the particular function and features of objects that are needed for or facilitate their functions.

The children used schemes that belonged to the categories ‘add’ or ‘remove’ for difficult transformations such as: the source of movement, things that are responsible for a particular sort of movement, the material that an object is made of, things that make an object a living thing. In the case of pairs which lack common functional schemes, children modified mainly parts considering their position, while in the transformations between objects with common functional schemes they modified mainly what parts can do and the material the objects are made of.

In the case of the generation of their own analogies, the children’s selection of the target analogy highlighted one of the most important features of their thinking, the matching between prior and new knowledge. That is, they showed a capacity to use relevant prior knowledge in reasoning even though objects or events in the new situation had never been directly associated with those in the remembered ones. Consider for example the child who gave as an analogy for a simple electric circuit, a squeezed orange. He used his imagination to create an analogy and possibly reorganise his existing knowledge patterns of the electric circuit in a new way.

In summary, the children used their imagination in order to achieve new structure in their “background” knowledge, through the processes of transformation and analogical-metaphorical projection. The children whenever they attempted to modify existing patterns in order to generate novel meanings imagined an entity as another entity. It has been suggested that powerful empirical schemes counteract children's resistance to some kind of transformations, making it easier to imagine things which it is difficult to imagine.

Analogical mapping is constructed between empirical schemes

Children have some mental representations for external reality. For example, their knowledge of the nature of water provides them with a scheme of how it moves. Also, their knowledge of electricity provides them with a scheme of how the electric flow moves. When a child considers an analogy between 'water movement through drinking straws' and 'flow movement through wires', he/she is trying to build a relation between those two schemes. The analogical projection is not between an internal mental model and the external world. It is between two internal mental models (Holyoak & Thagard, 1996). A researcher who attempts to make an analysis of analogies has to describe these mental representations, that is, the schemes which are the components of the analogical mapping.

Holyoak & Thagard (1996) point out that the construction of analogy is based on some 'schemas'. They mention as an example, the formation of the concepts sound waves and light waves as analogies from water waves. These analogies are based on the commonalities between the instances of the complex concept 'wave' which "convey patterns of relations among constituent elements, as schemas" (p.24). The concept (or better, scheme) 'wave' has been developed from a specific analogy, tied to a particular kind of example (water waves), to a more abstract entity that can be applied to a vast range of situations. Analogical thinking sets as a requirement that the person needs to be able to look at specific situations and somehow to pull out abstract common patterns even though the situations may be substantially different.

Analogies have in the past been mainly studied at a "propositional" level. In this research I attempted to investigate them at a nonpropositional level, identifying the nature of the empirical schemes that take part. Progress in our understanding of children's reasoning in the construction of analogies, may depend on studying children's "empirical schemes" as well as their structuring, that is, their synthesis into packages. Results show that there is structure in empirical schemes. Schemes are not just small fragments of knowledge, they are organised in packages., elements of which invoke each other.

Causal relationships in analogies

The analogies of the simple electric circuit that the children constructed are based on the relationship of causes to effects (an interpretation of a dimension identified through multidimensional scaling). Actions of some objects (causes) change the state of the world (effects). It seems that what often matters in an analogy is the set of causal relationships it evokes (Holyoak & Thagard, 1996). In explanatory uses of analogy such as in the tasks of the second study, what matters is the causal relationships in the source analogue that can suggest causes for what is to be explained in the target. Thus, in the analogy with the orange, the squeezing of the orange is the cause of the production of the juice, and that explains a similar cause the 'closing of the switch in the electric circuit' which has as effect, the production of an entity (flow).

When the children gave their analogical example having as source example an electric circuit, their reasoning tended to follow a linear causal relationship. They postulated a group of elements as a "cause" which produced some "effects" (described by another group of elements). Furthermore, the second dimension played an important role in the construction of analogy is the "dynamic-static" dimension. The group with "dynamic" elements was clearly distinguished from that with the "static" ones.

Examples constrain empirical schemes

A theme which runs through a number of sections is the interaction between entities. That is, the way in which the empirical schemes - that describe an entity - are constrained, interact and are modified by other entities that take part in the same phenomenon. Children in classrooms are often asked to imagine entites as components of various phenomena. The way that various exemplified contexts work is related to the schematic way their components are perceived by children.

In the current thesis sets of entities (in a picture) were investigated (a) prior to being used as an example of an idea, and (b) when used as such an example. The meaning of entities changes from one case to the other. Thus, the use of an object in an example of an idea constrains the way children imagine the objects, highlighting or hiding some of its features. However, many examples can not constrain and succesfully reduce the appearance of the 'autonomous action' scheme, which appears to be too strong to be suppressed.

In general, with the special exemption of very few schemes, the objects in the the two examples of an idea, either stayed close together or moved closer together on all factors, when going to the exemplifying context. However, in some cases the examples of an idea might work in two opposite directions highlighting very different schemes of an entity. For instance in the example with the child who attempts to raise a stone in the sea, fewer children said that that the upthrust is a 'barrier' while in the example with the child who attempts to push down a ball into water more children said that upthrust is a 'barrier'.These shifts are related with the nature of the idea being exemplified and with the particular role that entities play in the example (e.g. protagonists, scientific entities, structure related objects). For example, the scientific entities (eg. potential energy, inertia, uptrust) appeared mainly as invisible entities out of an exemplifying context. They were not so well known and the example helps children to identify more schemes for the description of these abstract entities.

Broadly, we predict that for objects relevant to a given example, the frequencies of schemes will become more differentiated when the example is given. Examples appeared to work in a similar way as metaphors: they highlight or hide some features of entities, suggesting new ways of seeing entities.

Examples do not fit equally well to an idea

The children saw differences in how well examples fitted general ideas. 'Good' examples are the ones where the relevant features are salient (large), familiar, have the ability of autonomous action and are not too complex. It seems that there is a guiding structure of mental and external representations which follow the scheme: A generalization can have a best example. The addition of parallel examples can lead to "higher" more general generalizations, while the addition of counter examples can lead to "Lower" generalizations. The fit between example and an idea is good when empirical schemes such as 'support', 'barrier', 'autonomous action', are satisfied, and is poor when some are not.

The presence (or absence) of particular empirical schemes influences the fit between examples and ideas. The children in their comparisons between examples referred mainly to objects attributes such as quantities, qualities and necessity, objects relations such as spatiotemporal relations and objects existence. Considering the quantities of objects such as their size, weight and quantity, the children suggested changes that could make an example be 'better' following mainly the principle 'more is better' in various ways. For example, the bigger or heavier the protagonists of examples the bigger the scientific concept is, and the bigger the scientific entity the better the example. Particularly, in the examples of expansion, the children suggested changes in the shape of objects to make the examples better. Considering the idea of potential energy, the children argued that an example consisting of an object (eg. a child) which can be described by the scheme of autonomous action, is not a good example of the idea. In some cases the fit between examples and ideas is influenced by the inherent nature of the objects. Thus, an eagle does not fit so well with the idea "What goes up must come down" because "the eagle because of its *nature* can fly". Furthermore the spatiotemporal relations of objects influences the fit of examples with ideas. For example, for the idea "What goes up must come down", a stone rather a ball thrown in the air is a better example of the idea, because the "stone will come down more quickly than the ball". Also the position of objects in space and their relations with other objects that take part in an example of an idea play a crucial role in the fit between example and idea. For example, an aeroplane appeared as a better example of the idea of potential energy in comparison with a child up a tree, because of its greater distance from the ground.

The results were confirmed by the fact that the children suggested removing the things that played an important role in an example, when asked what would make the example worse.

8.3 Implications for science education

The thesis shows how the idea of schemes can be applied to the various kinds of thinking investigated. Some important implication of this research for science education follow.

Some 'barriers' to imagining scientific entities

At many points my dissatisfaction with the traditional approach to ontological categories should have been apparent. This research adds to the ontological perspective of conceptual change, the fact that the notion of ontologically distinct categories needs to be explored in terms of schemes. It has implications for science education because the transformation of everyday phenomena into scientific concepts may be based on common functional schemes.

Chi and her colleagues (1992, 1995) applied the notion of ontologically different concepts to the issue of conceptual change in science learning. She argues that learning in science involves conceptual change across ontological categories since the scientific meaning of many science concepts belongs to different ontological categories form the naive intuitive meaning held by students. Also, she proposed that some science concepts are more difficult to learn than others because they require a conceptual transition between different ontological categories. She based her analysis on the identification of predicates such as contain, move, block etc. which might be regarded as schemes.

The transformations which are explored in the present thesis are closely related with imagination. The earlier chapters of the thesis discuss a wide range of ways of using imagination. Here, I will make a few speculative points about imagination in science education. The starting point should be that imagination constructs knowledge even when it transforms knowledge into something unreal and impossible, and that this is the main path for creativity. Teachers should give children opportunities to make imaginative transformations: a. of objects (e.g. a human into a robot), b. events (e.g. a simple electric circuit into a bridge that opens and closes), (c) examples of ideas (e.g. make the example with a child up a tree of the idea 'what is raised has potential energy' a better one). Also children could use their imagination to generate their own analogies and examples of ideas.

Using examples of ideas in classrooms

All the world around us is full of abstract ideas. One can see such abstract ideas in the form of big headlines on the TV news, in newspapers, books, magazines etc. Concrete examples of these ideas help people to understand them. Something similar happens in science classrooms. A teacher often gives a general idea such as "When things are raised they have potential energy" and attempts to clarify it through the use of some concrete examples such as a boy up a tree or an aeroplane high up etc. Thus, the use of examples seems to be an important feature of the science classroom.

There are important implications from the results of the third study that show a shift in the way that entities are seen in different contexts. An example can not stand on its own without the commentary which helps readers to clarify its purpose. Exercises with the explicit description of examples by children can help teachers to see what for children the focus of the example. Teachers should know that examples do not work in the same way for all children. The presentation of more than one example seems appropriate.

Implications for science curriculum development

One important implication for science curriculum development is the construction of analogies by pupils. Holyoak and Thagard (1997) have suggested that one useful strategy for correcting pupils misconceptions may be to have pupils generate analogies themselves. In the present study, one could argue that many children knew the electric circuits well and only in this case could they create 'interesting' and useful analogies. In the case where students have little knowledge of the domain of instruction, it is expected that their analogies will be bad ones; however, Holyoak and Thagard (1997) argue that using the generation of analogies to point out children's misunderstandings would be a useful way of correcting their misconceptions. Children's analogies such as the analogy of an electric circuit with a squeezed orange, can be a helpful tool in the exploration of children's thinking, can illuminate the children's focus (e.g. in the current study schemes of processes seem to play a protagonist role), and can be a motivating factor in learning. Most of the children showed clear signs of excitement as they constructed their analogies, as I worked with them. As Holyoak and Thagard pointed out 'a good analogy is not only understood; it is also felt'.

A second implication for science curriculum development is the use of exercises in textbooks, asking children to give examples of ideas. Pupils seem to me to be able to give examples of ideas and a teacher could use these examples to learn more about their understanding. Particularly, exercises which compare examples of the same idea, and which consider positive and negative examples, can show what are the most important features of an idea for pupils.

Finally, imaginative transformations of objects and scientific entities can help children to understand the differences and the sameness between objects or between everyday and scientific use of entities. It seems to me that transformations such as a robot into human can help children to understand some metaphors (e.g. human as machine).

8.4 Limitations of the study

The limitations of the current research have to do with:
(a) the inclusion of many areas in the research
(b) the nature of the prompts used for the interviews
(c) the order of questions

The attempt to find common tools for analysing and understanding children's reasoning about the physical world seems to me to be important. Each of the studies (transformation, analogy, examples, examples and generalizations) could be the topic of a whole thesis. The idea in the current thesis is to use a common conceptual tool, that is empirical schemes, to describe all these various areas. Equally the exploration of these various areas gives a better picture of the nature of schemes. Briefly the advantages of an approach through a variety of linked studies are:

- to see and describe various kinds of thinking as imaginative transformations
- to use the same tool to explore the nature of various kinds of thinking
- to have a clearer picture of the nature of empirical schemes

One limitation of the studies presented in this thesis and particularly of the second study, is that children's focus on actions and common schemes (when they described an analogy or generated their own analogy) could be explained as the result of the content of the particular event (open/close the switch of the electric circuit). In the exploratory study, the use of a 'perfect analogy' may lead children to these responses. That is, the two analogical events had been selected by the author (of the science textbook) in a way that the focus in the analogy was to be on common actions and schemes and not on surface similarities. I tried to solve this problem in the main study where I explored the way that children produce by themselves spontaneous analogies although they can be "partial analogies". However, more events and analogies should be explored.

The order of questions in the questionnaire (study 3) was important. Firstly, the children were asked to give their own examples of an idea, then to reply to questions about objects without reference to any idea and finally to reply to questions about the same objects but now as a part of an example of a given idea. The children were asked to give their examples before they were presented with the textbook examples because I wanted to avoid any effect from the textbook examples chosen for the questionnaire in the construction of their own examples. Also, I did not put the questions about what the objects can do in general before the construction of examples, because I did not want the children to try to make their examples using the objects that they had described just before. In the questionnaire, the questions about objects without reference to any example came before those in which the objects were components of an example. I did not follow the opposite order because I thought that the children might focus on one example (the one that to be given to them) to give answers for what objects can do in general.

One could argue that the order of questions sets a particular context for the answer and to some extent influences children's responses. Unfortunately, any order would have limitations. The main limitation one could expect from the order followed, is that the children constructing their examples of a given idea at the beginning, might be influenced by the example of the given idea in the description for the objects out of any exemplifying context they made later. However, the changes that were observed in the children's responses for the objects between the non-exemplifying and exemplifying contexts show that any such effects were not sufficient to 'wipe out' differences between perception of entities used in exemplifying and non-exemplifying contexts.

8.5 Further research

The development of schemes with age could be followed up in longitudinal studies. Interviews and questionaires used in this research would need to be complemented by detailed case studies because one needs to be able to identify developmental factors the importance of which is revealed in questionnaires and interviews.

To see the extent to which not only pupils but also teachers construct, use analogies, examples, and ideas in a science classroom other detailed research is needed. Exemplification, analogical thinking and manipulation (transformation) of objects are everyday practices in science classrooms. However, there is no guide to suggest when an example or an analogy work well and the choice of examples or analogies is intutitive or a result of the teacher's experience. Research on how teachers use analogies and examples in school practice to shape pupils' view of the natural world and on how pupils transform and extend analogies and examples to construct a new entity is needed.

8.6 Concluding remarks

In writing this thesis I have become aware that there are gaps in past and present research into the analysis of the nature and the way that repeatable patterns are used in children's reasoning. The framework for the analysis of children's reasoning proposed in the current research offers a principle, that is the use of empirical schemes, which, not in itself novel, is applied here with the new aim of unifying a variety of studies in this way. This framework unifies the research on imaginative transformations (e.g. analogies, transformation of objects, transformation of examples into ideas and vice versa). It seems to me that this framework is a promising one in which research on imaginative transformation might be brought together. A number of features of children's reasoning were evident in the studies reported in the current thesis. Here, I will draw out what appear to me to be some of the general isssues:

- *Mental representations can be described as a multi-leveled system.*
- *These levels include a middle, basic level neither very abstract nor very concrete. The 'empirical level' is the basic level in thinking.*
- *Empirical schemes are knowledge structures about particulars.*
- *Children use imagination in transforming objects and events.*
- *A package of elements is transformed into another through analogies.*
- *Empirical schemes interact.*
- *Examples can be described using empirical schemes.*
- *Examples constrain empirical schemes.*

In the minds of the readers of this thesis, questions such as the following are likely to have arisen: how do we know that children use schemes in their reasoning? It seems to me now after having seen the various repeatable patterns in children's reasoning which I identified in this thesis, that if it is difficult to persuade someone that they exist, it is equally, or more, difficult to ignore the existence of these patterns and to hold that reasoning is not based on empirical schemes.

REFERENCES

Adey, P. (1995). Research and Cognitive Science. *Research in Science Education, 25*(1), 101-113.

Black, M. (1979). *Models and Metaphors.* Ithaca: Cornell University Press.

Bliss, J. (1994). Knowledge acquisition as an active process. In R. Lewis & P. Mendelsohn (Eds.), *Working Conference on Lessons from Learning IFIP TC 3/WG 3.3.* Archamps, France, 6-8 September 1993: Elsevier Science B.V. (North Holland).

Bliss, J., Monk, M., & Ogborn, J. (1983). *Qualitative Data Analysis for Educational Research.* London: Croom Helm.

Bliss, J., & Ogborn, J. (1997). *The final report to ESRC of the research project 'Empirical Abstraction'* (R0002357287). London: Institute of Education.

Carey, S. (1985). *Conceptual change in Childhood.* Cambridge, Mass: MIT Press.

Catambone, R., & Holyoak, K. J. (1989). Overcoming contextual limitations on problem-solving transfer. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15,* 1147-1156.

Chi, M. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In R. Giere (Ed.), *Cognitive models of science: Minnesota studies in the philosophy of science* (pp. 129-186). Minneapolis, MN: University of Minnesota Press.

Chi, M., Leeuw, N., Chiu, M.-H., & Lavancher, C. (1994). Eliciting self explanations improves understanding. *Cognitive Science, 18*(439-477).

Chi, M. T. H., & Bassok, M. (1989a). Learning from Examples via Self-Explanations. In L. Resnick (Ed.), *Knowing, Learning and Instruction* (pp. 251-282). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989b). Self Explanations: How Students Study and Use Examples in Learning to Solve Problems. *Cognitive Science, 13,* 145-182.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in Knowledge acquisition: A theoretical framework and Implications for Science instructions. *Review of Educational Research, 63*(1), 1-49.

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. *Cognitive Science, 12*(4), 563-586.

Cohen, I. B., & Westfall, R. S. (Eds.). (1995). *Newton.* New York: W.W Norton & Company.

Cummins, D. D. (1992). Role of analogical reasoning in the induction of problem categories. *Journal of Experimental Psychology: Memory, Learning and Cognition, 18*, 1103-1124.

Dagher, Z. R. (1995). Review of studies on effectiveness of instructional analogies in science education. *Science Education, 79*(3), 295-312.

DeJong, G. (1989). The role of explanation in analogy; or, The curse of an alluring name. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 346-365). Cambridge: Cambridge University Press.

diSessa. (1993). Towards an epistemology of Physics. *Cognition and Instruction, 10*(2 and 3), 105-225.

diSessa, A. A. (1988). Knowledge in Pieces. In G. Forman & P. Pufall (Eds.), *Constructivist in the computer age.* Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Douglas, A. R. (1996). What Counts as Quality in Qualitative Research. *Science Education, 80*(3), 243-248.

Driver, R., Guesne, E., & Tiberghein, A. (Eds.). (1985). *Children's Ideas in Science.* Milton Keynes, Philadelphia: Open University Press.

Duit, R. (1990). On the role of analogies, similes and metaphors in learning sciences. *Science Education, 75*(6), 649-672.

Elio, R., & Anderson, J. R. (1983). Effects of category generalizations and instance similarity on schema abstraction. *Journal of Experimental Psychology: Learning memory and Cognition, 113*, 541-555.

Everitt, B. (1980). *Cluster analysis.* (2nd Edition ed.). London: Heinemann Educational Books.

Gelley, A. (Ed.). (1995). *Unruly Examples.* Stanford, California: Stanford University Press.

Gelman, R. (1979). Preschoolers' Understandings of Simple Object Transformations. *Child Development, 51*(3), 691-699.

Gentner, D. (1988). Metaphor as structure mapping, The relational shift. *Child Development, 59*(1), 42-59.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.), *Similarity and Analogical Reasoning* (pp. 199-244). New York: Cambridge University Press.

Gentner, D., & Gentner, D. R. (1983). Flowing water or teeming crowds: mental models of electricity. In D. Gentner & A. Stevens (Eds.), *Mental models* . Hillsdale, NJ: Lawrence Erlbaum Associates.

Gentner, D., & Stevens, A. (1983). *Mental Models.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gentner, D., & Toupin, C. (1986). Systematicity and surface similarity in the development of analogy. *Cognitive Science, 10*, 277-300.

Gick, M. L., & Holoyak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 14*, 1-38.

Gopnik, A., & Wellman, H. M. (1994). The theory theory. In L. A. Hirchfeld & S. A. Gelman (Eds.), *Mapping the mind* . Cambridge: Cambridge University Press.

Gosgrove, M. (1995). A study of science-in-the-making as students generate an analogy for electricity. *International Journal of Science Education, 17*(3), 295-310.

Gosgrove, M., Osborne, R., & Carr, M. (1989). Lesson frameworks for changing children's ideas. In R. Osborne & P. Freyberg (Eds.), *Learning in science: the implications of children's science* . Auckland: Heinemann.

Goswami, U. (1991). *Analogical reasoning in children.* Hove (UK): Lawrence Erlbaum Associates Publishers.

Hammersley, M. (1996). The relationship between qualitative and quantitative research: paradigm loyalty versus methodological electricism. In J. T. E. Richarson (Ed.), *Handbook of Qualitative Research* (pp. 159-174). Leicester, UK: BPS Books.

Hildebrand, D. K., Laing, J. D., & Rosenthal, H. (1977). *Prediction Analysis of Cross Classifications.* New York.

Holyoak, K. J. (1985). The pragmatics of analogical transfer. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 59-87). New York: Academic Press.

Holyoak, K. J., & Koh, K. (1987). Surface and structural similarity in analogical transfer. *Memory and Cognition, 15*, 332-340.

Iding, M. K. (1997). How analogies foster learning from science texts? *Instructional Science, 25*, 233-253.

Johnson, M. (1987). *The Body in the Mind.* Chicago: Chicago University Press.

Johnson, M. (1989). Some constraints on embodied analogical understanding. In D. Helmson (Ed.), *Analogical reasoning* . Dordrecht: Kluwer Academic Publishers.

Johnson-Laird, P. N. (1983). *Mental models: Towards a Cognitive Science of Language, Inference and Consciousness.* Cambridge: Cambridge University Press.

Johnson-Laird, P. N. (1994). Mental models and probabilistic thinking. *Cognition, 50*(189-209).

Kaufman, D. R., Patel, V. L., & Magder, S. A. (1996). The explanatory role of spontaneously generated analogies in reasoning about physiological concepts. *International Journal of Science Education, 18*(3), 369-386.

Keane, M. T. (1991). Consciousness, Analogy and Creativity. *Behavioral and Brain Sciences, 14*(4), 682-696.

Keane, M. T., Ledgeway, T., & Duff, S. (1994). Constraints on analogical mapping: A comparison of three models. *Cognitive science, 18*, 387-438.

Keenan, T. (1995). Fables of Responsibility. In A. Gelley (Ed.), *Unruly Examples* . Stanford, California: Stanford University Press.

Keil, F. C. (1989). *Concepts, kinds and cognitive development.* Cambridge: MA: Bradford books.

Kieras, D. E., & Bovair, S. (1986). The acquisition of procedures from text. A production system analysis of transfer of training. *Journal of Memory and Language, 25*, 507-524.

Lakoff, G. (1987). *Women, Fire and Dangerous Things.* Chicago: Chicago University Press.

Lakoff, G., & Johnson, M. (1981). *Metaphors We Live By.* Chicago: Chicago University Press.

Lawson, A. E. (1993). The importance of analogy: A prelude to the special issue. *Journal of Research in Science Teaching, 30*(10), 1213-1214.

LeFevre, J., & Dixon, P. (1986). Do written instructions need examples? *Cognition and Instruction, 3*, 1-30.

Lewis, C. (1988). Why and how to learn why: Analysis-based generalization of procedures. *Cognitive Science, 2*, 211-256.

Lyons, J. D. (1995). Circe's Drink and Sorbonic wine: Montaigne's Paradox of Experience. In A. Gelley (Ed.), *Unruly Examples* . Stanford, California: Stanford University Press.

Mardia, K. V., Kent, J. T., & Bibby, J. M. (1979). *Multivariate analysis.* London: Academic Press.

Mariani, M. C., & Ogborn, J. (1991). Towards an ontology of common sense reasoning. *International Journal of Science Education, 13*(1), 66-85.

Mariani, M. C. (1992). *Some dimensions of commonsense reasoning about the physical world.* Unpublished Ph.D., University of London.

Mason, J. (1994). Linking qualitative and quantitative data analysis. In A. Bryman & R. G. Burgess (Eds.), *Analyzing Qualitative Data* (pp. 89-110). London: Routledge.

McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: naive beliefs about the motion of objects. *Science, 210*, 1139-1141.

Mitchell, T. M., Keller, R. M., & Kedar-Cabelli, S. T. (1986). Explanation-based generalization: A unifying view. *Machine Learning, 1*, 48-80.

Niaz, M. (1997). Can we integrate qualitative and quantitative research in Science Education? *Science Education, 6*(3), 291-300.

Novick, L. (1988). Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14*, 510-520.

Ogborn, J. (1994). *Theoretical and empirical investigations of the nature of scientific and commonsense knowledge*, Ph.D., University of London.

Ogborn, J. (1996). Science. In P. Gordon (Ed.), *Recent Developments in Education Research* (pp. 147-174 ISBN 0-7130-0192-5). London: Woburn Press.

Ogborn, J., & Bliss, J. (1990). A Psycho-Logic of Motion. *European Journal of Psychology of Education, 4*, 379-390.

Osborne, J. (1983). Modifying children's ideas about electric current. *Research in Science and Technological Education, 1*(1), 73-82.

Osborne, R., & Freyberg, P. (Eds.). (1985). *Learning in Science: The implication of children's science.* London: Heinemann.

Pfund, H., & Duit, R. (1994). *Bibliography: Students alternative frameworks and science education* Reports: IPN Keil.

Piaget, J. (1970). *Genetic Epistemology.* New York: W.W Norton & Company.

Piaget, J., & Garcia, R. (1987). *Toward a logic of meaning.* New Jersey: Lawrence Erlbaum.

Pierce, & Gholson. (1994). Surface similarity and relational similarity in the development of analogical problem solving: Isomorphic and Non Isomorphic transfer. *Developmental Psychology, 30*(5), 724-737.

Pirolli, P. (1991). Effects of Examples and Their Explanations in a Lesson on Recursion: A Production System analysis. *Cognition and Instruction, 8*(3), 207-259.

Pirolli, P. L., & Anderson, J. R. (1985). The role of learning from examples in the acquisition of recursive programming skills. *Canadian Journal of Psychology, 39*, 240-272.

Reed, S., Willis, D., & Guarino, J. (1994). Selecting Examples for Solving Word Problems. *Journal of Educational psychology, 86*(No. 3), 380-388.

Reed, S. K. (1993). A schema-based theory of transfer. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition and instruction.* (pp. 36-67). Norwood, NJ: Ablex.

Reed, S. K., Ackinclose, C. C., & Voss, A. A. (1990). Selecting analogous problems: Similarity versus inclusiveness. *Memory and Cognition, 18*, 83-98.

Reed, S. K., & Bolstad, C. A. (1991). Use of Examples and Procedures in Problem Solving. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17*(4), 753-766.

Reed, S. K., Dempster, A., & Ettinger, M. (1985). Usefulness of analogous solutions for solving algebra word problems. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11*, 106-125.

Rissland, E. L. (1991). Example-Based Reasoning. In J. Voss, D. Perkins, & J. Segal (Eds.), *Informal Reasoning and Education* (pp. 187-208).

Rosch, E. (1975). Cognitive Representations of Semantic Categories. *Journal of Experimental Psychology: General, 104*(3), 192-233.

Rosch, E. (1978). Principles of Categorisation. In E. Rosch & B. Lloyd (Eds.), *Cognition and Categorisation* . New Jersey: Lawrence Erlbaum.

Ross, B. H. (1984). Remindings and their effects in learning as cognitive skill. *Cognitive Psychology, 16*, 371-416.

Ross, B. H., & Kennedy, P. T. (1990). Generalizing From the Use of Earlier Examples in Problem Solving. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16*(1), 42-55.

Shepardson, & Moje. (1994). The nature of fourth graders' understandings of electric circuits. *Science Education, 78*(5), 489-514.

Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought: the insides story. *Cognition, 56*, 129-163.

Slotta, J. D., Chi, M. T. H., & Joram, E. (1995). Assessing Students' Misclassifications of Physics Concepts: An Ontological Basis for Conceptual Change. *Cognition and Instruction, 13*(3), 373-400.

Stocklmayer, & Treagust. (1994). A historical analysis of electric currents in textbooks: A century of influence on physics education. *Science & Education, 3*(131-154).

Sweller, J., & Cooper, G. A. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction, 2*, 59-89.

Treagust, D. F., Duit, R., Joslin, P., & Lindauer, I. (1992). Science Teachers' use of analogies: observations from classroom practice. *International Journal of Science Education, 14*(4), 413-422.

Tyson, L. M., Venville, G. L., Harrison, A. G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education, 81*, 387-404.

VanLehn, K. (1986). Arithmetic procedures are induced from examples. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 133-179). Hillsdale, NJ: Lawrence Erlbaum Associates.

Venville, G. J., & Treagust, D. F. (1996). The role of analogies in promoting conceptual change in biology. *Instructional Science, 24*, 295-320.

Ward, M., & Sweller, J. (1990). Structuring effective worked examples. *Cognition and Instruction., 7*, 1-39.

Wellman, H. M. (1990). *The child's theory of mind.* Cambridge: MIT Press/Bratford Books.

Wittgenstein, L. (1953). *Philosophical Investigations.* New York: Macmillan.

Wong. (1993). Self-generated analogies as tools for constructing and evaluating explanations of scientific Phenomena. *Journal of Research in Science Teaching, 30*(4), 367-380.

Appendix 2.1 The final report to ESRC of the research project 'Empirical Abstraction'.

Empirical Abstraction and Concrete Physical Reasoning Schemes

Final Report

Background

Some such notion as 'scheme' is present in a wide range of work on cognitive development and reasoning. It is already there in Bartlett, and it essential to the thought of Piaget (Bliss 1995, Piaget and Garcia 1987). The nature of reasoning schemes has been debated in the writings of, amongst others, Carey (1985), Keil (1979, 1981, 1990, 1992), Gelman (1990), Carey and Gelman (1991), Hirschfield and Gelman (1994), and diSessa (1988, 1993). The notion is implicit in much early work in cognitive science on 'naive physics' (e.g. Hayes 1979, 1985), and is implicated in much work on mental models (e.g. Gentner and Stevens, 1983). A similar notion is involved in work on categorisation (e.g. Rosch and Lloyd 1978). There is however, very little agreement in detail about what constitutes a scheme, beyond it being some internalised patterned complex of activity or expectations. Some authors have a broad-brush approach, e.g. Keil's notion of modes of construal of the world, or the idea of large ontological categories such as physical event or object (Carey 1985, Chi 1992). Others (e.g. diSessa) hold that units of thought are many, varied and fragmentary. Some (e.g. Johnson-Laird 1983) use a notion like mental model or scheme to indicate tools used *for* thought; others (e.g. Gentner and Stevens) use a similarly-named notion to describe patterns in *what* people think. Some (e.g. Spelke 1990, Medin et al 1990) see certain schemes as innate; others look for developmental mechanisms. It is this lack of agreement about a crucial idea which motivated us to investigate methods for identifying and characterising schemes.

Here, we restrict our focus to schemes originating in reasoning about the physical world, in making sense of physical objects and events, but even so the variety of views sketched in above can be found. Our essential starting point is Piaget's notion of 'empirical abstraction', an outcome of the child's physical interaction with the world, leading to internalised schemes representing the physical nature of things. However, having had the idea, Piaget neglected it, being more interested in logical and mathematical schemes. Indeed he saw the dependence of physical reasoning schemes on the behaviour of physical objects themselves as a difficulty for his theorising. We, by contrast, see such schemes as 'effort' and 'support', derived from the activity of making and experiencing movements, not only as basic elements in everyday reasoning about force and motion (Ogborn 1985, Bliss and Ogborn 1990, 1992, 1993, 1994), but also as potential building blocks for reasoning - often metaphorically - about many other domains. And we find support (note the metaphor!) in such work as that of Lakoff and Johnson (Lakoff and Johnson 1981, Lakoff 1987, Johnson 1987) grounding semantics in bodily action.

If the notion of 'scheme' has any value, it must be the case that one can identify 'the same' scheme being used in different contexts. It must also be possible to name and characterise a number of schemes of rather general use; it would be desirable to have some analysis of or typology of schemes. And it would be very helpful to have a variety of empirical methods adapted to the further investigation of the existence, use and nature of schemes. Our guiding hypothesis was that these goals might be achievable, in the limited case of physical reasoning schemes deriving from empirical abstraction.

Objectives

The overall goal of the research was a preliminary and limited investigation of empirical abstraction and concrete physical reasoning schemes, to pave the way for further research, in the context of pupils' engagement with scientific ideas; more specifically:

- to contribute to the theory of everyday common-sense thinking and reasoning through the development of an analytic framework for the classification of concrete physical reasoning schemes and the development of a typology of concrete physical schemes as tools for thinking.

- to contribute to knowledge of the development and use of children's concrete physical reasoning schemes, with relevance to the learning of science.

- to contribute to the development of research tools in two ways:

    -by the development of a methodological framework for investigating concrete physical schemes as tools for thinking.

    -by the construction and testing of a novel set of generic tasks for the investigation of concrete physical reasoning schemes.

These objectives were translated into nine more specific research questions, of three kinds: analytical, empirical and methodological. These questions are reproduced and addressed in the Results section later.

We have addressed all the specific research questions. The analytical questions were addressed through the process of identifying putative schemes for investigation, and of attempting to identify schemes in use in data obtained. We now see more clearly the nature of schemes as articulated packages of potential, and recognise more sharply the inter-connectedness of many schemes.

The empirical and methodological questions were addressed jointly through the construction of, piloting, and analysis of data from, a planned set of elicitation tasks. The intended relationship to learning of science, though present, played a more minor role than expected, in part because of the need for tasks to be suitable for both 6-7 and 13-14 year-olds.

The strongest results are an analytic framework for thinking about the nature of schemes, with new features informed by our results, the construction of a number of generally applicable (generic) tasks designed to investigate different aspects of schemes, and the evidence we can present of the stable existence from an early age of a fairly small number of physical reasoning schemes which inform much reasoning, physical and non-physical.

The main weakness in the results derives from the fact that, being committed to developing a range of generic tasks, the timetable did not allow enough for the full revision and re-trial of tasks, so that some have had to be piloted with rather small numbers of subjects. We accepted this rather than restricting the number of tasks developed, because we found that the different tasks all gave usefully different perspectives on the issues involved in defining, eliciting and characterising schemes.

The project benefited greatly (at no cost) from the work of an associated doctoral student, Mr C A Tsatsarelis, who independently conducted several relevant studies (and later joined the project team). Where these studies are mentioned, they are credited explicitly to him.

Methods: 1 Overview and Design

A central objective was to develop a methodological framework, producing generic tasks available across different types of schemes. A theoretical typology of schemes was originally intended to be one axis of the framework. It quickly became clear that the way schemes relate to one another is more complex and more interesting than anticipated, so that the theoretical analysis needed to be informed by data from tasks to be devised.

In its place we conducted a content analysis of a range of texts, including science texts but also newspapers and journals, looking for metaphorical uses of physical reasoning schemes. It was striking how frequent these were, and how many were based on very simple physical processes: forcing, pressing, containing, blocking, flowing, moving, hitting, balancing, breaking, bending. Others (e.g. reflection, combustion) were present, but it was these mechanical processes which seemed most often to be invoked. We decided to focus attention on these schemes, with a reasonable range of them in the various tasks to be developed.

A first dimension of our methodological framework was four categories of tasks (see proposal):

- imaginative transformations
- thinking of something as...
- instances of something like...
- thinking metaphorically with physical schemes

Another dimension distinguished whether tasks required the production or recognition of a 'scheme' or an instance of one (generative or selective tasks). In both, counter-suggestions probe the strength of commitment to ideas. We also varied the extent to which the schemes under investigation were explicit or not.

A third dimension was the need to adapt tasks to a wide age range (from 6 years old). Tasks relying too much on language were not suitable for very young children. In piloting we paid attention to whether tasks seemed authentic and produced a good flow of spontaneous thought.

The tasks themselves used a range of stimuli, non-linguistic as well as linguistic: pictures, objects, metaphors, stories, etc. They used a range of elicitation techniques, from open invitations to speculate, through interviews about specific stimuli, to 'yes/no' responses. They was designed to have possible generic forms, that is to be able to be adapted to different domains.

Our previous work suggests that many physical reasoning schemes originate through children's actions on and experience of the physical world early in their development. These actions are internalised by the age of 5 or 6, acting as tools for thinking and generating knowledge about the world which becomes highly tacit. Devising tasks to explore such tacit thinking is difficult. Subjects may be asked to make explicit things which are so obvious and taken-for-granted that they normally remain unsaid. In the various tasks we adopted a range of strategies to help to make such thinking explicit, for example by presenting objects whose behaviour is surprising, by creating unusual scenarios, by inviting participants to imagine the world behaving oppositely to how it should, by asking questions appropriate to one ontological category about entities belonging to another (e.g. can the mind move by itself?). Throughout, therefore, everyday thinking was challenged.

Task categories

Ten studies were conducted. One analysed texts for the metaphorical use of schemes. Nine (three conducted by Mr Tsatsarelis) involved scheme-elicitation tasks, and fall into four groups according to the methodological framework above.

Imaginative transformations... asking for entities or events to be transformed in imagination. These tasks investigate schemes through seeing what is held invariant in transformations. Difficulties of transformation suggest boundaries between incompatible schemes. Four such tasks were devised:

Imaginative denial of rules (Topsy Turvy World),
Imaginative constructions (Lonely Giant);
Transforming an object into another (Object transformation) [Tsatsarelis];
Transforming an event into another (Event analogies) [Tsatsarelis]

Thinking of something as... trying to think of instances as like a given scheme (e.g. is a gale like the flow of something?). Something concrete is to be imagined or explained in one or more general ways, going from the instance to the scheme. Two such tasks were devised:

Fitting schemes to counter-expectations (Anomalies)
Dimensions of schemes (Ontologies)

Instances of something like.. creating or identifying instances of a scheme (e.g. what counts as a 'container'?), going now from the scheme to the instance. Two such tasks were devised:

Application of Schemes (Prototypes)
Fit of examples to (scientific) ideas (Examples) [Tsatsarelis]

Thinking metaphorically with physical schemes: using physical schemes as the basis of metaphors to reason about non-physical situations. One such task was devised, given that data about metaphorical uses was also available from the text analysis and from several other tasks:

Schemes as metaphors (Metaphors)

Methods: 2 Task development and specific results

In this section we summarise the various tasks developed, and outline specific results from each. Fuller details are in Appendix 2.

Imaginative Transformations
Imaginative denial of rules (Topsy Turvy World)

Task design:
Generative. Schemes not presented explicitly (implicit in goals set).
Focus on constraints on changing schemes.
Setting: common knowledge.
Schemes commonly evoked: up-down, fall, support, contain, rigidity, flow.

Children:	
6-7 years	19
13-14 years	6

Children were asked to imagine what familiar actions (e.g. making tea) would be like in a world in which everything is 'topsy turvy'.

'Inverting' one scheme affects others (e.g. if things fall upwards, support is changed). Thus schemes are related in packages; inversion of everything leads to contradiction. Very fundamental ('Kantian') schemes (inside-outside, bounded space, time sequence, cause-effect) are conserved and not inverted. Up and down, support, falling, rigidity, fluidity can be changed.

Imaginative constructions (Lonely Giant)

Task design:
Generative. Schemes not presented explicitly (implicit in goals set).
Focus on schemes through unusual uses of materials and resources. Mainly functional schemes invoked.
Setting: common knowledge.
Schemes commonly evoked: container, motion, force, rigidity, cause-effect.

Children:

6-7 years	5
13-14 years	7

Children were asked to imagine constructing a car from more or less unsuitable materials (e.g. bricks, paper, boxes, trees) so that materials had to be transformed in imagination.

The results bear upon theories of abstraction. Older children had a generic notion of 'car', with explicit broad functional units; materials were shaped to fit these functions. Younger children started from available materials, letting their nature or appearance suggest a use. But these uses were still organised around functional schemes, though implicitly (e.g. a paper bag for a seat because both are containers). Younger children's thinking was transductive; older children thought functionally.

Transforming an object into another (object transformation) [Tsatsarelis]

Task design:
Generative. Schemes not presented explicitly (implicit in goals set).
Focus on invariances of schemes through making 'impossible' imaginative transformations. Special attention to transformation across ontological categories, and on functional schemes.
Setting: common knowledge.
Schemes commonly evoked: functions such as move by itself, fly, contain.

Children:

11-12 years	38 (Greek)

Children were asked to transform one object of a pair into the other. Pairs could belong to the same ontological category or not (natural living kinds or artefacts). Artefacts did or did not share common functional schemes.

Transformations between objects of the same ontological kind were easy. Transformations from one kind to another were harder; hardest in the direction from artefact to living thing. Shared functional schemes made cross-category transformations easier. Shared schemes can bridge ontological differences.

Transformational steps used four devices: adding, modifying, removing and keeping constant particular features. Shared functional schemes led to use of 'keeping constant'. Lack of common schemes led to use of 'modify' or 'remove'.

Transforming one event into another (event analogies) [Tsatsarelis]

Task design:
Generative. Schemes not presented explicitly (implicit in goals set).
Focus on the schematic nature of school science processes, through construction of analogies.
Setting: school science knowledge.
Schemes commonly evoked: flow, action, path, barrier.

Children:
11-12 years 39 (Greek)

Given pictures taken from school science text books of processes of scientific interest (e.g. current in a circuit) children were asked to construct analogies for these processes.

They could find analogies, generally drawing on schemes from everyday knowledge. Detailed statistical analysis of the co-occurrence of elements in analogies (objects, scientific entities, processes) shows that the underlying thinking is regular and well-structured. Dimensions 'dynamic vs. static' and 'cause vs. effect' can be seen. Types of structure were such as 'a source/container provides something which can flow, if acted on dynamically'. Interaction with scientific knowledge appears to have left children with broad pictures of the nature of a number of processes, not simply with surface facts.

Thinking of something as...
Fitting schemes to counter-expectations (Anomalies)

Task design:
Generative. Schemes not presented explicitly (implicit in goals set).
Focus on the use or adaptation of schemes to predict and account for the behaviour of objects which appear to violate common knowledge schemes.
Setting: common knowledge (unusual devices).
Schemes commonly evoked: support, balance, motion, force, rigidity, fluidity.

Children:
13-14 years 7

Children were asked to account for the behaviour of objects ('potty putty', a gyroscope, an executive 'perpetual motion' toy) which behaved in ways violating their expectations.

A given object evokes a package of schemes, e.g. movement, rigidity and support. The behaviour of these anomalous objects violated such schemes, allowing us to see how they interact. Schemes were not abandoned but rather imagined as realised or combined in novel ways (e.g. motion lends support). We observed a dynamic process of scheme fitting and revision. Action on the objects was crucial to produce revision of scheme fitting.

Dimensions of schemes (Ontologies)

Task design:
Selective. Schemes pre-selected, implicit in diagnostic questions.
Focus on detecting the consistent presence of schemes in thinking about a wide variety of objects, some unpredictable in their scheme-formation.
Setting: common knowledge.
Schemes: object in motion, source of motion, support, container, carrier, fluid flow.

Participants:

13-14 years	58 (one group of 28; one group of 30)
adults	22

This task, using a questionnaire format with simple yes/no answers, was designed to complement small scale interview tasks.

Hypothesised schemes could be recovered from patterns of responses to simple ontological questions (e.g. "Does it hold something up?"; "Does it stop something falling?" for 'support'), showing how a variety of physical entities were understood in terms of such schemes. Of 22 objects asked about, some were 'unproblematic' in terms of schemes (e.g. a car); others were chosen to be problematic (e.g. the mind).

Factor and cluster analysis extracted schematic groupings which were closely related to those built into the design. With some variations, these were applicable as much to problematic objects as to unproblematic ones, and were similar across age differences. An unanticipated rather abstract scheme, 'fillable space', appeared to emerge. The 'problematic' exemplars all had intelligible (but not a priori predictable) descriptions in terms of these schemes (e.g. the mind as a container and carrier)

It appears that something like such schemes can be taken to 'exist' in participant's thinking about the physical world.

Instances of something like...
Application of Schemes (Prototypes)

Task design:
Selection. Schemes presented explicitly.
Focus on recognising instances of schemes in a variety of different physical contexts.
Setting: common knowledge.
Schemes: support, containment, flow, floating.

Children:

6-7 years	29
13-14 years	6

Children first agreed about a target-scheme shown in a picture. They then had to identify other examples of the scheme in each of nine different contexts, shown as drawings of scenes (e.g. a waiter serving customers wine; a bath overflowing). Finally they chose the best example from all the pictures.

Younger and older children showed a similar underlying pattern of difference in their use of all four schemes. Each scheme was used in a local and specific way by 6-7 year olds but more generically and across more contexts by the older ones.

For example, for 'support' younger children's examples are obvious (waiter-tray) or local (bath-legs); older children choose less obvious examples (e.g. chairs tightropes and trampolines supporting people). Young children used 'containment' only in a local sense (cups-containing-drinks) - spaces did not 'contain', as they did for older children. 'Flow' was similar. 'Float' showed the same tendency, but older children had not yet extended its range of convenience very much.

Fit of examples to scientific ideas (Examples) [Tsatsarelis]

Task design:
Selective. Schemes implicit in choice of examples and questions.
Focus: Examples and generalisations. How particular cases function as examples or counter examples of general 'scientific' ideas. How seeing a case as an example constrains its schematisation.
Setting: school science knowledge.

Children:
11-12 years six groups of about 40 (Greek)

Firstly, children were given a 'scientific' idea (e.g. light travels in straight lines), and an example, a parallel example and a possible counter-example. They were asked whether the examples were good or not, and whether the example changed the idea for them.

Examples tended to be judged good on grounds of salience or immediacy (size or speed). Counter examples produced specialisations of ideas, or over-ride principles. Parallel examples sometimes lead to a wider generalisation.

Secondly, a questionnaire presented first a picture of a scene (e.g. a boy up a tree) and then the same scene but now described as an example of a scientific idea (e.g. potential energy). Six such ideas were used, each with two different picture-examples. Both before and after revealing the idea, children were asked whether elements of the picture might fit a number of schemes (e.g. block something, force something, contain something).

Interpretable factors could be extracted (e.g. autonomous action, static barrier/support, particular or generic location). Factor scores provide a characterisation of the elements of the examples in terms of these schemes.

After presenting the idea, assignment to schemes became more differentiated and selective. Seeing something as an example constrains how it is imagined.

Thinking metaphorically with physical schemes
Schemes as metaphors (Metaphors)

Task design:
Selective. Schemes presented explicitly.
Focus: use of physical reasoning schemes in thinking metaphorically about non-physical situations.
Setting: common knowledge.
Schemes: support, flow, containment, barrier, floating, balance.

Children:
13-14 years 6

For each of the above schemes, we constructed a pair of scenarios predicted to be one plausible and one implausible example of the scheme used metaphorically (e.g. containing feelings, supporting a person's activities). The non-examples each violated what we took to be one criterial aspect of the scheme (e.g. proximity for support).

Children were asked whether such scenarios were or were not good instances of a scheme used metaphorically (in the form of questions about the scenario of the type, "Would you say that Peter *contained* his feelings?"), and to explain why or why not.

Agreement with predictions was generally good. Disagreements arose mainly with 'flow' and 'floating'. Metaphors were taken not to apply on grounds relating to broad schematic features: e.g. that 'flow' should be continuous and not too rapid - discrete or rapid changes were disqualified. 'Floating' metaphors were often required to be rather literal to qualify.

Children could argue for or against the validity of these metaphors, invoking physical features of the schemes to do so.

Results: Overall

We originally posed the following three *analytical* research questions:

(1) What would be a plausible set of concrete physical reasoning schemes usable in a wide range of contexts of thinking about physical reality, and so in learning science?
(2) How can the differences between and the relationships between such schemes be characterised analytically? Can any claim that an analysis of types of schemes is in some sense comprehensive be sustained?
(3) What is the appropriate granularity at which to define schemes, from the highly general (e.g. space, object) to the more particular (e.g. running river, falling ball)?

To respond to them we have to be clearer about the nature of schemes. Using the language of complex adaptive systems (e.g. Holland 1995) we regard schemes as *tagged* (labelled) *re-usable building blocks* used in *packages* to make *models*. Take the scheme 'support', for example. It has acquired a name (*tag*) which people recognise instances of very early. It is widely re-usable (sitting on a chair, holding a cup, lending moral support). It is a building block used in combination with others such as fall, effort, solidity. The combined package of schemes constitutes a model allowing one to predict or account for events (that one will fall if the chair breaks; that morale has sagged).

A scheme has a small set of *potentials* (to adopt a linguistic term) which provide *entailments* and link it to other schemes. The potentials of 'support' include 'something underneath', 'prevented from falling', 'above the ground'. If a potential is not satisfied something must substitute for it (a bird has nothing underneath, so must support itself 'by its own effort'). Notice the intimate links to other schemes (falling and effort). *Entailments* are direct one-step inferences from 'how things are'. That removing support will make something fall is such an entailment.

Schemes need to be neither too specific nor too generic. The more generic, the greater the possible range of convenience. But the more specific, the greater the number of entailments. Effective thought requires a compromise. Thus support is less specific than 'resting on something solid', but more specific than 'being there'. Its re-usability derives from this: it is generic enough to be used in many situations but not so generic as to apply almost everywhere. This makes it recognisable, able to carry a usable tag-label.

The 'right' level of specificity is relative to the domain of thought (for experts, highly generic things become specific). This makes answers to questions about granularity and completeness into empirical questions for given domains. But it does seem (empirically) that the schemes appropriate to thinking about the movement (or not) of physical objects, established early in life, prove to be re-usable in many other domains, including social life. A quite small set of a dozen or so such schemes accounts for a good proportion of metaphors found in texts (movement, action/force/effort, container, carrier, support, fall, barrier, space, flow, break/not break, stretch/squash, balance).

This discussion leaves open the question whether 'schemes' are a linguistic or psychological phenomenon. We think the question ill posed. Were they not tagged and so used in communication, they would not acquire their (growing) power. But they would not become essential metaphoric components of meaning (Lakoff 1987, Johnson 1987) if they were ill-fitted to making effective and predictive mental models. Such over-determination makes schemes very *stable*.

Evidence to sustain this analysis comes from a number of tasks. No task ran into difficulty over *tagging* schemes, even with very young children. The Prototypes task shows directly that tagged schemes are readily recognisable. In generative tasks, similar scheme tags were produced by children. *Re-usability* in different physical contexts is shown by the Prototypes task; re-usability in non-physical contexts by the Metaphors task and the Ontologies task, and is further shown by the spontaneous use of metaphor in other tasks. Generative tasks all showed schemes being spontaneously re-used. The Topsy Turvy and Anomalies tasks were good at showing how schemes are linked to others in *packages*, making *models*. This packaging helps account for the difficulty in bridging ontological categories in the Object Transformation task. The Examples task shows how being part of a model constrains the choice of schemes. The existence of *entailments* deriving from *potentials* is brought out by the Ontologies task, showing how sets of possibilities cohere into schemes. The Lonely Giant and Prototypes tasks showed change in *generic* levels with age. Many tasks illustrated how children could use schemes to attempt to model a variety of new - even peculiar - situations, with the Event Analogies task illustrating that *models* (analogies) are made up of coherently organised schemes. The evidence (e.g. from the Topsy Turvy task) that schematic thinking tends to be conservative, avoiding contradicting very basic pre-suppositions, lends further support to the idea that schemes are rather *stable*, also found elsewhere (e.g. Ontologies task).

Our proposal put the following empirical research questions:

(4) Given a plausible selection of schemes covering the main types identified, can these be shown to exist, in the sense that any given scheme is reliably used in a similar way in a number of different contexts?
(5) How are such schemes used? How do they support making inferences and generating explanations in situations of interest in science?
(6) How is one scheme rather than another selected for use? On what basis are schemes entertained or rejected?
(7) What differences can be found between schemes available relatively early (6-7 years) and in early adolescence (13-14)?

Two tasks directly addressed question (4): the Prototypes task and the Ontologies task. The first showed that schemes identified by example and name (tag) could be identified in a variety of physical contexts. The second showed that schemes analysed into component entailments could be recovered as clusters or factors across a wide range of objects, including several where schemes apply metaphorically. Less directly, the set of other tasks taken together, by showing that similar schemes emerge spontaneously in generative tasks, play a role in transformations, and are used in metaphor, further sustains the result that schemes can be shown to 'exist'.

Question (5) was addressed so far as science is concerned in the Event Analogies and Examples tasks. The first shows that children's analogies for processes of scientific interest have an articulated structure making use of concrete reasoning schemes. The second shows that particular examples of scientific ideas are understood through everyday physical schemes, each constraining the other to focus on how the example *is* an example. It also shows that scientific ideas themselves (e.g. potential energy) have intelligible concrete schematic representations.

Questions (6) and (7) may be addressed together. All three tasks done with both ages indicated that the basic schemes to do with physical movement and change were available by the earlier age, able to be recognised and produced spontaneously. There was however evidence of development with age. Schemes appear to start associated with common directly experienced contexts, but with age expand to cover a wider range of contexts, being used to account for less obvious situations. Schemes like support and effort causing movement are established very early, and by age 13-14 are being used metaphorically. Schemes like flow and floating are rather tied to common contexts at age 6-7 and are just beginning to expand their applicability by age 13-14. However, even at age 6-7 schemes like support and effort involve substantial abstraction, being used in a variety of different contexts. For younger children, schemes tend to be evoked when their potentials are obviously at issue (e.g. a waiter supporting a tray might drop it). Older children also see these potentials at work when they might have been taken for granted (e.g. support given to a person sitting in a chair). Schemes are entertained or rejected on the basis of their direct entailments (e.g. flow is smooth; discrete motion isn't flow). The Anomalies task shows the dynamics of changing the fit of schemes. When an expectation from one scheme is violated, a scheme which provides the required behaviour is sought, and then its other potentials are considered. The need to think again was strongly tied to action.

Lastly, we address the two original *Methodological* research questions:

(8) What combinations of methods are needed to sustain a claim that a scheme has been adequately identified and characterised?
(9) Can generic forms of tasks be developed for investigating different schemes in varied contexts, so that one might claim comparability between schemes or contexts?

Our view is (as above) that the 'existence' of schemes is over-determined - that they 'exist' in language and discourse, in action, in imagined action, and in mental models. For this reason, we looked for data of these different kinds, perhaps giving primacy to imagined action as a bridge between the others.

We claim to have developed a range of generic tasks able to be used more widely to investigate schematic reasoning. The Ontologies and Prototypes tasks are clearly adaptable to a variety of different schemes. The Topsy Turvy strategy of imaginatively denying rules has general application manipulating schemes evoked by varying the goal set. Similarly the Metaphors task provides a generally usable framework. Other tasks could be adapted, but the above seem the strongest candidates for generic tasks.

Activities

We worked within the research network of the London Mental Models Group. Presentations at seminars and conferences included:

- Institute of Education, University of London (Autumn 1995, Autumn 1996);
- University of Sussex (Autumn 1996);
- ECER/BERA conference (Exeter Autumn 1995);
- European Research Student Summer School in (Barcelona Summer 1996);
- Situated Cognition Task Force (European Science Foundation Summer 1996);
- Human and Machine Learning Conference (Belgium Autumn 1996).

Papers have been accepted for the European Association for Research in Learning and Instruction (Athens Summer 1997) and for the European Association for Research in Science Education (Rome Summer 1997).

Outputs

Two papers (provided with this report) have been submitted for publication:

Empirical Abstraction and the imaginative denial of rules
Minds, buckets and paper bags: Are there stable physical reasoning schemes?

Further papers are in draft form:

Empirical abstraction and concrete reasoning schemes: a theoretical analysis
The Lonely Giant: from abstract to concrete?
Recognising prototypes of schemes
Concrete physical reasoning schemes in metaphor: analysis of some texts
Dealing with anomalous objects - dynamics of fitting schemes

Mr Tsatsarelis is writing up his work for the PhD thesis, and has presented papers at conferences, with further conference papers accepted.

We intend to produce a book presenting the work within a wider perspective.

Impacts

The project was designed to develop methods and theory to impact on future research - a proposal has already been generated. There has been valuable synergy with a concurrent ESRC project (Visual communication in science - Kress and Ogborn).

Future research priorities

Our original proposal explicitly offered the present work as establishing a number of research tools for further research. Future priorities might be:

- to look at a wider variety of schemes using similar tools.
- using the tools to follow more carefully the development in generic level of schemes, over the years 6 to 16 or so.
- to use the tools to trace the relationship of concrete physical reasoning schemes to scientific ideas as they are learned.
- to study of the use in popularised science of metaphors drawing on common-sense schemes.
- to investigate in greater depth the *process* of using concrete physical schemes in reasoning about problems.

Appendix 1

References

Bliss J. 1995 Piaget and after: the case of learning science, *Studies in Science Education*, Vol 25, pp 139-172

Bliss J and Ogborn J 1990 A psycho-logic of motion.*European Journal of Psychology of Education* Vol V, No 4, pp 379-390

Bliss J and Ogborn J 1993 Steps towards the formalisation of a psycho-logic of motion. *Journal of Intelligent Systems* Vol 3, No 1, pp 3-48

Bliss J and Ogborn J 1992 Steps towards the formalisation of a psycho-logic of motion. In A Tiberghien , H Mandl (Eds) *Intelligent Learning Environments and Knowledge Acquisition in Physics* NATO ASI Series, Springer Verlag: Berlin

Bliss J and Ogborn J 1994 Force and Motion from the Beginning. *Journal of Learning and Instruction*, Vol 4, pp 7-25

Carey S 1985 *Conceptual Change in Childhood* MIT Press: Cambridge Mass.

Carey S & Gelman R (Eds) 1991. *The Epigenesis of Mind.* Hillsdale New Jersey: Lawrence Erlbaum.

Chi M.T.H. 1992. Conceptual change within and across ontological categories. In R. Giere (Eds.), *Cognitive Models of Science: Minnesota Studies in the Philosophy of Science* pp 129-160. Minneapolis: University of Minnesota Press.

diSessa A 1988 Knowledge in pieces. In G Forman, P Pufall (Eds) 1988 *Constructivism in the Computer Age* Lawrence Erlbaum: New Jersey

diSessa A 1993. Towards an epistemology of physics. *Cognition and Instruction*, Vol 10, (Nos 2 & 3), pp 105-225.

Gelman R 1990 First principles organise attention to and learning about relevant data: number and the animate-inanimate distinction as examples. *Cognitive Science* Vol 14, pp 79-106

Gentner D and Stevens A (Eds) 1983 *Mental Models* Lawrence Erlbaum: New Jersey

Hayes P 1979 The naive physics manifesto. In D Michie (Ed) 1978 *Expert Systems in the Micro-Electronic Age* University of Edinburgh Press: Edinburgh

Hayes P 1985.The second naive physics manifesto. In J Hobbs, R Moore (Eds) 1985 *Formal Theories of the Commonsense World* Ablex: New Jersey

Hirschfield L A & Gelman S A 1994 *Mapping the Mind*, Cambridge, Cambridge University Press

Holland J H 1995 *Hidden Order: How Adaptation Builds Complexity*. Reading MA: Addison Wesley.

Johnson M 1987 *The Body in the Mind: the bodily basis of meaning, imagination and reason* University of Chicago Press: Chicago

Johnson-Laird P 1983 *Mental Models* Cambridge University Press: Cambridge

Keil F 1979 *Semantic and conceptual development: an ontological perspective* Harvard University Press: Cambridge, Mass.

Keil F 1981 Constraints on knowledge and cognitive development. *Psychological Review* Vol 88, No 3, pp 197-227

Keil F C 1989 *Concepts, kinds and cognitive development.* Cambridge MA: Bradford Books

Keil F 1990 Constraints on constraints: Surveying the epigenetic landscape. *Cognitive Science*, Vol 14, pp 135-168

Keil F 1992 The origins of an autonomous biology. In M Gunnar, M Maratos (Eds) *Modularity and constraints in language and cognition* Lawrence Erlbaum: New Jersey

Lakoff G 1987 *Women, Fire and Dangerous Things* Chicago University Press: Chicago

Lakoff G and Johnson M 1981 *Metaphors We Live By* Chicago University Press: Chicago

Mariani M-C & Ogborn J 1991 Towards an ontology of commonsense reasoning. *International Journal of Science Education* Vol 13, No 1 pp 69-85

Mariani M-C & Ogborn J 1995 The ontology of physical events. *International Journal of Science Education* Vol 17, No 5, pp 643-661.

Medin D, Woo-Kyoung A, Bettger J, Florian J, Goldstone R, Lassaline M, Markman A, Rubinstein J and Wisniewski E 1990. Safe takeoffs - Soft landings. *Cognitive Science,* Vol 14,.pp 169-178

Ogborn J 1985 Understanding students' understandings: an example from dynamics. *European Journal of Science Education* , Vol 7, No 2 pp 141-150

Piaget J. & Garcia, R. 1987. *Vers une Logique des Significations* Geneva: Murionde. (translated 1991, *Toward a Logic of Meaning* Lawrence Erlbaum: New Jersey).

Rosch E and Lloyd B 1978 *Cognition and Categorisation* Lawrence Erlbaum: New Jersey

Simons D, Keil F C 1995 An abstract to concrete shift in the development of biological thought: the insides story. *Cognition,* Vol 56, pp 129-163.

Spelke E 1990 Principles of object perception. *Cognitive Science,* Vol 14, pp 29-56

Appendix 2

Description of and results from tasks

This appendix amplifies the account of tasks and specific results from them given in the section **Method: 2 Task development and specific results** in the body of the Report.

Imaginative Transformations
Imaginative denial of rules (Topsy Turvy World)

In this generative task, nineteen 6 - 7 year old children and six of 13 - 14 years old were asked to imagine a world in which everything is 'topsy turvy'. They are asked to imagine carrying out a number of familiar actions, but in a world where everything is the opposite, in every imaginable way, of everything in the everyday world. They had to think of the ways in which things might be 'topsy turvy'. Four familiar actions were used as scenarios:

- Making tea;
- Diving into a swimming pool from a spring board;
- Playing football;
- Flying a kite.

Time required prevented the younger children from considering every scenario; the majority gave accounts for the first two.

Analysis focused on inferring schemes underlying attempts to 'invert' events or actions, and their interactions. For example, in 'making tea' the 'up-down' scheme may be reversed; as a result a number of associated schemes are affected, notably falling, support and containment. Equally interesting are schemes which resist inversion: for example a container retains its 'inside-outside' scheme. Rigidity and containment go together, defining boundaries. In the 'diving' scenario again the up-down' scheme is reversed, but now calls in question the nature of water in the pool-container; one solution is to alter the fluid nature of the water into something more rigid, rather than imagining water 'contained upside down'. The two examples show how the context can determine the way in which individuals put schemes together into packages. In doing so, schemes veer towards conservatism; not allowing too much change; nor allowing reasoning about the impossible. For example, there were no instances of objects being transformed into spaces or vice-versa; the existence of 'before and after' sequences was retained; there were always cause- effect relations. In other words, the basic Kantian schemes or dimensions remained unchanged.

Imaginative constructions (Lonely Giant)

This generative task required children to imagine constructing an entity (e.g. a car) from more or less unsuitable materials (e.g. bricks, paper, boxes, trees) so that these materials had to be transformed in imagination. We expected this to let us see how objects and materials were schematised.

Five 6-7 year-olds and six 13-14 year-olds were interviewed. The interview scenario proposed an island, with a range of resources shown in pictures on cards: trees, water (a river, a lake), bricks, boxes, paper, plastic, old engines, together with tools: knife, hammer, saw, string and rope, glue. Older children were asked to imagine themselves on the island. For the younger children, the island was presented as the home of a lonely giant who had to make things for himself.

Results for 'making a car' were those analysed. A clear difference appeared between younger and older children. Younger children worked mainly from the available materials, focusing on a particular resource (e.g. paper bag, plastic) and suggesting how it could be used for a specific component (e.g. a seat, seat-belts), constructing the car ad hoc. They were influenced by appearance - e.g. metal is shiny so use that for a roof. By contrast, older children used a more generic notion of 'a car' - uniformly a body, wheels, engine - and set about constructing these. They thought in functional schemes - e.g. a body contains so look for a container. Realising all the functions they needed often proved difficult - for instance steering or braking - but they kept the functions in mind and improvised a variety of (often implausible) solutions with the materials to hand.

This task highlights some basic questions about abstraction, similar to those raised by Simons and Keil (1995). Older children worked with an explicit generic (and in that special sense abstract) notion of a car. Younger children limited attention to particular resources and their potential, but in a sense also thought abstractly though implicitly - to make a seat from a paper bag is to treat both as containers ("You could sit in it"). Probably their reasoning is best characterised as transductive - going from one particular to another via some feature they share.

Transforming an object into another (Object transformation) [Tsatsarelis]

The generative task had eight sub-tasks. In each children were given pairs of objects and asked to imagine transforming one object, say a duck, into the other, say an eagle. The researcher drew each suggested change and then asked whether there was anything else to change, finally asking whether the original object had been transformed into the new object or whether there was still something wrong with it. The sample consisted of 38 Greek children on average 11.8 years old.

The objects were of two ontological categories: natural living kinds (e.g. human, eagle) and artefacts (e.g. aeroplane, toy car). In four sub-tasks the pair of objects belonged to the same ontological category, (e.g. duck to eagle); in the other four they belonged to different categories, (e.g. bird to toy car). In two of the latter sub-tasks the objects shared clear common functional schemes (e.g. eagle to aeroplane; both able to fly) while in the other two they did not (e.g. bird to toy car).

Transformations between objects of the same category were all easy (an 'easy' change is one where children finally agreed that their transformation was successful). In the four sub-tasks using objects in different categories, half the children were asked to transform natural objects into artefacts and the other half the reverse. In general children found it easier to move from natural objects to artefacts than the reverse. Transformations of objects in different categories were always easier when they shared functional schemes; this also eased the more difficult transformations from artefact to natural object.

Children used four different sorts of transformational device: adding, modifying, removing and keeping constant particular features. More changes were attempted in tasks where there were common functional schemes; it was only in these that the 'keep constant' device was used. The devices of 'modifying' and 'removing' features tended to be more heavily used in the (difficult) transformations from artefact to natural kind.

Other research (Keil 1989) suggests that transformations between different ontological kinds are not possible. These data show that, while difficult, children can make them, and that making them is helped if the objects have schemes in common, which help 'bridge' the objects. Such schemes construct of boundaries between categories.

Transforming one event into another (Event analogies) [Tsatsarelis]

This task focused on the use of schemes in the context of taught school scientific knowledge. Children were presented with pictures taken from school science text books of processes of scientific interest: the flow of current in an electric circuit lighting a lamp when a switch is closed, pushing a heavy object, the expansion and sagging of metal power lines when warm, the flow of heat from a hot object to a cooler one. After being asked what they could see in the pictures, they were asked to suggest an analogy - "It is like...". 39 Greek children, average age 11.6, took part.

The children were in general able to produce analogies, some of them surprising (the battery is like a carton of orange juice with a straw - you can get something to come out of it). In the analysis, elements of analogies could be characterised as being physical objects (e.g. switch), non-object-like entities (e.g. light) and processes (e.g. go along a wire). Counts were made of the numbers of times each kind of element was or was not associated with each other kind, in the analogies produced.

The analogies produced had distinctive schematic structures. The presence of some elements of analogies statistically predicts the presence or absence of others, in ways corresponding to broad schematic patterns. At the most general level of analysis, elements of analogies were seen to divide on two dimensions: cause vs. effect and static vs. dynamic. At a more specific level, broad possible types of structure could be seen, such as 'a source/container provides something which can flow, if acted on dynamically'. The existence of such patterns underlying the analogies suggests that they are not simply ad hoc fragments of knowledge pieced together, but reflect a number of basic schemes. Their interaction with scientific knowledge appears to have left them with broad pictures of what is going on in a number of processes, not simply with surface facts.

Thinking of something as...

Fitting schemes to counter-expectations (Anomalies)

This generative task was developed in order to examine schemes that pupils use when encountering objects that behave in unexpected way thus violating pupils' expectations.

We had three anomalous objects:
- "Potty putty" or silicone gel, which shows viscous flow but also bounces elastically and if hit hard is brittle.
- a toy gyroscope which spins stably resting on its point.
- an executive toy in which a magnetic roller rests horizontally in mid air and will spin without appreciable slowing down.

Seven 14 year old children were interviewed individually about two objects each. They were asked to make predictions about the objects' behaviour, to test predictions, and to provide explanations and in the light of what they had seen.

A given object evokes a package of schemes, e.g. movement, rigidity and support. The behaviour of these anomalous objects violated such schemes, allowing us to see how they interact in packages. For example, potty putty is soft and soft things cannot be broken, so 'hardness' became an issue, nor did it squash flat when hit, thus 'force' was problematic. Both the rolling magnet and the gyroscope violated the 'support' scheme, the gyroscope the 'balance' scheme, and the rolling magnet the 'force' scheme ("magnets can pull or push but they cannot cause spinning!"). We observed a dynamic process of scheme fitting and revision. Action on the objects was crucial to produce revision of scheme fitting.

Dimensions of schemes (Ontologies)

This task, using a questionnaire format with simple yes/no answers was designed to complement small scale interview tasks which require much interpretation of responses. It uses a method adapted from Mariani and Ogborn (1991, 1995).

The aim was to discover whether hypothesised schemes could be recovered from patterns of responses to simple ontological questions, and if so, how a variety of physical entities were understood in terms of such schemes. Five putative schemes were chosen: 'object in motion', 'source of motion', 'support', 'container/carrier', and 'fluid flow'. 22 questions thought to be diagnostic of these schemes were created - for example "Does it hold something up?"; "Does it stop something falling?" for 'support'. The questions were asked about 22 exemplars, 12 chosen to be relatively unproblematic to characterise in these respects (e.g. a car, a table) and 10 chosen to be problematic (e.g. music, the mind). The 'unproblematic' exemplars were tried on two very different samples: a group of adults and a group of 13-14 year olds. The 'problematic' exemplars were tried on a comparable group of 13-14 year olds. Numbers in groups varied from 22 to 30.

The analysis looked for factors and clusters in a matrix of questions treated as variables and exemplars as cases, data in a matrix cell being the proportion of 'yes' responses to one question about one exemplar (e.g. Does it make sense to say that the mind stops something falling?"). In each case simple factor and cluster structures could be identified.

The results suggest that all three groups, differing in age and in the exemplars they were given, use a broadly similar set of schemes, close to but not always identical with those hypothesised in the design. A not wholly anticipated scheme emerged, which we term 'fillable space' (e.g. the surface of a table). Although the factors and clusters extracted for different groups varied somewhat, they were all always composed of combinations of the same elements: movement, action, container, carrier, support, barrier, space, fluid. The 'problematic' exemplars all had intelligible (but not a priori predictable) descriptions in terms of these elements. For example the mind was seen as a container and carrier; music as rather fluid-like.

We conclude, from the relative stability of schemes across a wide variety of exemplars at two very distinct ages, that something like such schemes can be taken to 'exist' in participant's thinking about the physical world, and that their literal and metaphorical uses are closely related.

The task in its generic form offers a way of getting at the use of schemes, and at differences between people in their use of schemes, able to be used in a wide range of domains and relatively easy to apply. The value of results does, however, clearly depend critically on the analysis of supposed schemes into a full range of diagnostic questions, and on an appropriate and varied selection of exemplars.

Instances of something like...
Application of Schemes (Prototypes)

This selection task aimed to examine the extent to which children identify schemes in a variety of contexts. Four target schemes - support, flow, containment and floating - were chosen. Four prompt pictures embodied these target-schemes (e.g. flow - liquid flowing from a bottle into a glass). Nine different contexts were drawn as pictures:

- astronauts working in space,
- a narrow-boat being pulled along a canal,
- a bath overflowing,
- a woman pushing a baby's pram also containing shopping,
- a loaded lorry going over a bridge, over fast flowing stream;

- a waiter serving customers wine in a restaurant,
- children jumping on a trampoline,
- bird carrying a branch flying against wind above river,
- trapeze artists performing in a circus.

There were twenty-nine 6-7 year olds, and six 13-14 year olds. A child was first shown a target-scheme picture and agreement obtained about the scheme shown. For the nine pictures in turn, they were asked to choose a good example of the target-scheme, and then asked for further examples in that picture. Finally they chose the best example found from all the pictures.

There are three scenarios where 'support' is not found: children-jumping-on-trampoline, astronauts-working-in-space, narrow-boat-pulled-laboriously-by-shoreman. The first two are obvious for the young children but the narrow-boat is unexpected. However for young children 'support' is probably secondary to the activity of the man-pulling-laboriously-boat. For older children only the astronaut scenario has no 'support' examples. Such examples are used differently in the two groups. For younger children examples are either obvious, waiter-tray, or local, bath-legs. Older children mention less obvious examples with objects, such as chairs, tightropes and trampolines, supporting people.

The trampoline, the circus, and the bird-flying-against-wind scenarios take place in fairly open spaces, major actors being humans or animals, not objects. For young children 'containment' is only seen in a local sense, cups-containing-drinks. This is reversed for the older children where these spaces now 'contain' people but space suits no longer 'contain' people, the case for young children. Here we see how with use the notion of 'containment' transforms itself and becomes more generic.

Woman-pushing-pram, children-jumping-on-trampoline and astronauts-working-in-space are scenarios which all imply doing something and making an effort. Older children argued that 'flow' needed to be an effortless, natural movement that was continuous and so ruled out these three scenarios. Younger children were more attached to salience - to smoothness of flowing, so including the last two examples but not the first. Again we see how a scheme has transformed itself in use.

Broadening the notion of doing something and making an effort to that of activity then we have: woman-pushing-pram, waiter-serving-people, bird-flying-against-wind, people-performing-in-circus, children-jumping-on-trampoline (astronauts-working-in-space excluded since for most children they 'float'). Interviews revealed that for young children 'floating' implied non-volitional movement without direction nor any real speed, involving partial support, thus excluding 'float' from the just listed scenarios. Older children modified their use of 'float', suggesting propulsion in some kinds of floating, as illustrated in last three earlier listed scenarios. Thus 'float' is being used in a more general sense and in a greater range of contexts.

Fit of examples to scientific ideas (Examples) [Tsatsarelis]

This study further investigated the notion of abstraction and generalisation - a necessary aspect of schemes - in the context of school science. It had two stages. In the first, examples of ideas related to school science were presented to 11-12 year old children. The ideas were: 'what goes up must come down', 'light travels in straight lines', and 'heat goes from hot to cold'. Three examples were given for each idea, one chosen to be a 'good' example, one a parallel but probably less obvious example, and one a potential counter-example. Children were asked to say whether the examples were good or not, and why, and whether seeing the example might change the idea for them.

Examples tended to be judged good on grounds of salience or immediacy (an effect is large or happens quickly). Counter examples tended to be dealt with either by specialisation (light travels in straight lines but is still bent by a lens) or by over-ride principles (a flying bird will come down in the end, but because it chooses to). Parallel examples sometimes lead to a wider generalisation.

In the second stage, a questionnaire study presented first a picture of a scene - for example a boy up a tree - and then the same scene but now described as an example of a scientific idea (e.g. potential energy). Six such ideas were used, each with two different picture-examples (e.g. replacing the boy up a tree by a pot on a balcony). All examples were taken from current text books used (in Greece) for children of 11-12 years. Each case - example and idea - was responded to by a group of between 30 and 40 children aged 11-12. They were asked about the elements of the picture before and after presenting it as an example of an idea. About each element, children were asked whether it could act by itself, block something, force something, contain something, be inside something, change shape, support something, and whether it is like an invisible idea of something. The questions are similar to those in the task Dimensions of Schemes.

A small number of interpretable factors could be extracted. For example, in the case of the two examples of potential energy they related to autonomous action, static barrier/support, and particular or generic location. Factors for the six ideas were not identical, but were intelligibly related. Factor scores provide a characterisation of the elements of the examples in terms of schemes. For example, 'potential energy' comes out as invisible, not specifically located, able autonomously to cause movement.

A notable result, stemming from the unusual design of asking questions about a scene before and after presenting it as an example of something, is the 'constraining' effect of seeing something as an example. In cases, frequencies of 'yes' answers to the range of questions asked became more differentiated, a few rising sharply and several dropping away. Seeing something as an example focuses attention on specific features, and inhibits thinking more broadly about possibilities.

Thinking metaphorically with physical schemes
Schemes as metaphors (Metaphors)

Concrete reasoning schemes form the basis of metaphors and analogies about the non-physical world. For each of the schemes support, flow, containment, block, float and balance we generated complementary pairs of scenarios; for one the scheme seemed able serve as a metaphor, for the other it appeared not to. For example:

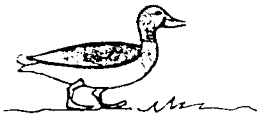
> *Possible example of 'containment':*
> When Peter heard that he'd been selected to play the lead in the school play, he just smiled even though he was very excited. Could you say that Peter contained his feelings?
> *Non-example of 'containment':*
> When Peter heard that he'd been selected to play the lead in the school play, he jumped up and down excitedly. Could you say that Peter contained his feelings?

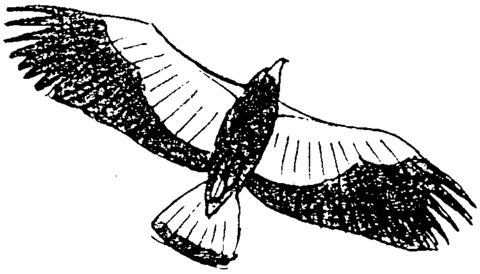
The non-examples each violated what we took to be one criterial aspect of the scheme (e.g. proximity for support). There were two such pairs for each scheme (three for 'balance'); making 13 pairs, 26 in all. We interviewed individually six 14 year old females. Each was read aloud two scenarios for a scheme, a positive form from one pair and a non-example from another. Most responded to all schemes (total 67 responses). They were asked to judge whether each was an instance or non-instance of the scheme, and to explain why.

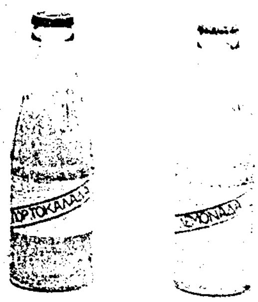
Agreement with positive and non-examples was generally very good. Disagreements arose mainly with 'flow' and 'float'. In both cases metaphors were taken not to apply on grounds relating to broad schematic features: e.g. that 'flow' should be continuous and not too rapid - discrete or rapid changes were disqualified. 'Floating' was sometimes rejected as a metaphor on rather literal grounds - that insubstantial things like ideas can't float.

On the whole, children could marshal arguments for or against the applicability of schemes to non-physical scenarios. Their arguments showed clearly the scheme-related expectations necessary for the scheme to be used metaphorically.

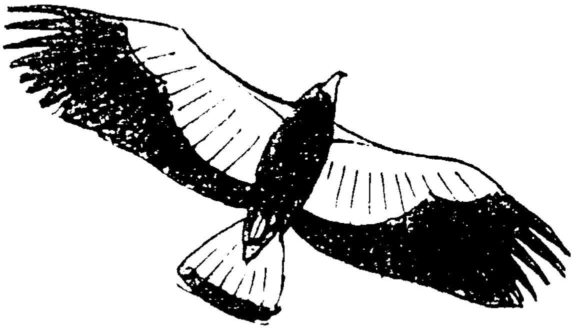
Appendix 4.1 Exploratory study: Transformations of objects (pictures)

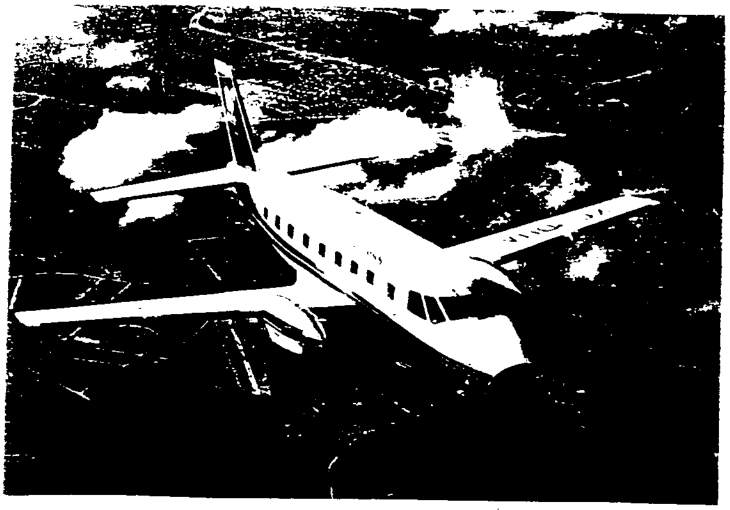


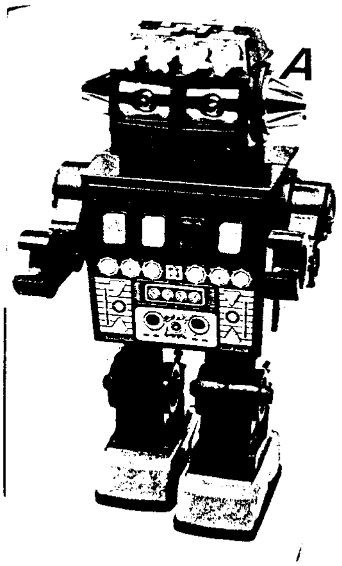


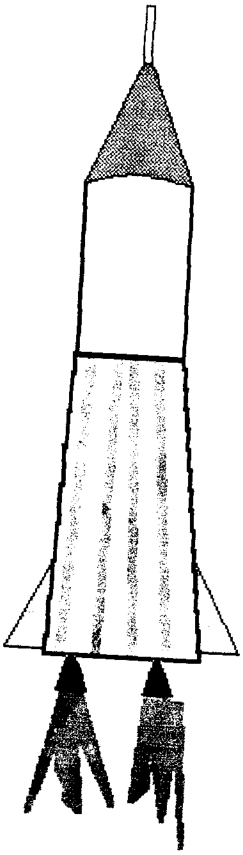


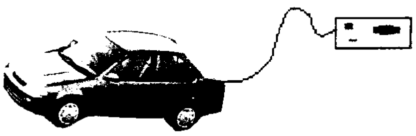
Appendix 4.2 Main study: Transformations of objects (pictures)











Appendix 4.3 Statistical significant differences for ontological categories

```
RESPONSE  by  TASK          (NATURAL -> ARTIFACT)

                  TASK                              Page 1 of 1
              Count   |
              Exp Val |Eagle-Ae Human-Ro Bird-Car Human-Ro
              Std Res |roplane  bot               cket        Row
                      |       1 |      2 |      3 |      4 | Total
RESPONSE      --------+---------+--------+--------+--------+
                 1    |    16   |   16   |    8   |    9   |    49
  Yes                 |   12.3  |  12.3  |  12.3  |  12.3  |  64.5%
                      |    1.1  |   1.1  |  -1.2  |   -.9  |
                      +---------+--------+--------+--------+
                 2    |     3   |    3   |   11   |   10   |    27
  No                  |    6.8  |   6.8  |   6.8  |   6.8  |  35.5%
                      |   -1.4  |  -1.4  |   1.6  |   1.3  |
                      +---------+--------+--------+--------+
               Column      19        19       19       19       76
                Total    25.0%     25.0%    25.0%    25.0%   100.0%

      Chi-Square                    Value             DF              Significance
--------------------             -----------         ----             ------------

Pearson                           13.04006             3                  .00455
Likelihood Ratio                  13.59869             3                  .00351
Mantel-Haenszel test for           9.53515             1                  .00202
      linear association

Minimum Expected Frequency -      6.750


                                                                       Approximate
     Statistic                     Value        ASE1       Val/ASE0   Significance
--------------------             ---------    --------     --------   ------------

Phi                                .41422                                .00455 *1
Cramer's V                         .41422                                .00455 *1

*1 Pearson chi-square probability
```

```
RESPONSE  by  TASK (ARTIFACT -> NATURAL)

                  TASKR                             Page 1 of 1
              Count   |
              Exp Val |Aeroplan Robot-Hu Bird-Car Human-Ro
              Std Res |e-Eagle  man               cket        Row
                      |       1 |      2 |      3 |      4 | Total
RESPONSR      --------+---------+--------+--------+--------+
                 1    |    15   |   14   |    2   |    2   |    33
  Yes                 |    8.3  |   8.3  |   8.3  |   8.3  |  43.4%
                      |    2.4  |   2.0  |  -2.2  |  -2.2  |
                      +---------+--------+--------+--------+
                 2    |     4   |    5   |   17   |   17   |    43
  No                  |   10.8  |  10.8  |  10.8  |  10.8  |  56.6%
                      |   -2.1  |  -1.8  |   1.9  |   1.9  |
                      +---------+--------+--------+--------+
               Column      19        19       19       19       76
                Total    25.0%     25.0%    25.0%    25.0%   100.0%

      Chi-Square                    Value             DF              Significance
--------------------             -----------         ----             ------------

Pearson                           33.58140             3                  .00000
Likelihood Ratio                  37.00756             3                  .00000
Mantel-Haenszel test for          27.49471             1                  .00000
      linear association

Minimum Expected Frequency -      8.250


                                                                       Approximate
     Statistic                     Value        ASE1       Val/ASE0   Significance
--------------------             ---------    --------     --------   ------------

Phi                                .66473                                .00000 *1
Cramer's V                         .66473                                .00000 *1

*1 Pearson chi-square probability
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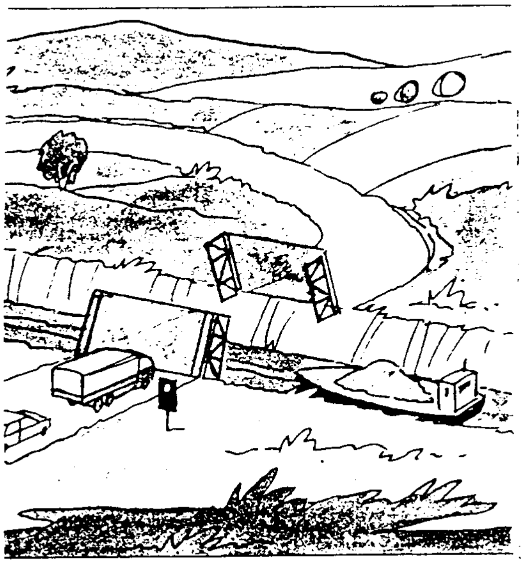
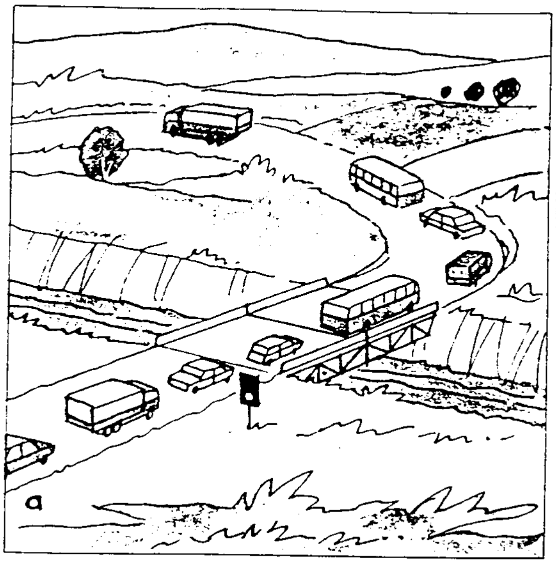
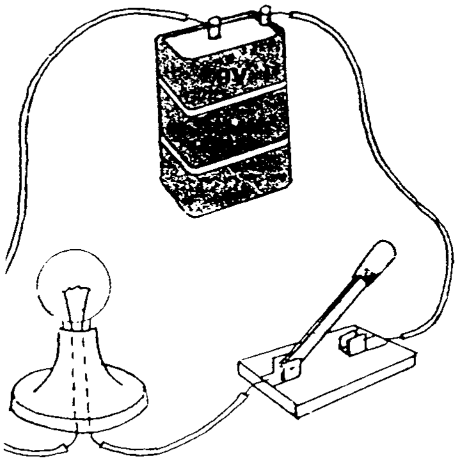
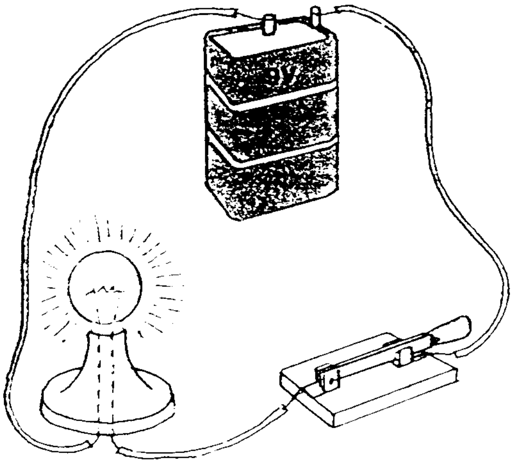
Appendix 5.1 Exploratory study: Transformations of events (pictures)

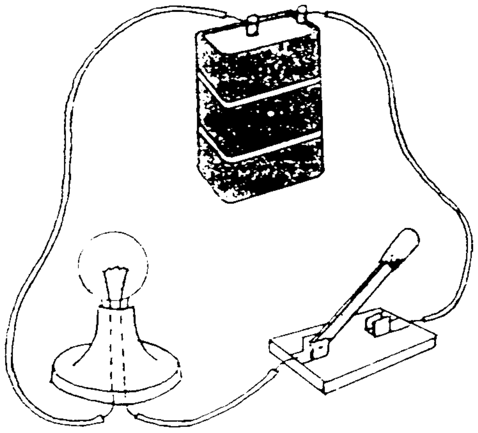


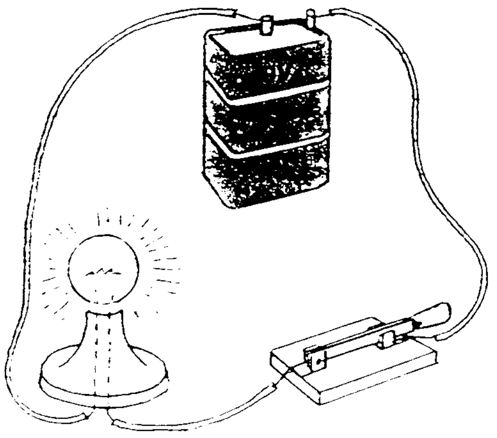






Appendix 5.2 Main study: Transformations of events (pictures)





Appendix 6.1 The questionnaire of the 3rd study in Greek

ΠΑΡΑΔΕΙΓΜΑΤΑ

Αυτό το ερωτηματολόγιο αφορά τα **διάφορα** παραδείγματα που μπορεί κάποιος να χρησιμοποιήσει, για να καταλάβει ή να εξηγήσει μια ιδέα στη Φυσική. Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις την ίδια ιδέα, χρησιμοποιώντας διάφορα παραδείγματα. Να θυμάσαι, οτι **δεν υπάρχουν σωστές ή λάθος απαντήσεις**, απλά γράψε αυτό που **εσύ** σκέφτεσαι.

Η Ιδέα

Σ' ένα βιβλίο Φυσικής, βρήκαμε την παρακάτω ιδέα:

> ***"Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια"***

ΠΡΟΣΕΞΕ ! ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Το δικό σου Παράδειγμα

Σκέψου ένα παράδειγμα για την παραπάνω ιδέα. Γράψε με λίγα λόγια το παράδειγμά σου.

....

....

....

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ
ΤΟ ΔΙΚΟ ΣΟΥ ΠΑΡΑΔΕΙΓΜΑ ΓΙ' ΑΥΤΗ ΤΗΝ ΙΔΕΑ.

Τι **μπορούν να κάνουν** διάφορα πράγματα;

Τέσσερα πράγματα που γνωρίζεις καλά, είναι:
ένα παιδί,
ο αέρας,
το έδαφος,
ένα δέντρο,
και ίσως γνωρίζεις κάτι για τη *Δυναμική Ενέργεια.*
Εμείς θέλουμε να μάθουμε τι νομίζεις εσύ, οτι όλα αυτα τα πράγματα **μπορουν να κάνουν**.

*Βάλε ένα √ σ' όλα αυτά που μπορούν να κάνουν...

Ποιο (ή ποια) απ' αυτά τα πέντε μπορεί να κάνει κάτι .... ↓	ΑΕΡΑΣ	ΠΑΙΔΙ	ΔΕΝΤΡΟ	ΕΔΑΦΟΣ	ΔΥΝΑΜΙΚΗ ΕΝΕΡΓΕΙΑ
όπως ένας φράκτης, ή ένας τοίχος μπορεί;	☐	☐	☐	☐	☐
όπως ένα στήριγμα για τα άλλα πράγματα, όπως ένα τραπέζι, μπορεί;	☐	☐	☐	☐	☐
όπως ένα δοχείο μπορεί να κάνει, να περιέχει κάτι άλλο μέσα του;	☐	☐	☐	☐	☐
όπως ένα σκληρό-στερεό πράγμα μπορεί να κάνει, να έχει αμέταβλητο σχήμα;	☐	☐	☐	☐	☐
όπως να βρίσκεται μεσα σε κάτι άλλο;	☐	☐	☐	☐	☐
όπως να κάνει τα πράγματα να κινούνται;	☐	☐	☐	☐	☐
όπως να κινείται ή να σταματά όταν αυτό θέλει;	☐	☐	☐	☐	☐
όπως να υπάρχει, χωρίς να το βλέπουμε ή να μπορούμε να το αγγίξουμε;	☐	☐	☐	☐	☐

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο "ερευνώ το φυσικό κόσμο". Να θυμάσαι οτι **δεν υπάρχουν σωστές ή λάθος απαντήσεις**, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

"Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια"

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:

Το παιδί ψηλά στο δέντρο έχει Δυναμική Ενέργεια

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

Κοίταξε πάλι το παράδειγμα του βιβλίου **"ένα παιδί ψηλά στο δέντρο"** *για την ιδέα* **"Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια".**

Σκέψου **τι κάνουν** *τα διάφορα πράγματα (παιδί, δέντρο, ...)* **σ' αυτό το παράδειγμα.**

Ποια απ' αυτά τα πέντε, σ'αυτό το παράδειγμα...

	ΑΕΡΑΣ	ΠΑΙΔΙ	ΔΥΝΑΜΙΚΗ ΕΝΕΡΓΕΙΑ	ΕΔΑΦΟΣ	ΔΕΝΤΡΟ
είναι όπως ένας φράχτης ή ένας τοίχος;	☐	☐	☐	☐	☐
είναι όπως ένα στήριγμα για τα άλλα πράγματα, όπως ένα τραπέζι;	☐	☐	☐	☐	☐
είναι όπως ένα δοχείο που μπορεί να έχει κάτι μέσα του;	☐	☐	☐	☐	☐
είναι όπως κάτι σκληρό με αμετάβλητο σχήμα, ένα στερεό πραγμά;	☐	☐	☐	☐	☐
είναι όπως κάτι που βρίσκεται μέσα σε κάτι άλλο;	☐	☐	☐	☐	☐
είναι όπως κάτι που κάνει τα πράγματα να κινούνται;	☐	☐	☐	☐	☐
είναι όπως κάτι που κινείται ή σταματά όταν αυτό θέλει;	☐	☐	☐	☐	☐
είναι όπως κάτι που δεν μπορούμε να δούμε, ή να αγγίξουμε, αλλά υπάρχει;	☐	☐	☐	☐	☐

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο "ερευνώ το φυσικό κόσμο". Να θυμάσαι οτι δεν υπάρχουν σωστές ή λάθος απαντήσεις, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

"Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια"

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:


Οι γλάστρες ψηλά στο μπαλκόνι έχουν Δυναμική Ενέργεια

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

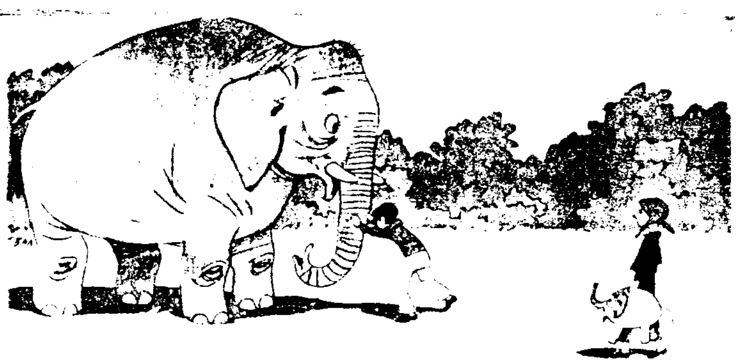
Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***"Όσο μεγαλύτερη μάζα έχουν τα σώματα τόσο δυσκολότερα μπορούν να κινηθούν, γιατί παρουσιάζουν μεγάλη αδράνεια"***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα:**



Ένα παιδί είναι εύκολο να μετακινήσει ένα μικρό παιχνίδι-ελέφαντα, αλλά είναι πολύ δυσκολότερο να κάνει να κινηθεί ένας μεγάλος ελέφαντας.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

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Η Ιδέα

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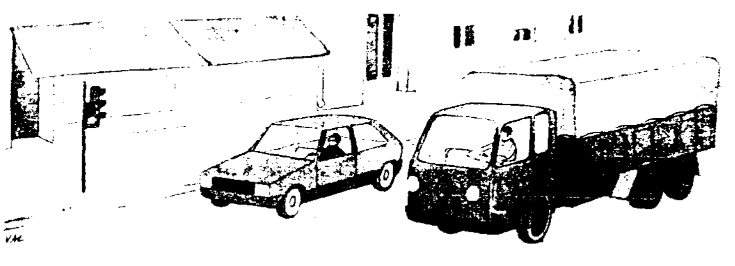
"Όσο μεγαλύτερη μάζα έχουν τα σώματα τόσο δυσκολότερα μπορούν να κινηθούν, γιατί παρουσιάζουν μεγάλη αδράνεια"

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:



Το φορτηγό που έχει μεγαλύτερη μάζα από το αυτοκίνητο, θα κινηθεί με μεγαλύτερη δυσκολία, και θα κινηθεί αργότερα από το αυτοκίνητο.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

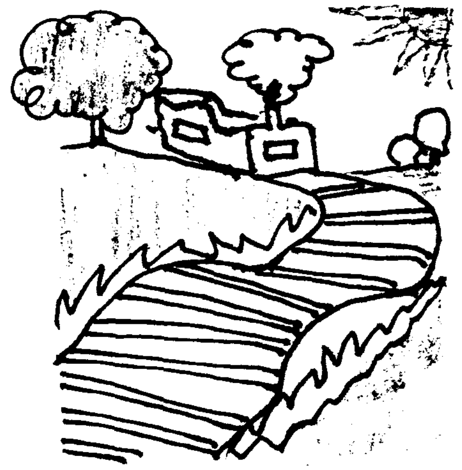
Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***"Όλα σχεδόν τα στερεά σώματα, όταν θερμαίνονται διαστέλλονται. Το φαινόμενο αυτό το λέμε διαστολή"***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το παράδειγμα:



Το καλοκαίρι οι σιδηροδρομικές γραμμές, εξαιτίας της μεγάλης θερμοκρασίας διαστέλλονται, και έτσι σχηματίζουν καμπύλες προς τα πάνω.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

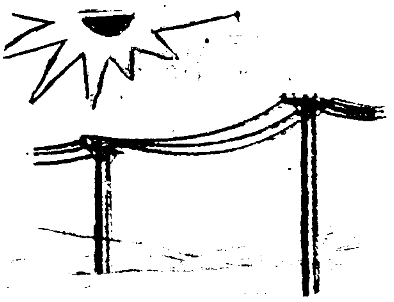
Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***“Όλα σχεδόν τα στερεά σώματα, όταν θερμαίνονται διαστέλονται. Το φαινόμενο αυτό το λέμε διαστολή”***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο “ερευνώ το φυσικό κόσμο”, βρήκαμε για την παραπάνω ιδέα το παράδειγμα:



Το καλοκαίρι τα ηλεκτροφόρα σύρματα της ΔΕΗ μεταξύ δύο στύλων, εξαιτίας της μεγάλης θερμοκρασίας διαστέλλονται, και έτσι είναι χαλαρά.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

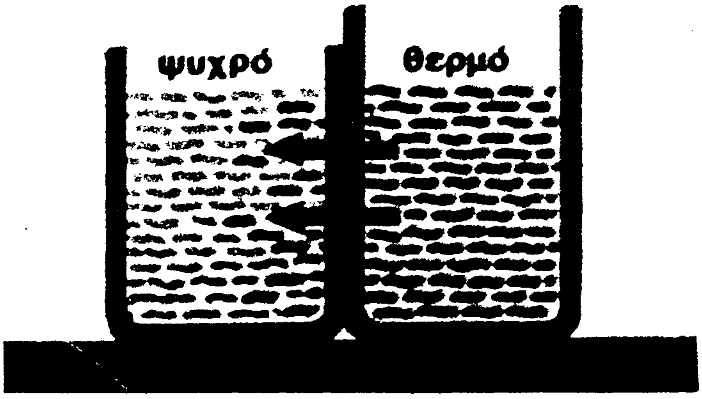
Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***"Όταν δύο σώματα βρίσκονται σε επαφή, η θερμότητα μεταδίδεται πάντοτε από το θερμότερο σώμα προς το ψυχρότερο."***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:



Τοποθετούμε δύο δοχεία με νερό (το ένα περιέχει ζεστό και το άλλο κρύο νερό) σε επαφή. Η θερμότητα μεταδίδεται από το ζεστό προς το κρύο σώμα.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

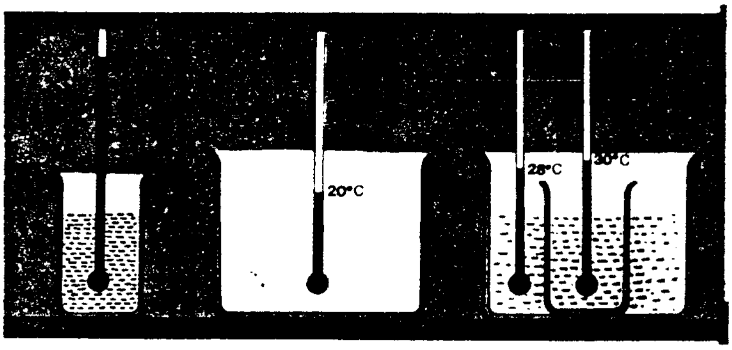
Σ’ ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

“Όταν δύο σώματα βρίσκονται σε επαφή, η θερμότητα μεταδίδεται πάντοτε από το θερμότερο σώμα προς το ψυχρότερο.”

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο “ερευνώ το φυσικό κόσμο”, βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:



Τοποθετούμε ένα μεταλλικό δοχείο με ζεστό νερό, μέσα σ’ ένα άλλο μεγαλύτερο δοχείο που περιέχει κρύο νερό. Η θερμότητα μεταδίδεται από το ζεστό προς το κρύο σώμα.

ΓΥΡΝΑ ΠΙΣΩ Σ’ ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

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Η Ιδέα

Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***"Σε κάθε σώμα που βρίσκεται μέσα σ' ένα υγρό εξασκείται από το υγρό μια δύναμη από κάτω προς τα πάνω. Τη δύναμη αυτή τη λέμε Άνωση"***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:

Δύσκολα μπορείς να βυθίσεις σε νερό μια μπάλα. Αν την αφήσεις ελεύθερη, αυτή θα πεταχτεί επάνω, εξαιτίας της Άνωσης που δέχεται από το νερό.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο “ερευνώ το φυσικό κόσμο”. Να θυμάσαι οτι **δεν υπάρχουν σωστές ή λάθος απαντήσεις**, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

Σ' ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***“Σε κάθε σώμα που βρίσκεται μέσα σ' ένα υγρό εξασκείται από το υγρό μια δύναμη από κάτω προς τα πάνω. Τη δύναμη αυτή τη λέμε Άνωση”***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο “ερευνώ το φυσικό κόσμο”, βρήκαμε για την παραπάνω ιδέα το **παράδειγμα**:

Ένα σώμα φαίνεται πιο ελαφρύ μέσα στο νερό απ' ό,τι έξω απ' αυτό, εξαιτίας της άνωσης προς τα πάνω, που δέχεται το σώμα από το νερό.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο "ερευνώ το φυσικό κόσμο". Να θυμάσαι οτι δεν υπάρχουν σωστές ή λάθος απαντήσεις, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

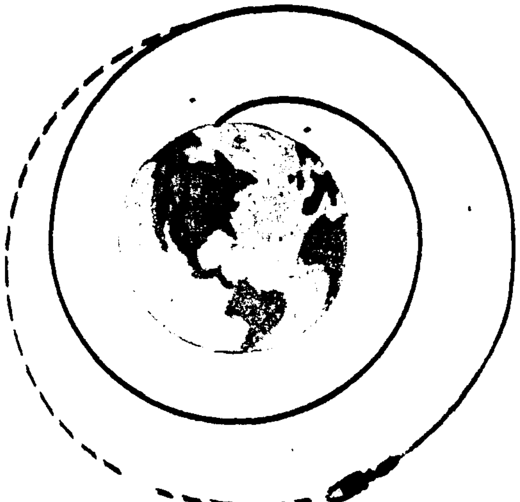
Η παρακάτω ιδέα, περιγράφει κάτι που συνήθως συμβαίνει στην καθημερινή μας ζωή:

"Όταν τα σώματα πάνε επάνω, πρέπει να έρθουν κάτω (στο έδαφος)"

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε **ένα παράδειγμα που δεν ταιριάζει** με την παραπάνω ιδέα:



Ο πύραυλος εκτοξεύεται από τη γη με ταχύτητα που ξεπερνά τα 40.000 χιλιόμετρα την ώρα. Έτσι υπερνικά την έλξη της γης και δεν επιστρέφει σ' αυτή

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο "ερευνώ το φυσικό κόσμο". Να θυμάσαι οτι **δεν υπάρχουν σωστές ή λάθος απαντήσεις**, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

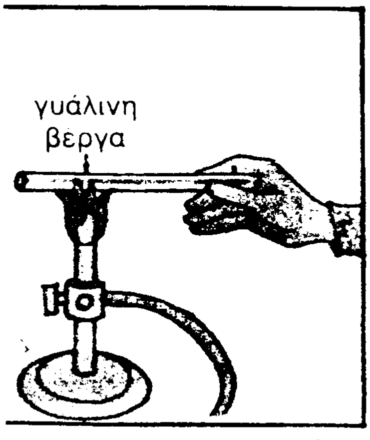
Η παρακάτω ιδέα, περιγράφει κάτι που συνήθως συμβαίνει στην καθημερινή μας ζωή:

"Πολλά σώματα αφήνουν τη θερμότητα να περνά εύκολα μέσα από τη μάζα τους"

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο "ερευνώ το φυσικό κόσμο", βρήκαμε **ένα παράδειγμα που δεν ταιριάζει** με την παραπάνω ιδέα:



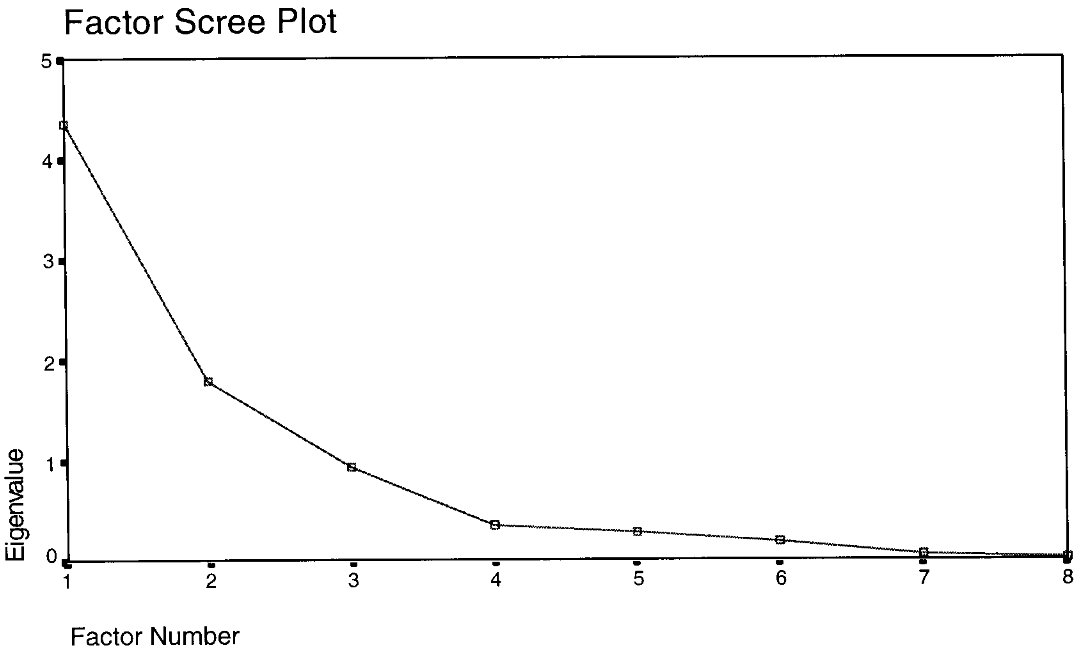
Μπορούμε να κρατήσουμε την άκρη της γυάλινης βέργας χωρίς να καούμε,, γιατί η γυάλινη βέργα δεν αφήνει τη θερμότητα να περνά εύκολα μέσα από τη μάζα της.

ΓΥΡΝΑ ΠΙΣΩ Σ' ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

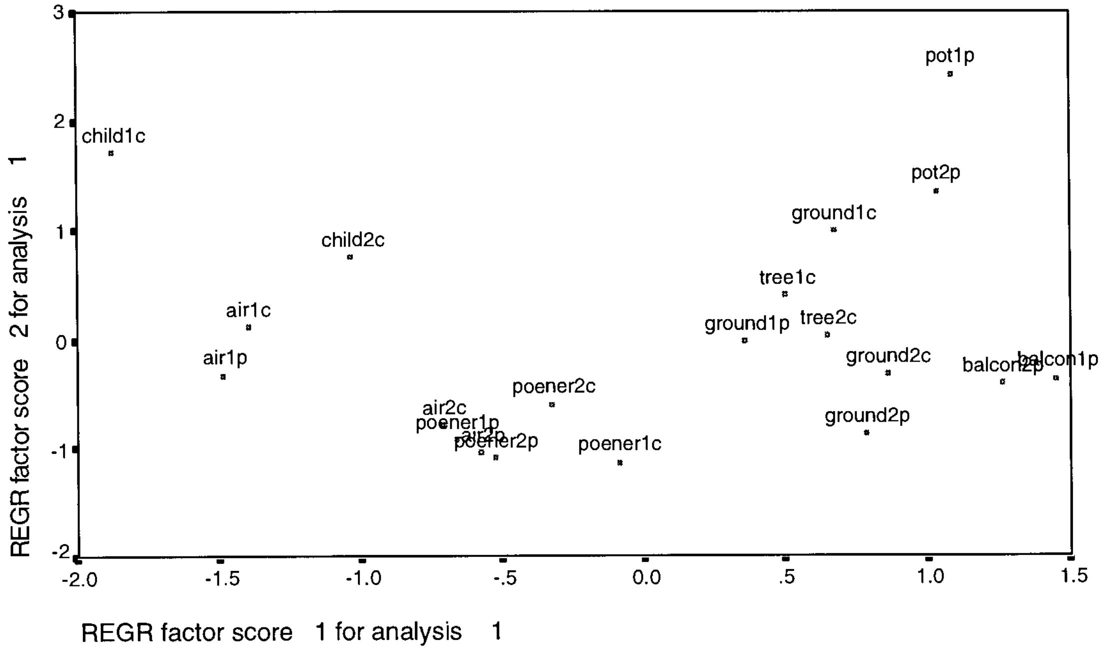
Appendix 6.2 Factor loadings and the factor scree plot for Potential Energy

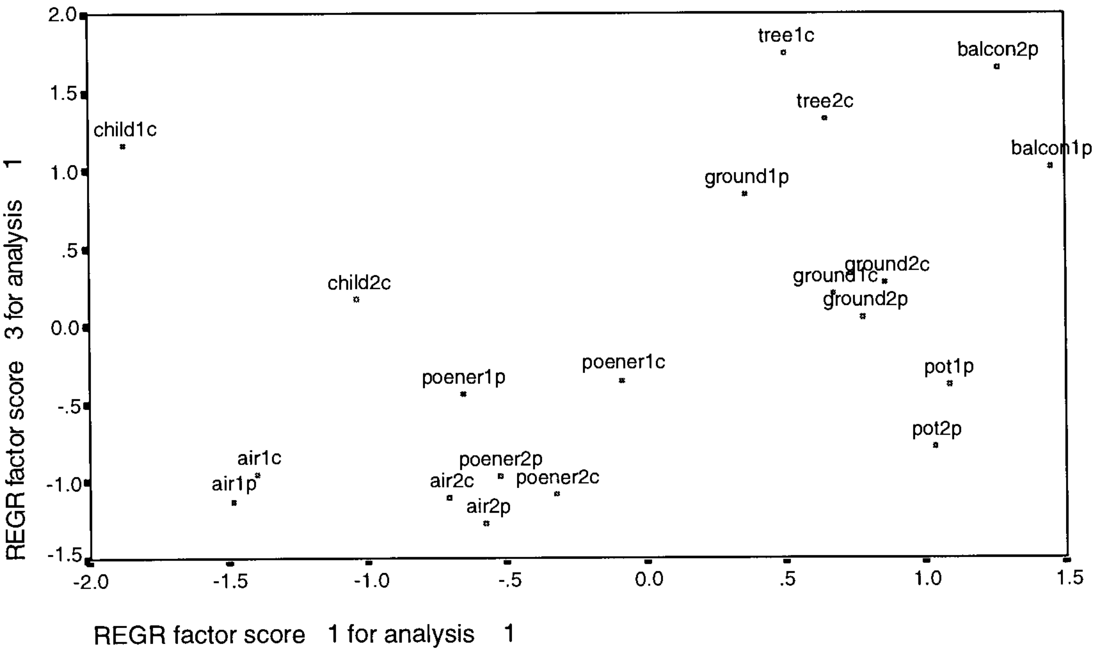
	Factor 1	Factor 2	Factor 3
Autonomy	**-.97899**	.11329	.07794
Force	**-.88949**	-.11855	-.12099
Container	.20856	**.90293**	.02084
Con.Subst	-.51099	**.84109**	-.09845
Rigidity	.35904	.48711	.40905
Barrier	-.16816	-.14655	**1.04217**
Support	.21468	.15370	**.78635**
Invisible E	-.39954	-.38858	-.48729

Sampling adequacy = .57774
Bartlett test = 130.62388, Significance = .00000



Appendix 6.3 Plots of factors for Potential Energy





Appendix 6.4 Potential energy: Percentages of 'yes' responses for each scheme

		Example with the 'pot'	Mc Nemar Test	Example with the 'Child'	Mc Nemar Test
Scientific entity	Barrier	V23-07	0.03	V24- 6	0.03
	Support	29-10		V41-21	0.04
	Container	3- 3		12-15	
	Rigidity	8- 3		15- 6	
	Cont. thing	32-21		*18-32	0.06
	Force	66-66		53-50	
	Autonomous	32-40		18-29	
	Invisible ent.	74-66		82-79	
Protagonist	Barrier	5- 5		44-26	
	Support	V61-.26	0.001	V82-29	0.000
	Container	92-79		V68-41	0.004
	Rigidity	V89-53	0.000	56-50	
	Cont. thing	V61-39	0.04	V65-44	0.02
	Force	3- 3		V88-61	0.02
	Autonomous	0- 8		V97-79	0.03
	Invisible ent.	0- 3		6- 6	
Structure-related objects	Barrier	37-24		21-26	
	Support	V87-39	0.000	V85-59	0.01
	Container	V55.16	0.000	V82-35	0.000
	Rigidity	37-29		41-38	
	Cont. thing	16- 8		32-15	
	Force	V45-21	0.004	35-24	
	Autonomous	21-13		6- 6	
	Invisible ent.	3- 3		6- 0	
Surface-related objects	Barrier	*29- 58	0.001	V76-53	0.008
	Support	95-89		85-88	
	Container	18-32		50-44	
	Rigidity	92-84		53-56	
	Cont. thing	8- 8		V41-24	0.03
	Force	3- 0		* 3-21	0.03
	Autonomous	0- 0		3- 9	
	Invisible ent.	0- 0		6- 0	
Irrelevant objects	Barrier	3- 0		15- 9	
	Support	11- 0		6- 3	
	Container	18-11		27-18	
	Rigidity	13- 5		29-12	
	Cont. thing	V37-16	0.02	V50-24	0.004
	Force	V95-71	0.004	V97-68	0.006
	Autonomous	V71-47	0.004	50-47	
	Invisible ent.	V89-74	0.03	94-91	

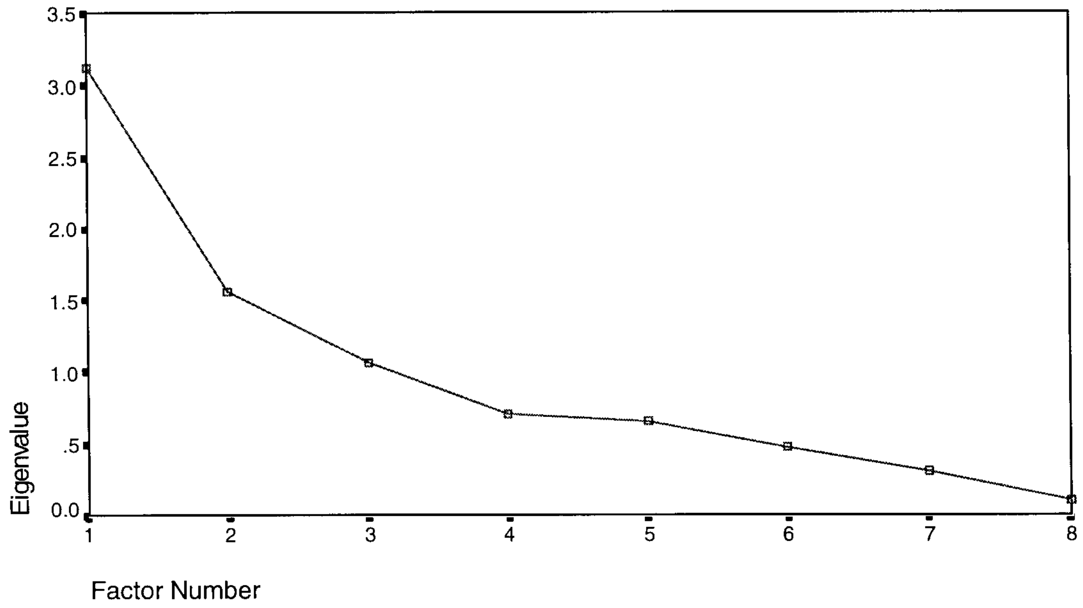
The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

Appendix 6.5 Factor loadings and the factor scree plot for Expansion

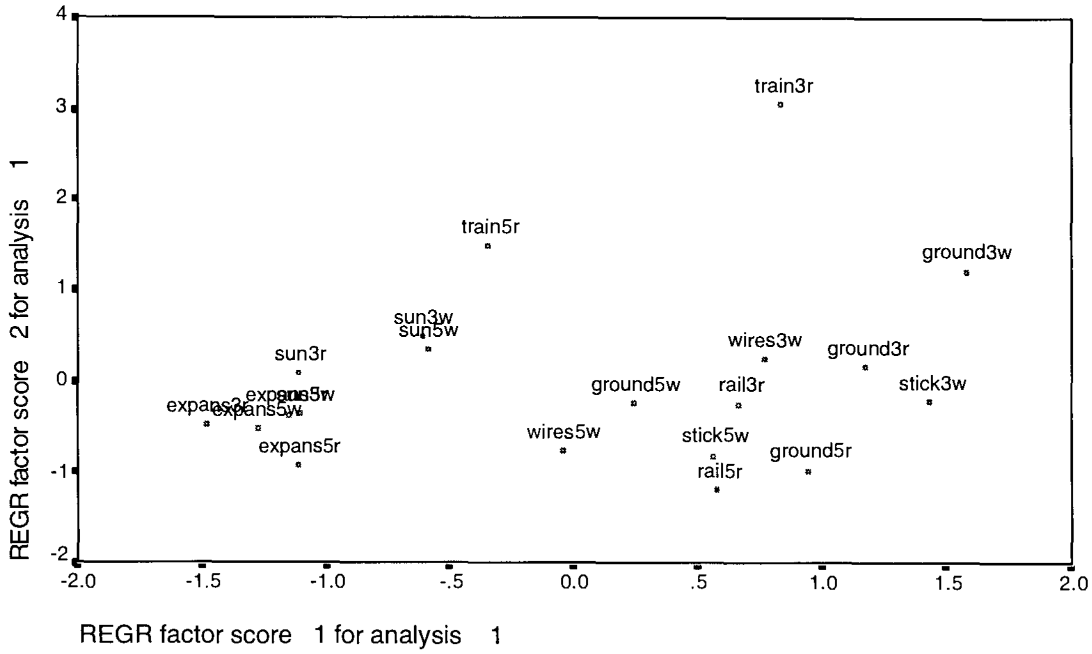
	Factor 1	Factor 2	Factor 3
SUPPORT	**.93418**	-.10160	-.16259
ENTITY	**-.86069**	.00851	-.14807
BARRIER	**.85065**	-.07621	.18353
CON.SUBS	.48051	.45012	-.09110
AUTONO	-.18737	**.88395**	.12596
CONTAINE	.40764	.56223	-.22914
RIGIDITY	.14699	.30864	**.78853**
FORCE	.02217	.40814	-.69694

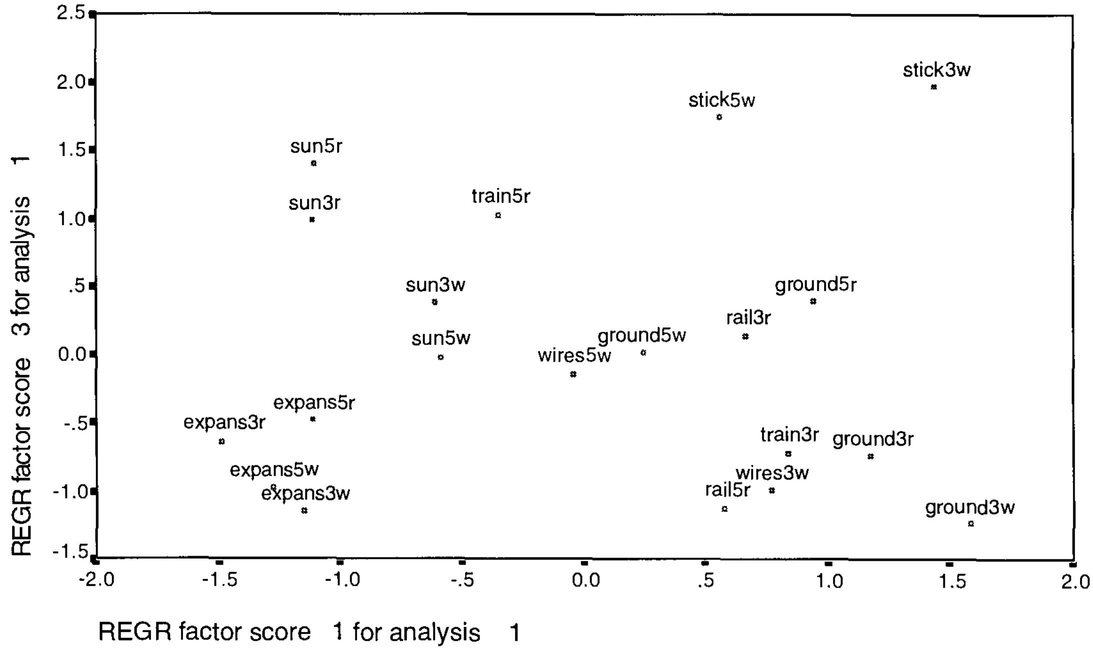
Sampling adequacy = .53665
Bartlett test = 50.64959, Significance = .00547

Factor Scree Plot



Appendix 6.6 Plots of factors for Expansion





Appendix 6.7 Expansion: Percentages of 'yes' responses for each scheme

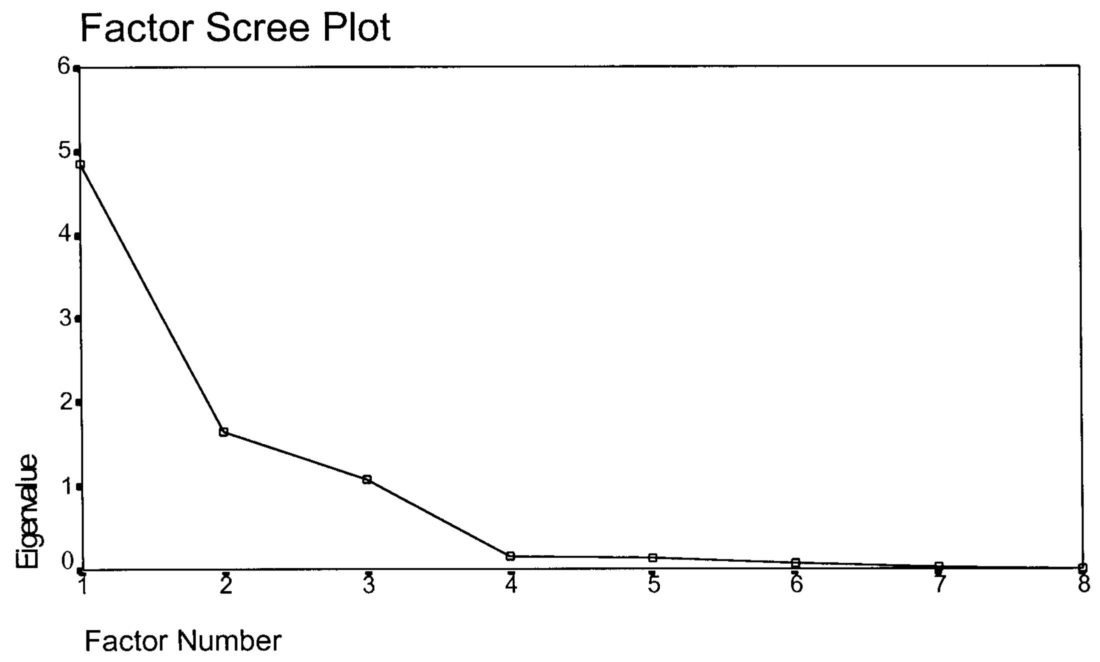
		Example with the 'railway'	Mc Nemar Test	Example with the 'wires'	Mc Nemar Test
Scientific entity	Barrier	9- 3		10- 0	
	Support	0- 6		8- 3	
	Container	6- 0		3- 3	
	Rigidity	15- 6		5- 5	
	Cont. thing	6- 6		13- 8	
	Force	36-24		45-40	
	Autonomous	9- 6		10-10	
	Invisible ent.	V67-36	0.002	55-43	
Protagonist	Barrier	18-27		13-13	
	Support	85-75		V58-13	0.000
	Container	3- 6		V55-35	0.008
	Rigidity	V67- 9	0.000	15- 8	
	Cont. thing	12- 3		V30-13	0.02
	Force	58-48		V33-10	0.004
	Autonomous	0- 0		3- 0	
	Invisible ent.	3- 0		3- 0	
Structure-related objects	Barrier	3- 0		10- 5	
	Support	0- 0		3- 3	
	Container	27-15		43-28	
	Rigidity	54-61		45-48	
	Cont. thing	6- 3		15-13	
	Force	18-12		*28-48	0.02
	Autonomous	12- 6		13- 8	
	Invisible ent.	42-33		33-20	
Surface-related objects	Barrier	30-18		V65-25	0.000
	Support	V55-27	0.01	*50-65	0.03
	Container	V73-30	0.000	10- 8	
	Rigidity	42-39		63-65	
	Cont. thing	V30- 6	0.007	V30-13	0.02
	Force	V70-21	0.000	3- 3	
	Autonomous	64-67		8- 0	
	Invisible ent.	3- 6		0- 5	
Irrelevant objects	Barrier	33-52		V38-20	0.02
	Support	V88-61	0.004	V90-48	0.000
	Container	V79-30	0.000	V78-25	0.000
	Rigidity	30-24		30-20	
	Cont. thing	9- 3		V33-13	0.02
	Force	V39-15	0.007	V55-20	0.005
	Autonomous	6- 6		15-18	
	Invisible ent.	6- 0		8- 5	

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

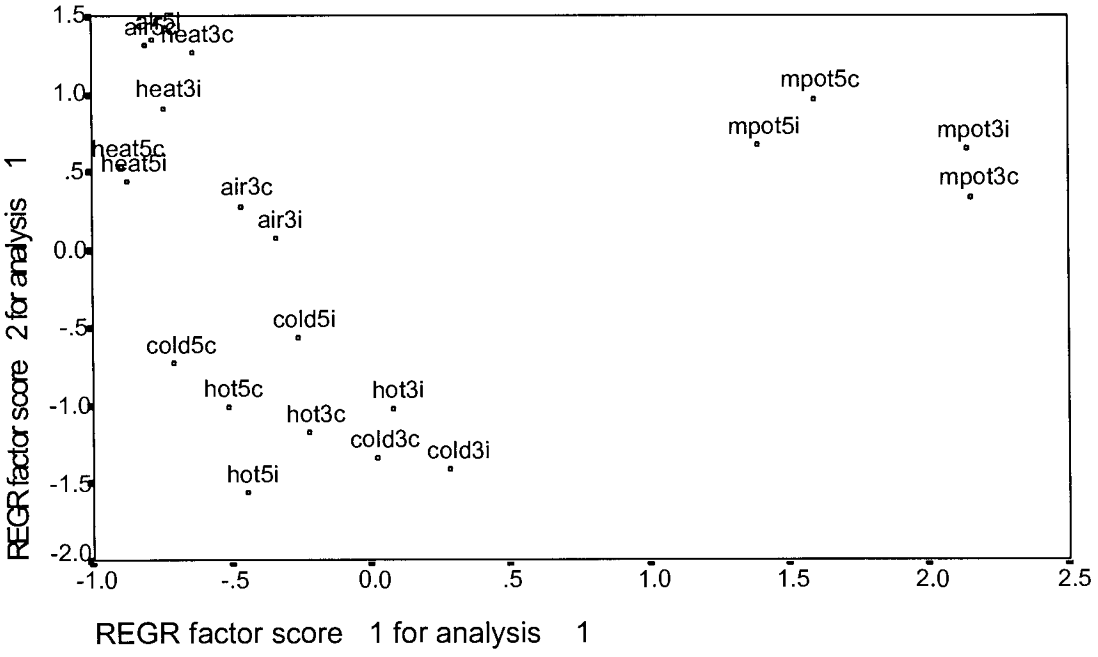
Appendix 6.8 Factor loadings and the factor scree plot for Thermal Equilibrium

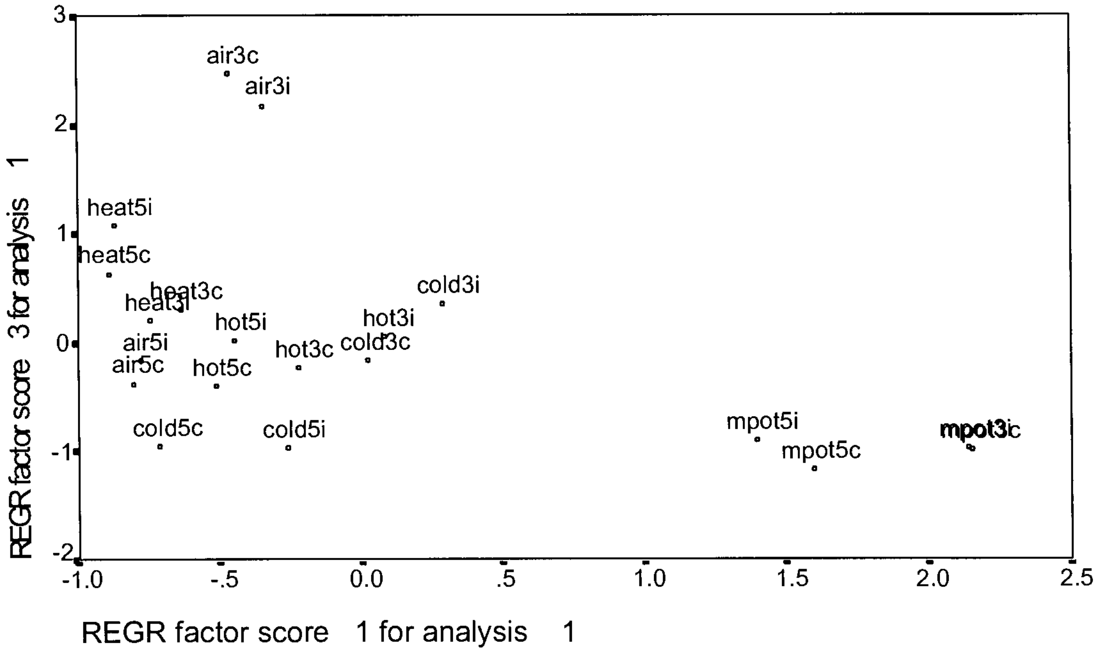
	Factor 1	Factor 2	Factor 3
SUPPORT	**1.01027**	-.03841	.10371
RIGIDITY	**.93020**	.14897	-.07508
CONTAINE	**.91714**	-.23890	-.08456
BARRIER	**.87975**	.31265	-.03406
CON.SUBS	-.17208	**-.92929**	.08533
AUTONOMO	-.03353	.16543	**.94326**
FORCE	.00730	-.39979	**.89635**
ENTITY	-.27435	.55695	**.62929**

Sampling adequacy = .68402
Bartlett test = 192.18099, Significance = .00000



Appendix 6.9 Plots of factors for Thermal Equilibrium





Appendix 6.10 Thermal Equilibrium: Percentages of 'yes' responses for each scheme

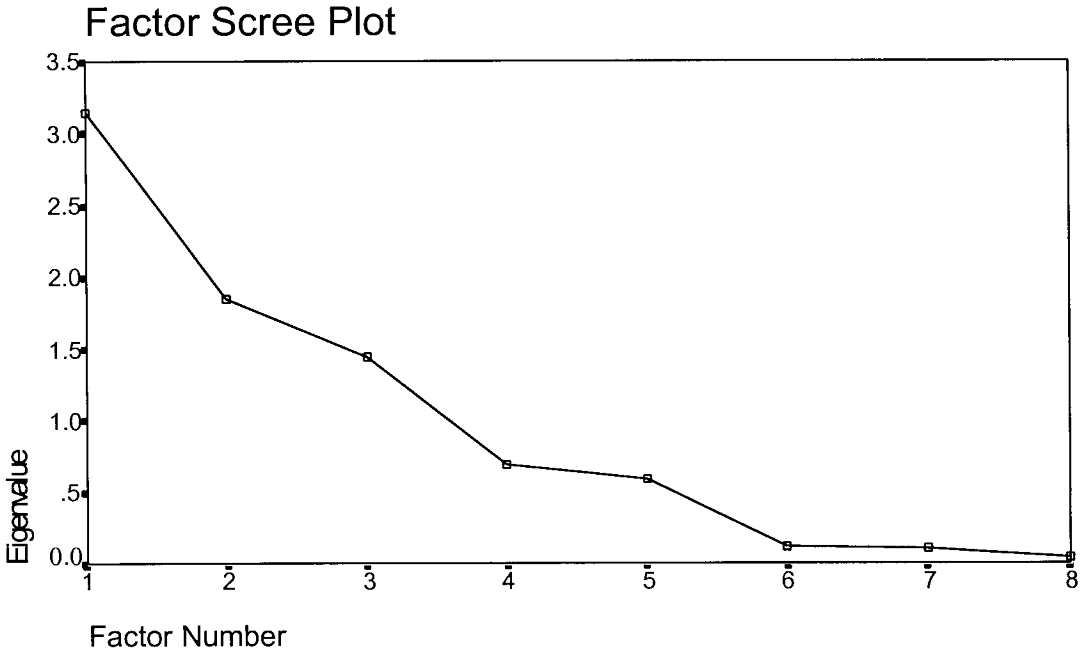
		Example: pots in 'contact'	Mc Nemar Test	Example:a pot inside another	Mc Nemar Test
Scientific entity	Barrier	8- 0		7- 0	
	Support	8- 0		3- 0	
	Container	8- 5		7- 3	
	Rigidity	8- 0		7- 0	
	Cont. thing	*25-53	0.003	47-53	
	Force	*28-50	0.01	*24-64	0.002
	Autonomous	33-28		27-40	
	Invisible ent.	78-88		83-87	
Protagonist	Barrier	0- 0		0- 0	
	Support	18- 5		V34- 0	0.002
	Container	38-28		47-37	
	Rigidity	10- 3		13- 3	
	Cont. thing	88-80		77-93	
	Force	45-48		V50-73	0.04
	Autonomous	13- 5		20- 7	
	Invisible ent.	0- 0		3- 0	
Structure-related objects	Barrier	3- 0		0- 0	
	Support	V25- 3	0.004	V40-10	0.01
	Container	V48-15	0.001	60-53	
	Rigidity	15- 3		13- 7	
	Cont. thing	93-88		87-70	
	Force	V48-10	0.000	V60- 7	0.005
	Autonomous	13- 5		V27- 7	0.03
	Invisible ent.	0- 0		0- 0	
Surface-related objects	Barrier	55-65		V73-47	0.008
	Support	V88-38	0.000	80-60	
	Container	93-98		83-77	
	Rigidity	V78-60	0.04	V73-50	0.04
	Cont. thing	V38-10	0.001	30-17	
	Force	0- 3		3-13	
	Autonomous	0- 0		0- 0	
	Invisible ent.	0- 0		0- 3	
Irrelevant objects	Barrier	5- 0		7- 3	
	Support	13- 5		17- 0	
	Container	18- 5		V23- 3	0.03
	Rigidity	3- 0		3- 3	
	Cont. thing	V56-10	0.000	V57- 7	0.000
	Force	V95-15	0.000	V97-23	0.000
	Autonomous	V80-20	0.000	V67-27	0.004
	Invisible ent.	V95-48	0.000	V87-43	0.002

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

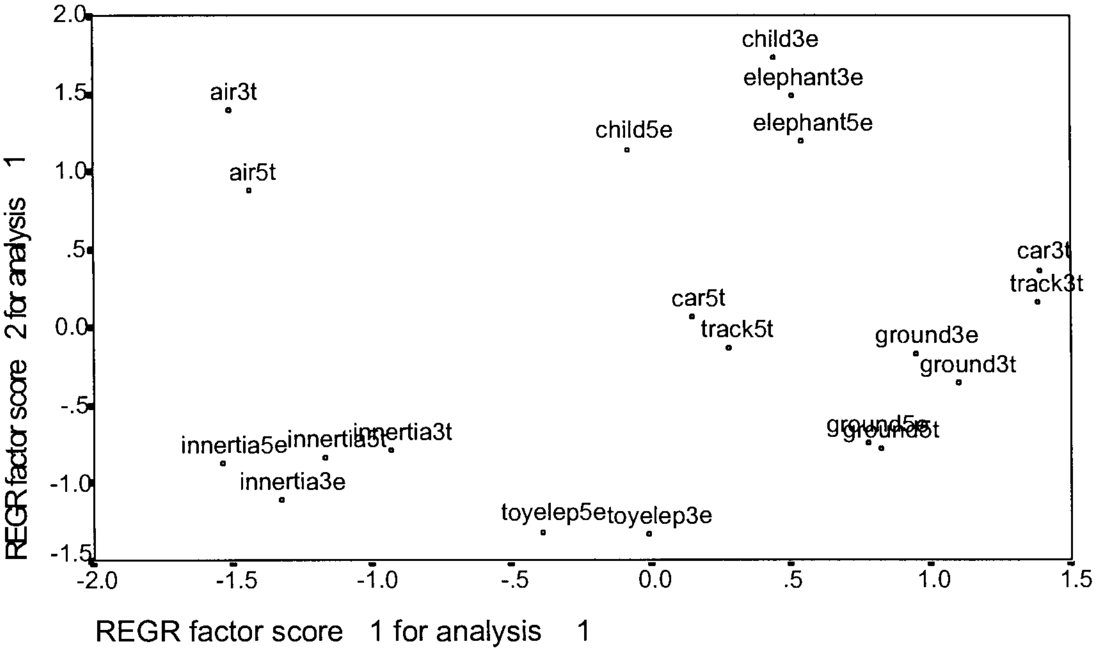
Appendix 6.11 Factor loadings and the factor scree plot for Inertia

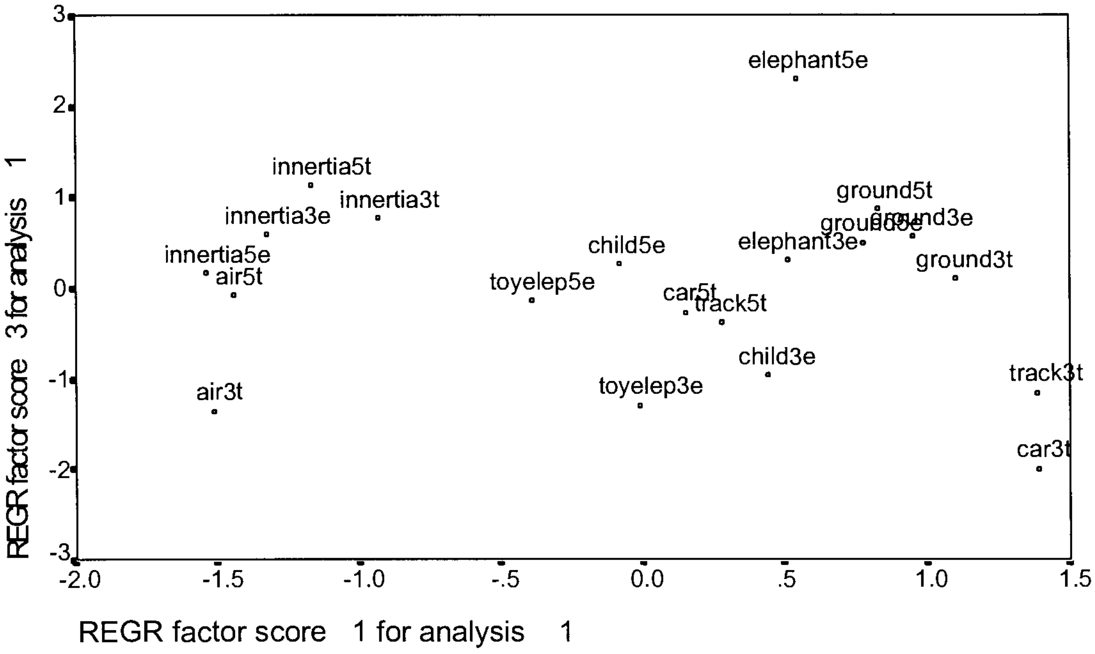
	Factor 1	Factor 2	Factor 3
ENTITY	**-.90853**	.06887	-.07320
RIGIDITY	**.88285**	.18295	.20258
SUPPORT	**.86607**	-.02185	-.07565
CONTAINE	**.67082**	-.05101	-.50426
FORCE	-.00250	**.97703**	.02296
AUTONO	.01247	**.95778**	-.09268
CONT.SUB	-.06421	.00232	**-.87083**
BARRIER	.00776	-.08493	**.76339**

Sampling adequacy = .43409
Bartlett test = 97.79008, Significance = .00000



Appendix 6.12 Plots of factors for Inertia





Appendix 6.13 Inertia: Percentages of 'yes' responses for each scheme

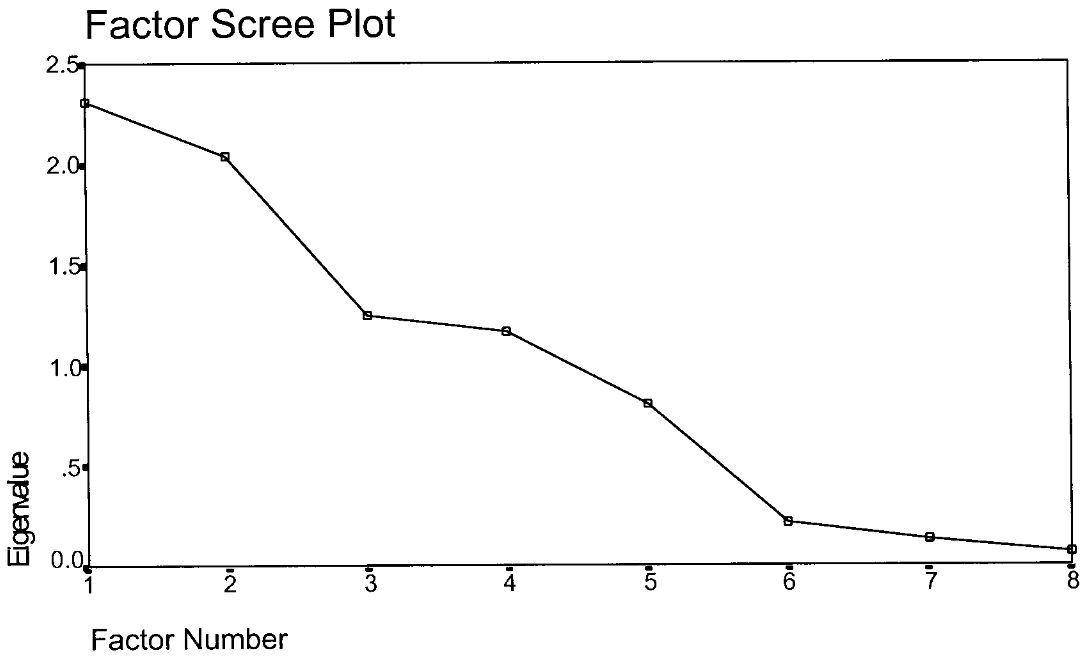
		The example with the 'car'	Mc Nemar Test	The example with the 'elephant'	Mc Nemar Test
Scientific entity	Barrier	55-68		39-26	
	Support	3- 8		0- 4	
	Container	11- 8		0- 9	
	Rigidity	16- 5		9- 4	
	Cont. thing	26-21		22-22	
	Force	16-26		9-27	
	Autonomous	18- 8		4- 0	
	Invisible ent.	50-58		*65-87	0.06
Protagonist	Barrier	18-21		*17-78	0.000
	Support	V84-45	0.000	V57-13	0.002
	Container	V92-37	0.000	26- 9	
	Rigidity	V44-26	0.04	*39-61	0.06
	Cont. thing	47-37		17- 9	
	Force	V50-37	0.06	74-83	
	Autonomous	45-40		V96-61	0.08
	Invisible ent.	0- 0		4- 0	
Structure-related objects	Barrier	13-16		0- 4	
	Support	V82-35	0.000	9- 0	
	Container	V10032	0.000	V35- 9	0.313
	Rigidity	V48-26	0.008	30-22	
	Cont. thing	V71-32	0.000	V57-26	0.04
	Force	58-42		0- 0	
	Autonomous	50-44		0- 0	
	Invisible ent.	3- 0		0- 0	
Surface-related objects	Barrier	*19-32	0.06	30-22	
	Support	V92-76	0.03	83-87	
	Container	V68-18	0.000	V61-27	0.007
	Rigidity	32-44		30-35	
	Cont. thing	8-13		4-13	
	Force	40-24		V56-26	0.02
	Autonomous	V24- 5	0.02	17- 9	
	Invisible ent.	0- 0		0- 0	
Irrelevant objects	Barrier	3-11		4- 0	
	Support	3- 0		V65-13	0.000
	Container	24-11		V35- 9	0.313
	Rigidity	5- 3		35-35	
	Cont. thing	V53-18	0.001	V48-13	0.008
	Force	V95-74	0.007	91-78	
	Autonomous	71-61		V96-65	0.02
	Invisible ent.	V84-68	0.03	4- 4	

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

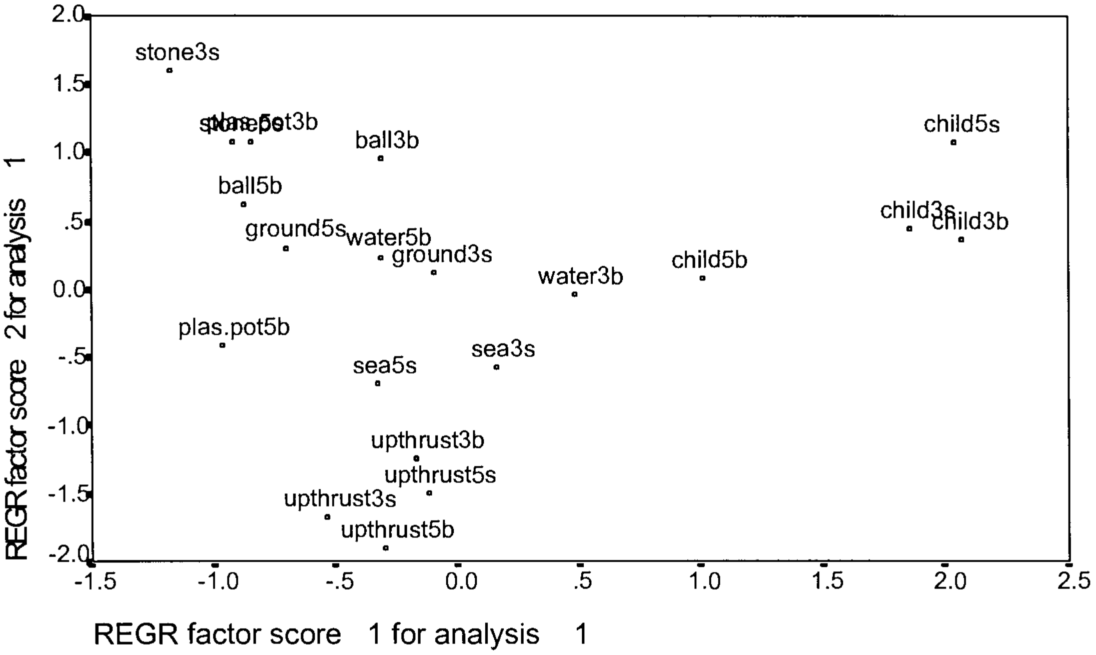
Appendix 6.14 Factor loadings and the factor scree plot for Upthrust

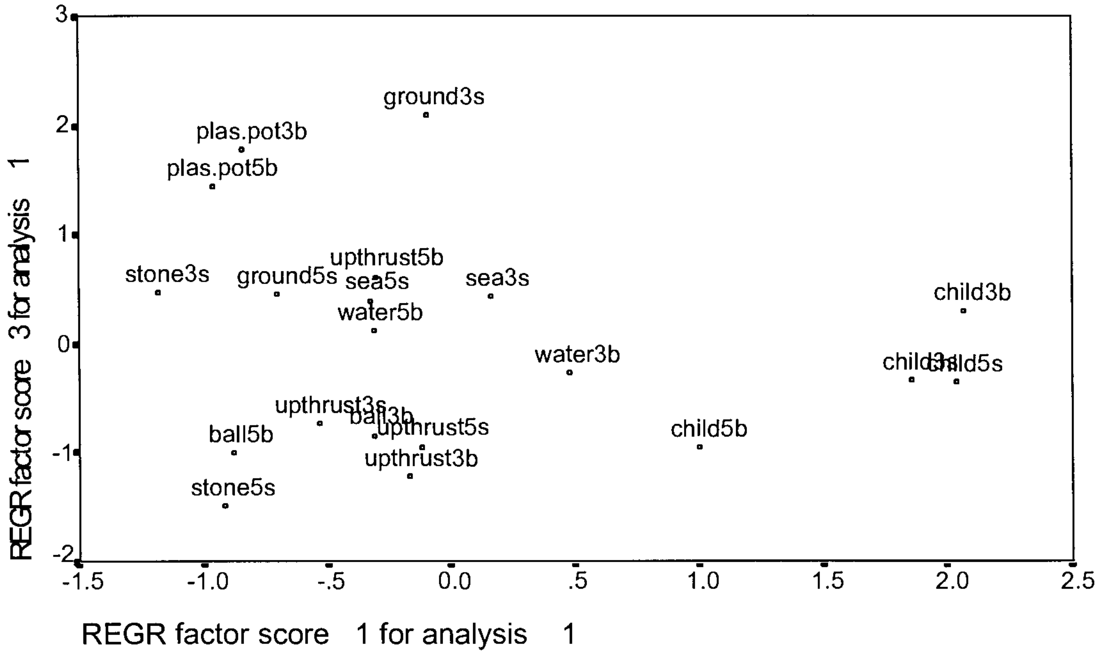
	Factor 1	Factor 2	Factor 3
FORCE	**.89936**	-.33970	-.04092
AUTONO	**.87522**	.22258	-.10035
ENTITY	-.09373	**-.80987**	-.24993
RIGIDITY	-.41576	**.80460**	.08461
CON.SUBS	.09116	**.61228**	-.19947
SUPPORT	.52012	.21804	**.78492**
BARRIER	-.36022	-.24890	**.68289**
CONTAINE	-.09100	.02319	**.50577**

Sampling adequacy = .39142
Bartlett test = 69.57655, Significance = .00002



Appendix 6.15 Plots of factors for Upthrust





Appendix 6.16 Upthrust: Percentages of 'yes' responses for each scheme

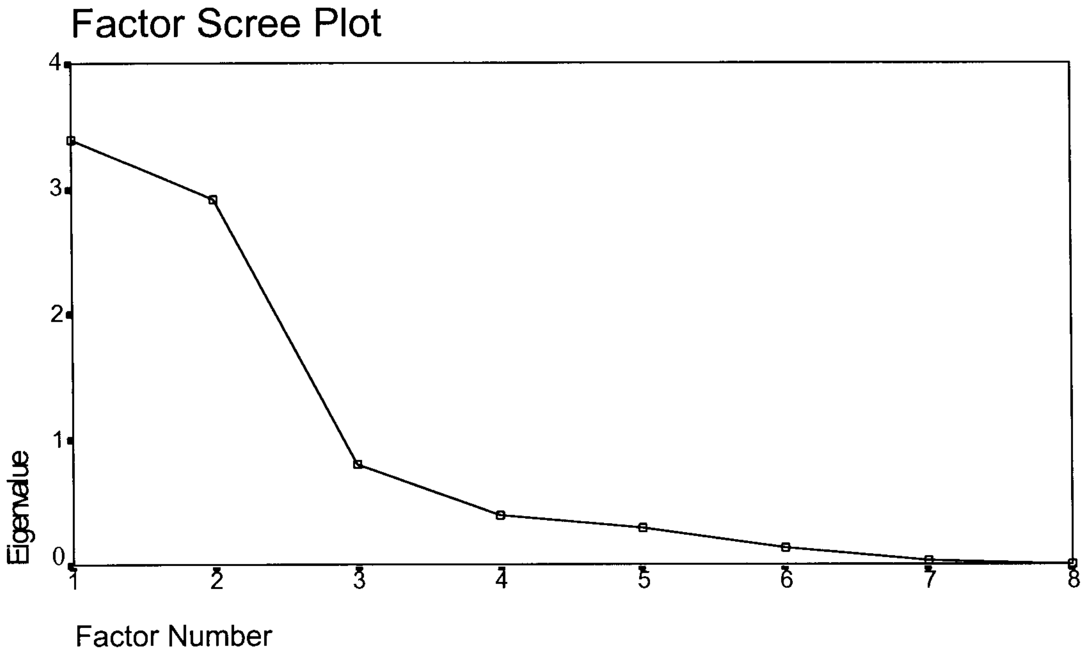
		The example with the 'ball'	Mc Nemar Test	The example with the 'stone'	Mc Nemar Test
Scientific entity	Barrier	*14--61	0.000	29-14	
	Support	*11-36	0.01	14-33	
	Container	11-17		19-10	
	Rigidity	19-11		4- 4	
	Cont. thing	14-17		19-33	
	Force	58-69		38-48	
	Autonomous	17- 3		10- 5	
	Invisible ent.	67-69		76-85	
Protagonist	Barrier	6- 6		V43- 5	0.007
	Support	14- 8		V52- 5	0.002
	Container	V61-33	0.02	14-14	
	Rigidity	36-42		V81-48	0.02
	Cont. thing	V81-33	0.000	67-57	
	Force	V33-11	0.02	5-10	
	Autonomous	19-11		5-10	
	Invisible ent.	6- 3		5- 0	
Structure-related objects	Barrier	*20-36	0.03	10-14	
	Support	31-36		38-24	
	Container	50-42		86-91	
	Rigidity	11-17		10- 5	
	Cont. thing	75-86		24-15	
	Force	V81-36	0.000	62-38	
	Autonomous	11- 6		5- 5	
	Invisible ent.	11-14		15-10	
Surface-related objects	Barrier	17- 6		5- 0	
	Support	V75-25	0.000	58-81	
	Container	V31-11	0.04	24-10	
	Rigidity	19-25		19-29	
	Cont. thing	V56- 8	0.000	*38-76	0.008
	Force	V94-64	0.001	81-86	
	Autonomous	92-81		95-81	
	Invisible ent.	11- 3		0- 5	
Irrelevant objects	Barrier	47-56		38-24	
	Support	V72-50	0.02	V86-52	0.02
	Container	V67-42	0.02	V67-24	0.004
	Rigidity	58-25		38-38	
	Cont. thing	V58-11	0.000	10-10	
	Force	8-11		V34- 5	0.03
	Autonomous	6- 0		15-10	
	Invisible ent.	0- 6		0- 0	

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

Appendix 6.17 Factor loadings and the factor scree plot for the transmission of heat

	Factor 1	Factor 2
Autonomy	**.93419**	-.27605
Force	**.93564**	.01461
Barrier	**.91059**	.05294
Support	.70639	.63415
Con.Subst	.47948	-.25396
Invisible E	-.02529	**-.94943**
Rigidity	-.19423	**.87541**
Container	-.12253	**.86082**

Sampling adequacy = .42424
Bartlett test = 57.64846, Significance = .00081



Transmission of heat: Percentages of 'yes' responses for each scheme

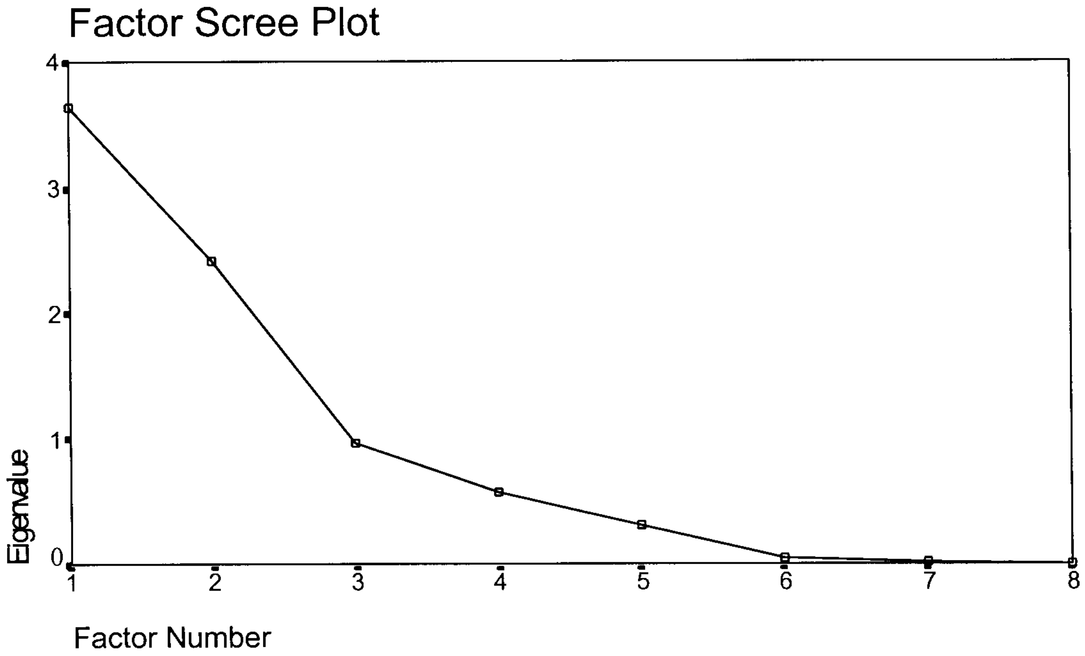
		The example with the 'glass'	Mc Nemar Test
Scientific entity	Barrier	5 - 5	
	Support	3 - 3	
	Container	11- 8	
	Rigidity	11- 8	
	Cont. thing	34- 29	
	Force	11- 16	
	Autonomous	29- 26	
	Invisible ent.	71- 79	
Protagonist	Barrier	0 - 8	
	Support	8 - 8	
	Container	32- 22	
	Rigidity	*47- 66	0.02
	Cont. thing	V53- 16	0.000
	Force	8- 58	
	Autonomous	8- 8	
	Invisible ent.	5- 3	
Structure-related objects	Barrier	3- 5	
	Support	*21- 42	0.04
	Container	74- 84	
	Rigidity	55- 47	
	Cont. thing	29- 13	
	Force	8 - 3	
	Autonomous	0 - 5	
	Invisible ent.	8 - 3	
Surface-related objects	Barrier	V32-11	0.008
	Support	84-68	
	Container	*32-50	0.02
	Rigidity	32-45	
	Cont. thing	V50-21	0.003
	Force	87-89	
	Autonomous	V71-50	0.02
	Invisible ent.	5 - 3	
Irrelevant objects	Barrier	13- 8	
	Support	3 - 3	
	Container	13- 3	
	Rigidity	18- 8	
	Cont. thing	V42- 18	0.004
	Force	V74- 21	0.000
	Autonomous	V68- 16	0.000
	Invisible ent.	V79- 50	0.001

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

Appendix 6.18 Factor loadings and the factor scree plot for gravity

	Factor 1	Factor 2
Invisible E	**-.88077**	-.07181
Container	**.84949**	.12287
Support	**.82863**	-.10870
Rigidity	**.76693**	.13603
Barrier	**.73754**	.00848
Autonomy	.21670	**.96392**
Con.Subst	.23171	**.90655**
Force	-.40029	**.83167**

Sampling adequacy = .30786
Bartlett test = 70.33438, Significance = .00002



Gravity: Percentages of 'yes' responses for each scheme

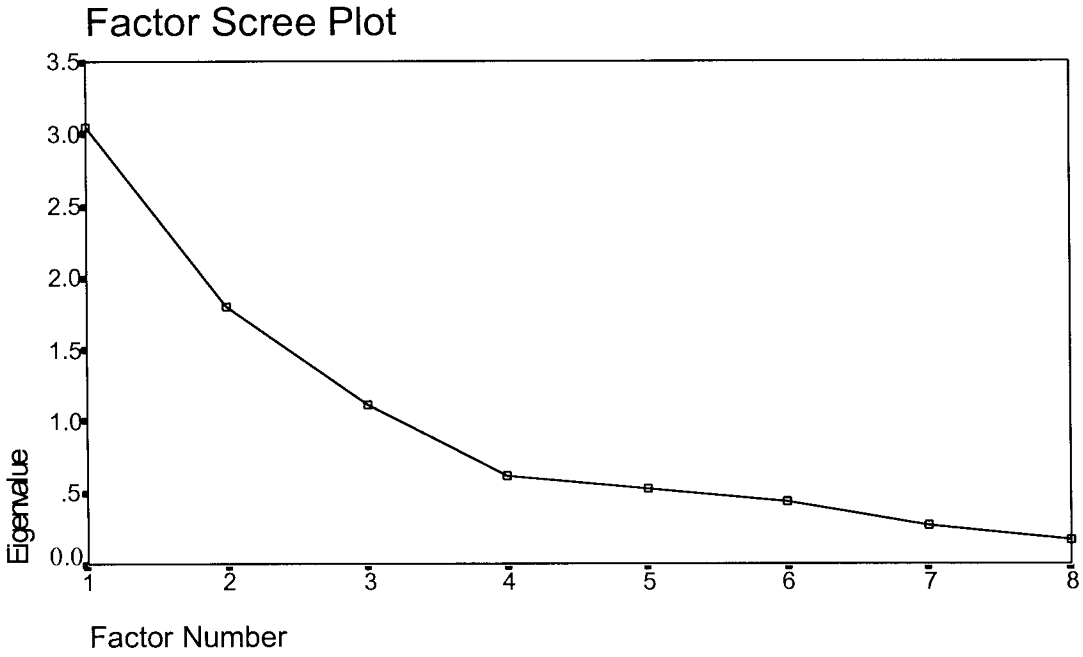
		The example with the 'rocket'	Mc Nemar Test
Scientific entity	Barrier	0 - 8	
	Support	V25- 6	0.02
	Container	6- 14	
	Rigidity	11- 8	
	Cont. thing	11- 17	
	Force	44- 39	
	Autonomous	8 - 8	
	Invisible ent.	81-78	
Protagonist	Barrier	*11-39	0.002
	Support	42-56	
	Container	83-94	
	Rigidity	69-86	
	Cont. thing	42-56	
	Force	36-42	
	Autonomous	56-53	
	Invisible ent.	11-6	
Structure-related objects	Barrier	*28-56	0.002
	Support	V94-42	0.000
	Container	V72-22	0.000
	Rigidity	22-14	
	Cont. thing	19-31	
	Force	33-25	
	Autonomous	22-14	
	Invisible ent.	0 - 0	
Surface-related objects	Barrier	V50-14	0.000
	Support	V69-22	0.000
	Container	V58-14	0.000
	Rigidity	V39-8	0.001
	Cont. thing	*64-81	0.03
	Force	81-64	
	Autonomous	89-78	
	Invisible ent.	6- 3	
Irrelevant objects	Barrier	6 - 8	
	Support	11- 25	
	Container	33- 25	
	Rigidity	14- 6	
	Cont. thing	V58- 3	0.000
	Force	86- 81	
	Autonomous	61-56	
	Invisible ent.	81-92	

The pairs of numbers show the percentages of the children who used each scheme to describe various objects in the non-exemplifying context (the first number) and in the exemplifying context (the second number). 'V' means statistically significant decrease and '*' means statistically significant increase.

Appendix 6.19 Factor loadings and the factor scree plot for all examples

	Factor 1	Factor 2	Factor 3
SUPPORT	**.81463**	.16560	-.30793
INV. ENTITY	**-.80742**	.22828	-.11272
CONTAINE	**.79020**	-.04118	.22477
RIGIDITY	**.74505**	-.18400	-.22353
FORCE	-.17134	**.92117**	.13594
AUTON.AC	-.02439	**.90913**	.10386
CON.SUBS	.17591	.22209	**.82796**
BARRIER	.48602	-.03832	**-.63902**

Sampling adequacy = .65276
Bartlett test = 367.92691, Significance = .00000



Appendix 7.1 The questionnaire of the 4th study in Greek

ΠΕΡΙΓΡΑΦΩΝΤΑΣ ΠΑΡΑΔΕΙΓΜΑΤΑ

Είναι σημαντικό να θυμάσαι οτι εσύ μπορείς να εξηγήσεις μια ιδέα με πολλά παραδείγματα. Μερικά από αυτά τα παραδείγματα είναι καλύτερα από κάποια άλλα, και μερικά είναι χειρότερα. Με αυτό το ερωτηματολόγιο, θέλουμε να δούμε, πως εσύ καταλαβαίνεις κάποια παραδείγματα που υπάρχουν στο βιβλίο “ερευνώ το φυσικό κόσμο”. Να θυμάσαι οτι **δεν υπάρχουν σωστές ή λάθος απαντήσεις**, απλά γράψε αυτό που εσύ σκέφτεσαι.

Η Ιδέα

Σ’ ένα βιβλίο Φυσικής βρήκαμε την παρακάτω ιδέα:

> ***“Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια”***

ΠΡΟΣΕΞΕ ! ! Όλες οι ερωτήσεις που θα ακολουθήσουν αφορούν αυτή την ιδέα.

Ένα Παράδειγμα

Στο βιβλίο “ερευνώ το φυσικό κόσμο”, βρήκαμε για την παραπάνω ιδέα το **παράδειγμα:**

Το παιδί ψηλά στο δέντρο
έχει Δυναμική Ενέργεια

ΓΥΡΝΑ ΠΙΣΩ Σ’ ΑΥΤΗ ΤΗ ΣΕΛΙΔΑ, ΑΝ ΧΡΕΙΑΣΤΕΙ ΝΑ ΘΥΜΗΘΕΙΣ ΑΥΤΟ ΤΟ ΠΑΡΑΔΕΙΓΜΑ (ΤΟΥ ΒΙΒΛΙΟΥ) ΓΙΑ ΤΗΝ ΠΑΡΑΠΑΝΩ ΙΔΕΑ.

Ένα παράδειγμα για την ιδέα "Όταν τα σώματα είναι ανυψωμένα, έχουν ενέργεια, που τη λέμε Δυναμική Ενέργεια" είναι "**Ένα παιδί ψηλά στο δέντρο**" *(κοίταξε την εικόνα στη σελίδα 4). Σ' αυτό το παράδειγμα παίρνουν μέρος: το παιδί, το δέντρο, το έδαφος, ο αέρας και η Δυναμική ενέργεια. Πώς θα μπορούσες να το αλλάξεις αυτό για να το κάνεις ένα* **καλύτερο παράδειγμα;**

Κάνε το/την... →	Μεγαλύτερο	Να μην Υπάρχει	Βαρύτερο	Να κάνει κάτι Γρηγορότερα	Να αλλάξει το Σχήμα του	Να βρίσκεται πιο Μακριά
παιδί	☐	☐	☐	☐	☐	☐
δέντρο	☐	☐	☐	☐	☐	☐
αέρα	☐	☐	☐	☐	☐	☐
έδαφος	☐	☐	☐	☐	☐	☐
Δυν. Ενέργεια	☐	☐	☐	☐	☐	☐

Τι αλλαγές θα έκανες, για να το κάνεις ένα **χειρότερο παράδειγμα;**

Κάνε το/την... →	Μεγαλύτερο	Να μην Υπάρχει	Βαρύτερο	Να κάνει κάτι Γρηγορότερα	Να αλλάξει το Σχήμα του	Να βρίσκεται πιο Μακριά
παιδί	☐	☐	☐	☐	☐	☐
δέντρο	☐	☐	☐	☐	☐	☐
αέρα	☐	☐	☐	☐	☐	☐
έδαφος	☐	☐	☐	☐	☐	☐
Δυν. Ενέργεια	☐	☐	☐	☐	☐	☐

Appendix 7.2 Cochran Q Test for potential energy

```
POTENTIAL ENERGY          ***BETTER***
FEATURES
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  35    3   BAAWA
  35    3   BABIG
  34    4   BAEXI
  36    2   BAHEA
  24   14   BAQUI
  37    1   BASHA

     Cases       Cochran Q        D.F.   Significance
      38          26.8110          5       .0001

EXAMPLE:     2  Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  34    0   BAAWA
  33    1   BABIG
  32    2   BAEXI
  33    1   BAHEA
  18   16   BAQUI
  33    1   BASHA

     Cases       Cochran Q        D.F.   Significance
      34          55.1942          5       .0000
```

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= air
B = pot/child
C = balcony/tree
D = ground
E = potential energy

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  15   23   BBAWA
  19   19   BBBIG
  38    0   BBEXI
  22   16   BBHEA
  35    3   BBQUI
  29    9   BBSHA

     Cases       Cochran Q        D.F.   Significance
      38          50.3200          5       .0000

EXAMPLE:     2  Child - - - - - Cochran Q Test
 Cases
 = 1  = 0   Variable

  25    9   BBAWA
  13   21   BBBIG
   0   34   BBEXI
  16   18   BBHEA
   8   26   BBQUI
   8   26   BBSHA

     Cases       Cochran Q        D.F.   Significance
      34          45.1667          5       .0000
```

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

Cases
 = 0  = 1   Variable

  29    9   BCAWA
  26   12   BCBIG
  38    0   BCEXI
  34    4   BCHEA
  38    0   BCQUI
  26   12   BCSHA

     Cases       Cochran Q        D.F.   Significance
      38          28.5152          5       .0000

EXAMPLE:     2  Child - - - - - Cochran Q Test
Cases
 = 1  = 0   Variable

   8   26   BCAWA
  23   11   BCBIG
   0   34   BCEXI
   4   30   BCHEA
   0   34   BCQUI
   8   26   BCSHA

     Cases       Cochran Q        D.F.   Significance
      34          65.5389          5       .0000
```

```
EXAMPLE:      1   Pot - - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

  11   27  BDAWA
   4   34  BDBIG
   2   36  BDEXI
   4   34  BDHEA
   0   38  BDQUI
   5   33  BDSHA

      Cases        Cochran Q         D.F.   Significance
        38         17.3333             5        .0039


EXAMPLE:      2   Child - - - - - Cochran Q Test

Cases
 = 1  = 0   Variable

  24   10  BDAWA
   2   32  BDBIG
   0   34  BDEXI
   2   32  BDHEA
   1   33  BDQUI
   7   27  BDSHA

      Cases        Cochran Q         D.F.   Significance
        34         76.4634             5        .0000
```

```
EXAMPLE:      1   Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  33    5  BEAWA
  29    9  BEBIG
  37    1  BEEXI
  34    4  BEHEA
  22   16  BEQUI
  37    1  BESHA

      Cases        Cochran Q         D.F.   Significance
        38         33.2432             5        .0000


EXAMPLE:      2   Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  33    1  BEAWA
  24   10  BEBIG
  33    1  BEEXI
  32    2  BEHEA
  32    2  BEQUI
  34    0  BESHA

      Cases        Cochran Q         D.F.   Significance
        34         28.0556             5        .0000
```

```
POTENTIAL ENERGY         ***WORSE***

EXAMPLE:      1   Pot - - - - - Cochran Q Test



EXAMPLE:      2   Child - - - - - Cochran Q Test

  Cases
  = 0  = 1   Variable

   32    2  WAAWA
   30    4  WABIG
   24   10  WAEXI
   28    6  WAHEA
   27    7  WAQUI
   32    2  WASHA

      Cases        Cochran Q         D.F.   Significance
        34         11.1832             5        .0479
```

```
EXAMPLE:      1   Pot- - - - - Cochran Q Test
Cases
 = 0  = 1   Variable

  30    8  WBAWA
  30    8  WBBIG
  16   22  WBEXI
  30    8  WBHEA
  32    6  WBQUI
  26   12  WBSHA

      Cases        Cochran Q         D.F.   Significance
        38         23.2143             5        .0003


EXAMPLE:      2   Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  31    3  WBAWA
  27    7  WBBIG
  10   24  WBEXI
  18   16  WBHEA
  26    8  WBQUI
  24   10  WBSHA

      Cases        Cochran Q         D.F.   Significance
        34         35.1240             5        .0000
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  23  15  WCAWA
  28  10  WCBIG
  24  14  WCEXI
  33   5  WCHEA
  31   7  WCQUI
  27  11  WCSHA

     Cases     Cochran Q     D.F.  Significance
      38       10.4630        5       .0631
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  32   2  WCAWA
  24  10  WCBIG
  13  21  WCEXI
  28   6  WCHEA
  29   5  WCQUI
  23  11  WCSHA

     Cases     Cochran Q     D.F.  Significance
      34       35.7487        5       .0000
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  33   1  WDAWA
  25   9  WDBIG
  17  17  WDEXI
  27   7  WDHEA
  30   4  WDQUI
  21  13  WDSHA

     Cases     Cochran Q     D.F.  Significance
      34       28.4254        5       .0000
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  35   3  WEAWA
  35   3  WEBIG
  25  13  WEEXI
  31   7  WEHEA
  28  10  WEQUI
  30   8  WESHA

     Cases     Cochran Q     D.F.  Significance
      38       13.8095        5       .0169
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  33   1  WEAWA
  34   0  WEBIG
  21  13  WEEXI
  30   4  WEHEA
  30   4  WEQUI
  34   0  WESHA

     Cases     Cochran Q     D.F.  Significance
      34       36.4000        5       .0000
```

POTENTIAL EXAMPLE ***BETTER***

OBJECTS

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   35   3  BABIG
   19  19  BBBIG
   26  12  BCBIG
   34   4  BDBIG
   29   9  BEBIG

       Cases      Cochran Q       D.F.  Significance
        38         22.5600         4       .0002
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   33   1  BABIG
   21  13  BBBIG
   11  23  BCBIG
   32   2  BDBIG
   24  10  BEBIG

       Cases      Cochran Q       D.F.  Significance
        34         44.8333         4       .0000
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

    2  36  BAHEA
   16  22  BBHEA
    4  34  BCHEA
    4  34  BDHEA
    4  34  BEHEA

       Cases      Cochran Q       D.F.  Significance
        38         24.6154         4       .0001
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   33   1  BAHEA
   18  16  BBHEA
   30   4  BCHEA
   32   2  BDHEA
   32   2  BEHEA

       Cases      Cochran Q       D.F.  Significance
        34         34.6667         4       .0000
```

```
EXAMPLE:      1  Pot - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   24  14  BAQUI
   35   3  BBQUI
   38   0  BCQUI
   38   0  BDQUI
   22  16  BEQUI

       Cases      Cochran Q       D.F.  Significance
        38         40.5333         4       .0000
```

```
EXAMPLE:      2  Child - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   18  16  BAQUI
   26   8  BBQUI
   34   0  BCQUI
   33   1  BDQUI
   32   2  BEQUI

       Cases      Cochran Q       D.F.  Significance
        34         38.1277         4       .0000
```

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   37    1  BASHA
   29    9  BBSHA
   26   12  BCSHA
   33    5  BDSHA
   37    1  BESHA

      Cases       Cochran Q       D.F.  Significance
        38        21.1556           4        .0003


EXAMPLE:     2  Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   33    1  BASHA
   26    8  BBSHA
   26    8  BCSHA
   27    7  BDSHA
   34    0  BESHA

      Cases       Cochran Q       D.F.  Significance
        34        14.9524           4        .0048
```

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   35    3  BAAWA
   15   23  BBAWA
   29    9  BCAWA
   27   11  BDAWA
   33    5  BEAWA

      Cases       Cochran Q       D.F.  Significance
        38        32.2105           4        .0000


EXAMPLE:     2  Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   34    0  BAAWA
    9   25  BBAWA
   26    8  BCAWA
   10   24  BDAWA
   33    1  BEAWA

      Cases       Cochran Q       D.F.  Significance
        34        71.4699           4        .0000
```

POTENTIAL ENERGY ***WORSE***

OBJECTS

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   27   11  WABIG
   30    8  WBBIG
   28   10  WCBIG
   25   13  WDBIG
   35    3  WEBIG

      Cases       Cochran Q       D.F.  Significance
        38        10.1754           4        .0376


EXAMPLE:     2  Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   30    4  WABIG
   27    7  WBBIG
   24   10  WCBIG
   25    9  WDBIG
   34    0  WEBIG

      Cases       Cochran Q       D.F.  Significance
        34        12.6923           4        .0129
```

```
EXAMPLE:     1  Pot - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   27   11  WAEXI
   16   22  WBEXI
   24   14  WCEXI
   30    8  WDEXI
   25   13  WEEXI

      Cases       Cochran Q       D.F.  Significance
        38        12.4091           4        .0146


EXAMPLE:     2  Child - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   24   10  WAEXI
   10   24  WBEXI
   13   21  WCEXI
   17   17  WDEXI
   21   13  WEEXI

      Cases       Cochran Q       D.F.  Significance
        34        17.5676           4        .0015
```

EXAMPLE: 1 Pot - - - - - Cochran Q Test

EXAMPLE: 2 Child - - - - - Cochran Q Test

```
Cases
= 0 = 1  Variable

 28   6  WAHEA
 18  16  WBHEA
 28   6  WCHEA
 27   7  WDHEA
 30   4  WEHEA

     Cases      Cochran Q      D.F.  Significance
      34        14.3226          4      .0063
```

EXAMPLE: 1 Pot - - - - - Cochran Q Test

EXAMPLE: 2 Child - - - - - Cochran Q Test

EXAMPLE: 1 Pot - - - - - Cochran Q Test

EXAMPLE: 2 Child - - - - - Cochran Q Test

```
Cases
= 0 = 1  Variable

 32   2  WASHA
 24  10  WBSHA
 23  11  WCSHA
 21  13  WDSHA
 34   0  WESHA

     Cases      Cochran Q      D.F.  Significance
      34        24.5091          4      .0001
```

EXAMPLE: 1 Pot - - - - - Cochran Q Test

```
Cases
= 0 = 1  Variable

 33   5  WAAWA
 30   8  WBAWA
 23  15  WCAWA
 33   5  WDAWA
 35   3  WEAWA

     Cases      Cochran Q      D.F.  Significance
      38        17.4118          4      .0016
```

EXAMPLE: 2 Child - - - - - Cochran Q Test

Appendix 7.3 Cochran Q Test for expansion

```
EXPANSION                    ***BETTER***
FEATURES
EXAMPLE:      1  railway - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  29   4  BABIG
   3  30  BAEXI
   5  28  BAHEA
   1  32  BAQUI
  13  20  BASHA
   6  27  BAAWA

      Cases       Cochran Q       D.F.  Significance
       33         78.1884          5        .0000

EXAMPLE:      2  wires - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  31   9  BABIG
   0  40  BAEXI
   6  34  BAHEA
   5  35  BAQUI
  13  27  BASHA
  12  28  BAAWA

      Cases       Cochran Q       D.F.  Significance
       40         68.5019          5        .0000
```

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= rail/wires
B = ground
C = sun
D = train/pylons
E =expansion

```
EXAMPLE:      2  wires - - - - - Cochran Q Test
 Cases
  = 0 = 1  Variable

   33   7  BBBIG
   36   4  BBEXI
   38   2  BBHEA
   39   1  BBQUI
   31   9  BBSHA
   39   1  BBAWA

      Cases       Cochran Q       D.F.  Significance
       40         15.8491          5        .0073
```

```
EXAMPLE:      1  railway - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

   8  25  BCBIG
   0  33  BCEXI
   2  31  BCHEA
   2  31  BCQUI
   3  30  BCSHA
  12  21  BCAWA

      Cases       Cochran Q       D.F.  Significance
       33         27.4779          5        .0000

EXAMPLE:      2  wires - - - - - Cochran Q Test
Cases
 = 1 = 0  Variable

  18  22  BCBIG
   0  40  BCEXI
   1  39  BCHEA
  15  25  BCQUI
   5  35  BCSHA
   8  32  BCAWA

      Cases       Cochran Q       D.F.  Significance
       40         43.4492          5        .0000
```

```
EXAMPLE:      1  railway - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   26    7  BDBIG
   30    3  BDEXI
   22   11  BDHEA
    6   27  BDQUI
   28    5  BDSHA
   27    6  BDAWA

        Cases       Cochran Q        D.F.   Significance
         33         58.6181           5        .0000

EXAMPLE:      2  wires - - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   12   28  BDBIG
    2   38  BDEXI
    6   34  BDHEA
    0   40  BDQUI
   12   28  BDSHA
   11   29  BDAWA

        Cases       Cochran Q        D.F.   Significance
         40         25.9202           5        .0001
```

```
EXAMPLE:      1  railway - - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   13   20  BEBIG
    3   30  BEEXI
    1   32  BEHEA
    1   32  BEQUI
    4   29  BESHA
    0   33  BEAWA

        Cases       Cochran Q        D.F.   Significance
         33         35.3061           5        .0000

EXAMPLE:      2  wires - - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   23   17  BEBIG
    2   38  BEEXI
    1   39  BEHEA
    9   31  BEQUI
    2   38  BESHA
    2   38  BEAWA

        Cases       Cochran Q        D.F.   Significance
         40         64.8246           5        .0000
```

```
EXPANSION         ***WORSE***

EXAMPLE:      1  railway - - - - - Cochran Q Test
Cases
 = 0  = 1   Variable

   32    1  WABIG
   19   14  WAEXI
   30    3  WAHEA
   30    3  WAQUI
   20   13  WASHA
   23   10  WAAWA

        Cases       Cochran Q        D.F.   Significance
         33         28.4706           5        .0000

EXAMPLE:      2  wires - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   38    2  WABIG
   12   28  WAEXI
   32    8  WAHEA
   33    7  WAQUI
   13   27  WASHA
   26   14  WAAWA

        Cases       Cochran Q        D.F.   Significance
         40         65.4412           5        .0000
```

```
EXAMPLE:      2  wires - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   34    6  WBBIG
   26   14  WBEXI
   35    5  WBHEA
   37    3  WBQUI
   23   17  WBSHA
   28   12  WBAWA

        Cases       Cochran Q        D.F.   Significance
         40         24.7382           5        .0002
```

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  29   4  WCBIG
  21  12  WCEXI
  27   6  WCHEA
  30   3  WCQUI
  24   9  WCSHA
  24   9  WCAWA

       Cases      Cochran Q       D.F.  Significance
        33        11.1006         5       .0494


EXAMPLE:     2  wires - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  33   7  WCBIG
  16  24  WCEXI
  31   9  WCHEA
  31   9  WCQUI
  20  20  WCSHA
  24  16  WCAWA

       Cases      Cochran Q       D.F.  Significance
        40        29.9791         5       .0000
```

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  31   2  WDBIG
  31   2  WDEXI
  23  10  WDHEA
  20  13  WDQUI
  26   7  WDSHA
  28   5  WDAWA

       Cases      Cochran Q       D.F.  Significance
        33        19.6309         5       .0015


EXAMPLE:     2  wires - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  33   7  WDBIG
  23  17  WDEXI
  28  12  WDHEA
  31   9  WDQUI
  23  17  WDSHA
  21  19  WDAWA

       Cases      Cochran Q       D.F.  Significance
        40        15.6550         5       .0079
```

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  32   1  WEBIG
  22  11  WEEXI
  29   4  WEHEA
  29   4  WEQUI
  31   2  WESHA
  26   7  WEAWA

       Cases      Cochran Q       D.F.  Significance
        33        18.0631         5       .0029


EXAMPLE:     2  wires - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  37   3  WEBIG
  15  25  WEEXI
  33   7  WEHEA
  33   7  WEQUI
  28  12  WESHA
  30  10  WEAWA

       Cases      Cochran Q       D.F.  Significance
        40        40.3670         5       .0000
```

EXPANSION ***BETTER***

OBJECTS

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
= 1 = 0   Variable

  29    4  BABIG
   1   32  BBBIG
   8   25  BCBIG
   7   26  BDBIG
  13   20  BEBIG

      Cases       Cochran Q        D.F.  Significance
        33        57.1139          4        .0000

EXAMPLE:     2  wires - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  31    9  BABIG
   7   33  BBBIG
  18   22  BCBIG
  12   28  BDBIG
  23   17  BEBIG

      Cases       Cochran Q        D.F.  Significance
        40        33.4095          4        .0000
```

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  28    5  BAHEA
  29    4  BBHEA
  31    2  BCHEA
  22   11  BDHEA
  32    1  BEHEA

      Cases       Cochran Q        D.F.  Significance
        33        15.3000          4        .0041
```

```
EXAMPLE:     1  railway - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  32    1  BAQUI
  33    0  BBQUI
  31    2  BCQUI
   6   27  BDQUI
  32    1  BEQUI

      Cases       Cochran Q        D.F.  Significance
        33        90.4667          4        .0000

EXAMPLE:     2  wires - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  35    5  BAQUI
  39    1  BBQUI
  25   15  BCQUI
  40    0  BDQUI
  31    9  BEQUI

      Cases       Cochran Q        D.F.  Significance
        40        29.8039          4        .0000
```

EXAMPLE: 1 railway - - - - - Cochran Q Test

Cases
= 1 = 0 Variable

13 20 BASHA
3 30 BBSHA
3 30 BCSHA
5 28 BDSHA
4 29 BESHA

Cases	Cochran Q	D.F.	Significance
33	15.4783	4	.0038

EXAMPLE: 2 wires - - - - - Cochran Q Test

Cases
= 0 = 1 Variable

27 13 BASHA
31 9 BBSHA
35 5 BCSHA
28 12 BDSHA
38 2 BESHA

Cases	Cochran Q	D.F.	Significance
40	13.5625	4	.0088

EXAMPLE: 1 railway - - - - - Cochran Q Test

Cases
= 1 = 0 Variable

6 27 BAAWA
2 31 BBAWA
12 21 BCAWA
6 27 BDAWA
0 33 BEAWA

Cases	Cochran Q	D.F.	Significance
33	18.8444	4	.0008

EXAMPLE: 2 wires - - - - - Cochran Q Test

Cases
= 0 = 1 Variable

28 12 BAAWA
39 1 BBAWA
32 8 BCAWA
29 11 BDAWA
38 2 BEAWA

Cases	Cochran Q	D.F.	Significance
40	19.7692	4	.0006

EXPANSION ***WORSE***
OBJECTS
EXAMPLE: 1 railway - - - - - Cochran Q Test

EXAMPLE: 1 railway - - - - - Cochran Q Test

Cases
= 0 = 1 Variable

19 14 WAEXI
29 4 WBEXI
21 12 WCEXI
31 2 WDEXI
22 11 WEEXI

Cases	Cochran Q	D.F.	Significance
33	16.1159	4	.0029

EXAMPLE: 2 wires - - - - - Cochran Q Test

Cases
= 1 = 0 Variable

28 12 WAEXI
14 26 WBEXI
24 16 WCEXI
17 23 WDEXI
25 15 WEEXI

Cases	Cochran Q	D.F.	Significance
40	14.4421	4	.0060

EXAMPLE: 1 railway - - - - - Cochran Q Test

```
Cases
= 0 = 1  Variable

 30   3  WAQUI
 30   3  WBQUI
 30   3  WCQUI
 20  13  WDQUI
 29   4  WEQUI

      Cases     Cochran Q      D.F.  Significance
       33        16.3404        4       .0026
```

EXAMPLE: 1 railway - - - - - Cochran Q Test

```
Cases
= 0 = 1  Variable

 20  13  WASHA
 27   6  WBSHA
 24   9  WCSHA
 26   7  WDSHA
 31   2  WESHA

      Cases     Cochran Q      D.F.  Significance
       33        10.3492        4       .0349
```

EXAMPLE: 2 wires - - - - - Cochran Q Test

```
Cases
= 1 = 0  Variable

 27  13  WASHA
 17  23  WBSHA
 20  20  WCSHA
 17  23  WDSHA
 12  28  WESHA

      Cases     Cochran Q      D.F.  Significance
       40        15.7403        4       .0034
```

EXAMPLE: 1 railway - - - - - Cochran Q Test

```
Cases
= 1 = 0  Variable

 10  23  WAAWA
  1  32  WBAWA
  9  24  WCAWA
  7  26  WDAWA
  5  28  WEAWA

      Cases     Cochran Q      D.F.  Significance
       33        10.0392        4       .0398
```

Appendix 7.4 Cochran Q Test for thermal equilibrium

THERMAL EQUILIBRIUM ***BETTER***

FEATURES

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

 36   4  BBBIG
 27  13  BBEXI
 37   3  BBHEA
 33   7  BBQUI
 37   3  BBSHA
 35   5  BBAWA

    Cases      Cochran Q      D.F.  Significance
     40        15.7194          5     .0077
```

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= air
B = cold water
C = metallic pots
D = hot water
E = heat

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

 34   6  BCBIG
  2  38  BCEXI
  6  34  BCHEA
  2  38  BCQUI
 20  20  BCSHA
  1  39  BCAWA

    Cases      Cochran Q      D.F.  Significance
     40        100.7678         5     .0000

EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

 26   4  BCBIG
  1  29  BCEXI
  4  26  BCHEA
  2  28  BCQUI
 13  17  BCSHA
  3  27  BCAWA

    Cases      Cochran Q      D.F.  Significance
     30        76.1765          5     .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  27  13  BDBIG
  39   1  BDEXI
  24  16  BDHEA
  26  14  BDQUI
  38   2  BDSHA
  39   1  BDAWA

      Cases      Cochran Q      D.F.  Significance
        40       42.4317         5      .0000

EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  16  14  BDBIG
  30   0  BDEXI
  13  17  BDHEA
  25   5  BDQUI
  29   1  BDSHA
  30   0  BDAWA

      Cases      Cochran Q      D.F.  Significance
        30       50.2071         5      .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  23  17  BEBIG
   0  40  BEEXI
   2  38  BEHEA
  21  19  BEQUI
   1  39  BESHA
   0  40  BEAWA

      Cases      Cochran Q      D.F.  Significance
        40       87.1053         5      .0000

EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  23   7  BEBIG
   0  30  BEEXI
   1  29  BEHEA
  18  12  BEQUI
   0  30  BESHA
   3  27  BEAWA

      Cases      Cochran Q      D.F.  Significance
        30       82.5393         5      .0000
```

```
POTENTIAL ENERGY        ***WORSE***

EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  39   1  WABIG
  28  12  WAEXI
  38   2  WAHEA
  34   6  WAQUI
  39   1  WASHA
  33   7  WAAWA

      Cases      Cochran Q      D.F.  Significance
        40       23.9076         5      .0002

EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

   4  26  WABIG
   8  22  WAEXI
   1  29  WAHEA
   3  27  WAQUI
   1  29  WASHA
   5  25  WAAWA

      Cases      Cochran Q      D.F.  Significance
        30       12.3256         5      .0306
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  28  12  WBBIG
  21  19  WBEXI
  26  14  WBHEA
  35   5  WBQUI
  33   7  WBSHA
  25  15  WBAWA

      Cases      Cochran Q      D.F.  Significance
        40       15.6923         5      .0078
```

```
EXAMPLE:     1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   36    4  WCBIG
   11   29  WCEXI
   33    7  WCHEA
   37    3  WCQUI
   23   17  WCSHA
   22   18  WCAWA

        Cases       Cochran Q      D.F.  Significance
          40        60.7087         5        .0000


EXAMPLE:     2  inside - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   29    1  WCBIG
    9   21  WCEXI
   28    2  WCHEA
   25    5  WCQUI
   16   14  WCSHA
   15   15  WCAWA

        Cases       Cochran Q      D.F.  Significance
          30        46.0185         5        .0000
```

```
EXAMPLE:     1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   37    3  WDBIG
    7   33  WDEXI
   38    2  WDHEA
   36    4  WDQUI
   35    5  WDSHA
   19   21  WDAWA

        Cases       Cochran Q      D.F.  Significance
          40        92.4242         5        .0000


EXAMPLE:     2  inside - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   28    2  WDBIG
   11   19  WDEXI
   29    1  WDHEA
   29    1  WDQUI
   26    4  WDSHA
   20   10  WDAWA

        Cases       Cochran Q      D.F.  Significance
          30        47.4845         5        .0000
```

```
EXAMPLE:     1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   40    0  WEBIG
    5   35  WEEXI
   39    1  WEHEA
   39    1  WEQUI
   39    1  WESHA
   31    9  WEAWA

        Cases       Cochran Q      D.F.  Significance
          40        132.5117        5        .0000


EXAMPLE:     2  inside - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   29    1  WEBIG
    5   25  WEEXI
   27    3  WEHEA
   27    3  WEQUI
   30    0  WESHA
   23    7  WEAWA

        Cases       Cochran Q      D.F.  Significance
          30        78.9521         5        .0000
```

POTENTIAL EXAMPLE ***BETTER***

OBJECTS

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   37   3  BABIG
   36   4  BBBIG
    6  34  BCBIG
   27  13  BDBIG
   17  23  BEBIG

       Cases      Cochran Q      D.F.  Significance
        40        70.0202        4       .0000


EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
= 0 = 1  Variable

   27   3  BABIG
   21   9  BBBIG
    4  26  BCBIG
   16  14  BDBIG
    7  23  BEBIG

       Cases      Cochran Q      D.F.  Significance
        30        45.7500        4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   33   7  BAEXI
   27  13  BBEXI
   38   2  BCEXI
   39   1  BDEXI
   40   0  BEEXI

       Cases      Cochran Q      D.F.  Significance
        40        28.5854        4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   37   3  BAHEA
   37   3  BBHEA
   34   6  BCHEA
   24  16  BDHEA
   38   2  BEHEA

       Cases      Cochran Q      D.F.  Significance
        40        27.3469        4       .0000


EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   29   1  BAHEA
   25   5  BBHEA
   26   4  BCHEA
   13  17  BDHEA
   29   1  BEHEA

       Cases      Cochran Q      D.F.  Significance
        30        35.7551        4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   34   6  BAQUI
   33   7  BBQUI
   38   2  BCQUI
   26  14  BDQUI
   19  21  BEQUI

       Cases      Cochran Q      D.F.  Significance
        40        30.1333        4       .0000


EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   28   2  BAQUI
   26   4  BBQUI
   28   2  BCQUI
   25   5  BDQUI
   12  18  BEQUI

       Cases      Cochran Q      D.F.  Significance
        30        38.4681        4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  39    1  BASHA
  37    3  BBSHA
  20   20  BCSHA
  38    2  BDSHA
  39    1  BESHA

       Cases        Cochran Q        D.F.  Significance
        40          52.7843           4       .0000
```

```
EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  30    0  BASHA
  27    3  BBSHA
  17   13  BCSHA
  29    1  BDSHA
  30    0  BESHA

       Cases        Cochran Q        D.F.  Significance
        30          40.4000           4       .0000
```

POTENTIAL ENERGY ***WORSE***

OBJECTS

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  39    1  WABIG
  28   12  WBBIG
  36    4  WCBIG
  37    3  WDBIG
  40    0  WEBIG

       Cases        Cochran Q        D.F.  Significance
        40          25.0000           4       .0001
```

```
EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 1 = 0   Variable

   4   26  WABIG
   7   23  WBBIG
   1   29  WCBIG
   2   28  WDBIG
   1   29  WEBIG

       Cases        Cochran Q        D.F.  Significance
        30           9.6296           4       .0472
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  28   12  WAEXI
  21   19  WBEXI
  11   29  WCEXI
   7   33  WDEXI
   5   35  WEEXI

       Cases        Cochran Q        D.F.  Significance
        40          43.5455           4       .0000
```

```
EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  22    8  WAEXI
  19   11  WBEXI
   9   21  WCEXI
  11   19  WDEXI
   5   25  WEEXI

       Cases        Cochran Q        D.F.  Significance
        30          26.7733           4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  38    2  WAHEA
  26   14  WBHEA
  33    7  WCHEA
  38    2  WDHEA
  39    1  WEHEA

      Cases      Cochran Q       D.F.  Significance
        40       33.0000          4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  39    1  WASHA
  33    7  WBSHA
  23   17  WCSHA
  35    5  WDSHA
  39    1  WESHA

      Cases      Cochran Q       D.F.  Significance
        40       39.2727          4       .0000
```

```
EXAMPLE:      1  contact - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  33    7  WAAWA
  25   15  WBAWA
  22   18  WCAWA
  19   21  WDAWA
  31    9  WEAWA

      Cases      Cochran Q       D.F.  Significance
        40       20.2899          4       .0004
```

```
EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  29    1  WASHA
  26    4  WBSHA
  16   14  WCSHA
  26    4  WDSHA
  30    0  WESHA

      Cases      Cochran Q       D.F.  Significance
        30       29.3333          4       .0000
```

```
EXAMPLE:      2  inside - - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  25    5  WAAWA
  22    8  WBAWA
  15   15  WCAWA
  20   10  WDAWA
  23    7  WEAWA

      Cases      Cochran Q       D.F.  Significance
        30       11.1538          4       .0249
```

Appendix 7.5 Cochran Q Test for inertia

INERTIA ***BETTER***

FEATURES

EXAMPLE: 1 lorry - - - - - Cochran Q Test

Cases = 1	= 0	Variable
12	26	BABIG
2	36	BAEXI
6	32	BAHEA
23	**15**	**BAQUI**
10	28	BASHA
13	**25**	**BAAWA**

Cases	Cochran Q	D.F.	Significance
38	33.3913	5	.0000

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= car/toy elephant
B = ground/child
C = lorry/elephant
D = air/ground
E = inertia

EXAMPLE: 1 lorry - - - - Cochran Q Test

Cases = 1	= 0	Variable
10	**28**	**BBBIG**
1	37	BBEXI
4	34	BBHEA
2	36	BBQUI
11	**27**	**BBSHA**
2	36	BBAWA

Cases	Cochran Q	D.F.	Significance
38	23.2258	5	.0003

EXAMPLE: 2 elephant- - - - - Cochran Q Test

Cases = 1	= 0	Variable
12	11	BBBIG
3	20	BBEXI
4	19	BBHEA
13	**10**	**BBQUI**
3	20	BBSHA
2	21	BBAWA

Cases	Cochran Q	D.F.	Significance
23	25.0680	5	.0001

EXAMPLE: 1 lorry- - - - - Cochran Q Test

Cases = 1	= 0	Variable
13	**25**	**BCBIG**
4	34	BCEXI
14	**24**	**BCHEA**
17	**21**	**BCQUI**
12	26	BCSHA
11	27	BCAWA

Cases	Cochran Q	D.F.	Significance
38	11.4257	5	.0436

EXAMPLE: 2 elephant- - - - - Cochran Q Test

Cases = 0	= 1	Variable
12	**11**	**BCBIG**
19	4	BCEXI
9	**14**	**BCHEA**
18	5	BCQUI
19	4	BCSHA
18	5	BCAWA

Cases	Cochran Q	D.F.	Significance
23	19.3262	5	.0017

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  22   1  BDBIG
  20   3  BDEXI
  23   0  BDHEA
  23   0  BDQUI
  18   5  BDSHA
  23   0  BDAWA

     Cases      Cochran Q      D.F.  Significance
      23        15.0000         5      .0104
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  10  28  BEBIG
   3  35  BEEXI
   6  32  BEHEA
   2  36  BEQUI
   4  34  BESHA
   2  36  BEAWA

     Cases      Cochran Q      D.F.  Significance
      38        11.9748         5      .0351
```

POTENTIAL ENERGY ***WORSE***

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  24  14  WABIG
  31   7  WAEXI
  16  22  WAHEA
  33   5  WAQUI
  25  13  WASHA
  31   7  WAAWA

     Cases      Cochran Q      D.F.  Significance
      38        25.8120         5      .0001
```

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

   8  15  WABIG
   7  16  WAEXI
   9  14  WAHEA
   5  18  WAQUI
   1  22  WASHA
   3  20  WAAWA

     Cases      Cochran Q      D.F.  Significance
      23        10.7143         5      .0573
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

  11  27  WBBIG
   9  29  WBEXI
   6  32  WBHEA
   4  34  WBQUI
  13  25  WBSHA
   6  32  WBAWA

     Cases      Cochran Q      D.F.  Significance
      38        10.2023         5      .0697
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   32    6  WCBIG
   32    6  WCEXI
   28   10  WCHEA
   20   18  WCQUI
   24   14  WCSHA
   24   14  WCAWA

        Cases        Cochran Q        D.F.   Significance
          38         13.8583            5         .0165
```

```
EXAMPLE:       2   elephant- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

    2   21   WDBIG
    1   22   WDEXI
    1   22   WDHEA
    0   23   WDQUI
   10   13   WDSHA
    1   22   WDAWA

        Cases        Cochran Q         D.F.   Significance
          23         30.2174             5          .0000
```

```
EXAMPLE:       1   lorry- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   35    3  WEBIG
   25   13  WEEXI
   36    2  WEHEA
   36    2  WEQUI
   34    4  WESHA
   34    4  WEAWA

        Cases        Cochran Q        D.F.   Significance
          38         20.7937            5         .0009
```

```
EXAMPLE:       2   elephant- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   22    1  WEBIG
   16    7  WEEXI
   20    3  WEHEA
   21    2  WEQUI
   22    1  WESHA
   22    1  WEAWA

        Cases        Cochran Q        D.F.   Significance
          23         11.9565            5         .0354
```

POTENTIAL EXAMPLE ***BETTER***

OBJECTS

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   19   4  BABIG
   11  12  BBBIG
   12  11  BCBIG
   22   1  BDBIG
   20   3  BEBIG

        Cases      Cochran Q      D.F.  Significance
          23        20.1633         4       .0005
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   32   6  BAHEA
   34   4  BBHEA
   24  14  BCHEA
   38   0  BDHEA
   32   6  BEHEA

        Cases      Cochran Q      D.F.  Significance
          38        20.3922         4       .0004
```

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   18   5  BAHEA
   19   4  BBHEA
    9  14  BCHEA
   23   0  BDHEA
   20   3  BEHEA

        Cases      Cochran Q      D.F.  Significance
          23        24.0870         4       .0001
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   15  23  BAQUI
   36   2  BBQUI
   21  17  BCQUI
   35   3  BDQUI
   36   2  BEQUI

        Cases      Cochran Q      D.F.  Significance
          38        51.7368         4       .0000
```

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

   22   1  BAQUI
   10  13  BBQUI
   18   5  BCQUI
   23   0  BDQUI
   22   1  BEQUI

        Cases      Cochran Q      D.F.  Significance
          23        29.7436         4       .0000
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

  10   28   BASHA
  11   27   BBSHA
  12   26   BCSHA
   3   35   BDSHA
   4   34   BESHA

       Cases       Cochran Q       D.F.   Significance
        38         13.4615          4       .0092
```

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  25   13   BAAWA
  36    2   BBAWA
  27   11   BCAWA
  36    2   BDAWA
  36    2   BEAWA

       Cases       Cochran Q       D.F.   Significance
        38         23.4615          4       .0001
```

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  16    7   BAAWA
  21    2   BBAWA
  18    5   BCAWA
  23    0   BDAWA
  23    0   BEAWA

       Cases       Cochran Q       D.F.   Significance
        23         14.3704          4       .0062
```

POTENTIAL ENERGY   ***WORSE***

OBJECTS

```
EXAMPLE:      1  lorry- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  24   14   WABIG
  27   11   WBBIG
  32    6   WCBIG
  27   11   WDBIG
  35    3   WEBIG

       Cases       Cochran Q       D.F.   Significance
        38         10.2632          4       .0362
```

```
EXAMPLE:      2  elephant- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   8   15   WABIG
   8   15   WBBIG
   5   18   WCBIG
   2   21   WDBIG
   1   22   WEBIG

       Cases       Cochran Q       D.F.   Significance
        23         11.2632          4       .0238
```

```
EXAMPLE:     1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  16  22  WAHEA
  32   6  WBHEA
  28  10  WCHEA
  31   7  WDHEA
  36   2  WEHEA

      Cases      Cochran Q      D.F.  Significance
        38       32.1111          4       .0000


EXAMPLE:     2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  14   9  WAHEA
  14   9  WBHEA
  19   4  WCHEA
  22   1  WDHEA
  20   3  WEHEA

      Cases      Cochran Q      D.F.  Significance
        23       12.2791          4       .0154
```

```
EXAMPLE:     1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  33   5  WAQUI
  34   4  WBQUI
  20  18  WCQUI
  28  10  WDQUI
  36   2  WEQUI

      Cases      Cochran Q      D.F.  Significance
        38       23.8841          4       .0001


EXAMPLE:     2  elephant- - - - - Cochran Q Test

 Cases
 = 1 = 0   Variable

   5  18  WAQUI
   9  14  WBQUI
   3  20  WCQUI
   0  23  WDQUI
   2  21  WEQUI

      Cases      Cochran Q      D.F.  Significance
        23       13.3714          4       .0096
```

```
EXAMPLE:     1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  25  13  WASHA
  25  13  WBSHA
  24  14  WCSHA
  35   3  WDSHA
  34   4  WESHA

      Cases      Cochran Q      D.F.  Significance
        38       17.4925          4       .0016


EXAMPLE:     2  elephant- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  22   1  WASHA
  17   6  WBSHA
  15   8  WCSHA
  13  10  WDSHA
  22   1  WESHA

      Cases      Cochran Q      D.F.  Significance
        23       15.1818          4       .0043
```

```
EXAMPLE:     1  lorry- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

  31   7  WAAWA
  32   6  WBAWA
  24  14  WCAWA
  33   5  WDAWA
  34   4  WEAWA

      Cases      Cochran Q      D.F.  Significance
        38       10.4667          4       .0333
```

Appendix 7.6 Cochran Q Test for upthrust

```
UPTHRUST          ***BETTER***
FEATURES
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  31   5  BABIG
  35   1  BAEXI
  24  12  BAHEA
  30   6  BAQUI
  32   4  BASHA
  35   1  BAAWA

      Cases     Cochran Q      D.F.  Significance
       36       19.5669         5       .0015


EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

  19   2  BABIG
  19   2  BAEXI
  14   7  BAHEA
  20   1  BAQUI
  14   7  BASHA
  20   1  BAAWA

      Cases     Cochran Q      D.F.  Significance
       21       14.7619         5       .0114
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test
 Cases
 = 0 = 1  Variable

  22  14  BBBIG
  33   3  BBEXI
  33   3  BBHEA
  21  15  BBQUI
  33   3  BBSHA
  32   4  BBAWA

      Cases     Cochran Q      D.F.  Significance
       36       36.4286         5       .0000


EXAMPLE:      2  stone- - - - - Cochran Q Test
 Cases
 = 1 = 0  Variable

   9  12  BBBIG
   0  21  BBEXI
   6  15  BBHEA
   9  12  BBQUI
   2  19  BBSHA
   2  19  BBAWA

      Cases     Cochran Q      D.F.  Significance
       21       21.3208         5       .0007
```

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= ball/stone
B = child
C = water/sea
D = wash basin/ground
E = upthrust

```
EXAMPLE:     1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  24   12  BDBIG
  35    1  BDEXI
  34    2  BDHEA
  35    1  BDQUI
  25   11  BDSHA
  32    4  BDAWA

       Cases      Cochran Q      D.F.   Significance
        36        32.5214         5       .0000
```

```
UPTHRUST      ***WORSE***

EXAMPLE:     1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  25   11  WABIG
  31    5  WAEXI
  23   13  WAHEA
  32    4  WAQUI
  21   15  WASHA
  24   12  WAAWA

       Cases      Cochran Q      D.F.   Significance
        36        14.2857         5       .0139


EXAMPLE:     2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  14    7  WABIG
  11   10  WAEXI
   9   12  WAHEA
  15    6  WAQUI
   9   12  WASHA
  16    5  WAAWA

       Cases      Cochran Q      D.F.   Significance
        21        11.0938         5       .0496
```

```
EXAMPLE:     1  ball- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   7   29  WBBIG
  16   20  WBEXI
   4   32  WBHEA
   7   29  WBQUI
   6   30  WBSHA
  14   22  WBAWA

       Cases      Cochran Q      D.F.   Significance
        36        19.5506         5       .0015


EXAMPLE:     2  stone- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

   7   14  WBBIG
  10   11  WBEXI
   6   15  WBHEA
   2   19  WBQUI
  13    8  WBSHA
  10   11  WBAWA

       Cases      Cochran Q      D.F.   Significance
        21        17.3438         5       .0039
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   34    2   WCBIG
   26   10   WCEXI
   29    7   WCHEA
   28    8   WCQUI
   34    2   WCSHA
   28    8   WCAWA

       Cases       Cochran Q       D.F.   Significance
        36         11.9231          5        .0359


EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   19    2   WCBIG
    9   12   WCEXI
   20    1   WCHEA
   18    3   WCQUI
   12    9   WCSHA
   10   11   WCAWA

       Cases       Cochran Q       D.F.   Significance
        21         27.1212          5        .0001
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   32    4   WDBIG
   26   10   WDEXI
   31    5   WDHEA
   33    3   WDQUI
   23   13   WDSHA
   29    7   WDAWA

       Cases       Cochran Q       D.F.   Significance
        36         15.6338          5        .0080


EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   16    5   WDBIG
   12    9   WDEXI
   19    2   WDHEA
   14    7   WDQUI
    9   12   WDSHA
   17    4   WDAWA

       Cases       Cochran Q       D.F.   Significance
        21         16.5126          5        .0055
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   32    4   WEBIG
   26   10   WEEXI
   35    1   WEHEA
   27    9   WEQUI
   31    5   WESHA
   30    6   WEAWA

       Cases       Cochran Q       D.F.   Significance
        36         13.3740          5        .0201


EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   18    3   WEBIG
   11   10   WEEXI
   20    1   WEHEA
   20    1   WEQUI
   11   10   WESHA
   18    3   WEAWA

       Cases       Cochran Q       D.F.   Significance
        21         23.1034          5        .0003
```

UPTHRUST ***BETTER***

OBJECTS

```
EXAMPLE:        1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  31    5   BABIG
  22   14   BBBIG
  34    2   BCBIG
  24   12   BDBIG
  32    4   BEBIG

      Cases       Cochran Q        D.F.   Significance
        36        19.1724           4       .0007
```

```
EXAMPLE:        2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  19    2   BABIG
  12    9   BBBIG
  17    4   BCBIG
  18    3   BDBIG
  17    4   BEBIG

      Cases       Cochran Q        D.F.   Significance
        21        8.5882            4       .0723
```

```
EXAMPLE:        1  ball- - - - - Cochran Q Test

 Cases
 = 1  = 0   Variable

  12   24   BAHEA
   3   33   BBHEA
   1   35   BCHEA
   2   34   BDHEA
   3   33   BEHEA

      Cases       Cochran Q        D.F.   Significance
        36        19.7000           4       .0006
```

```
EXAMPLE:        1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  30    6   BAQUI
  21   15   BBQUI
  31    5   BCQUI
  35    1   BDQUI
  31    5   BEQUI

      Cases       Cochran Q        D.F.   Significance
        36        20.2264           4       .0005
```

```
EXAMPLE:        2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

  20    1   BAQUI
  12    9   BBQUI
  17    4   BCQUI
  20    1   BDQUI
  17    4   BEQUI

      Cases       Cochran Q        D.F.   Significance
        21        12.9697           4       .0114
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   32    4  BASHA
   33    3  BBSHA
   34    2  BCSHA
   25   11  BDSHA
   36    0  BESHA

       Cases       Cochran Q       D.F.   Significance
         36        17.5000          4        .0015
```

```
EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   14    7  BASHA
   19    2  BBSHA
   21    0  BCSHA
   18    3  BDSHA
   19    2  BESHA

       Cases       Cochran Q       D.F.   Significance
         21        11.1667          4        .0248
```

UPTHRUST ***WORSE***

OBJECTS

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 0  = 1   Variable

   25   11  WABIG
   29    7  WBBIG
   34    2  WCBIG
   32    4  WDBIG
   32    4  WEBIG

       Cases       Cochran Q       D.F.   Significance
         36        10.2500          4        .0364
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 1 = 0   Variable

   13   23  WAHEA
    4   32  WBHEA
    7   29  WCHEA
    5   31  WDHEA
    1   35  WEHEA

        Cases        Cochran Q        D.F.   Significance
          36         14.5455           4       .0057
```

```
EXAMPLE:      2  stone- - - - - Cochran Q Test

 Cases
 = 1 = 0   Variable

   12    9  WAHEA
    6   15  WBHEA
    1   20  WCHEA
    2   19  WDHEA
    1   20  WEHEA

        Cases        Cochran Q        D.F.   Significance
          21         26.2353           4       .0000
```

```
EXAMPLE:      1  ball- - - - - Cochran Q Test

 Cases
 = 1 = 0   Variable

   15   21  WASHA
    6   30  WBSHA
    2   34  WCSHA
   13   23  WDSHA
    5   31  WESHA

        Cases        Cochran Q        D.F.   Significance
          36         22.7407           4       .0001
```

```
EXAMPLE:       2  stone- - - - - Cochran Q Test

 Cases
 = 0 = 1   Variable

   16     5  WAAWA
   11    10  WBAWA
   17     4  WCAWA
   10    11  WDAWA
   18     3  WEAWA

        Cases        Cochran Q          D.F.   Significance
          21         14.3784             4       .0062
```

Appendix 7.7 Cochran Q Test for gravity

GRAVITY ***BETTER***
FEATURES
Example with rocket - - - - - Cochran Q Test

Cases
= 1 = 0 Variable

25 11 BABIG
4 32 BAEXI
7 29 BAHEA
26 10 BAQUI
18 18 BASHA
17 19 BAAWA

Cases	Cochran Q	D.F.	Significance
36	46.5094	5	.0000

Cases
= 0 = 1 Variable

36 0 BBBIG
28 8 BBEXI
35 1 BBHEA
34 2 BBQUI
34 2 BBSHA
34 2 BBAWA

Cases	Cochran Q	D.F.	Significance
36	17.1739	5	.0042

Cases
= 0 = 1 Variable

29 7 BCBIG
35 1 BCEXI
35 1 BCHEA
35 1 BCQUI
30 6 BCSHA
28 8 BCAWA

Cases	Cochran Q	D.F.	Significance
36	16.1538	5	.0064

Cases

= 0 = 1 Variable

32 4 BDBIG
33 3 BDEXI
36 0 BDHEA
27 9 BDQUI
34 2 BDSHA
34 2 BDAWA

Cases	Cochran Q	D.F.	Significance
36	15.4348	5	.0087

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= rocket
B =air
C = ground
D = people
E = gravity

- - - - - Cochran Q Test

Cases
= 0 = 1 Variable

35 1 BEBIG
28 8 BEEXI
33 3 BEHEA
32 4 BEQUI
35 1 BESHA
32 4 BEAWA

Cases	Cochran Q	D.F.	Significance
36	10.8065	5	.0554

GRAVITY ***WORSE***
Cases
= 0 = 1 Variable

27 9 WABIG
14 22 WAEXI
19 17 WAHEA
33 3 WAQUI
21 15 WASHA
24 12 WAAWA

Cases	Cochran Q	D.F.	Significance
36	27.9487	5	.0000

```
- - - - - Cochran Q Test


Cases
 = 1 = 0  Variable

  3  33  WBBIG
  9  27  WBEXI
  6  30  WBHEA
  9  27  WBQUI
  1  35  WBSHA
  8  28  WBAWA

      Cases      Cochran Q      D.F.  Significance
       36        10.7692         5      .0565



Cases

 = 0 = 1  Variable

  28   8  WCBIG
  20  16  WCEXI
  33   3  WCHEA
  29   7  WCQUI
  23  13  WCSHA
  31   5  WCAWA

      Cases      Cochran Q      D.F.  Significance
       36        19.7826         5      .0014
```

GRAVITY ***BETTER***

OBJECTS

Example with rocket - - - - - Cochran Q Test

```
Cases
 = 1 = 0  Variable

  25  11  BABIG
   0  36  BBBIG
   7  29  BCBIG
   4  32  BDBIG
   1  35  BEBIG

      Cases      Cochran Q      D.F.  Significance
       36        64.1846         4      .0000


Cases
 = 0 = 1  Variable

  32   4  BAEXI
  28   8  BBEXI
  35   1  BCEXI
  33   3  BDEXI
  28   8  BEEXI

      Cases      Cochran Q      D.F.  Significance
       36        9.2381          4      .0554
```

```
Cases
 = 1 = 0  Variable

  7  29  BAHEA
  1  35  BBHEA
  1  35  BCHEA
  0  36  BDHEA
  3  33  BEHEA

      Cases      Cochran Q      D.F.  Significance
       36        13.5652         4      .0088


Cases
 = 1 = 0  Variable

  26  10  BAQUI
   2  34  BBQUI
   1  35  BCQUI
   9  27  BDQUI
   4  32  BEQUI

      Cases      Cochran Q      D.F.  Significance
       36        62.5294         4      .0000
```

```
Cases
 = 1 = 0  Variable

  18  18  BASHA
   2  34  BBSHA
   6  30  BCSHA
   2  34  BDSHA
   1  35  BESHA

       Cases      Cochran Q       D.F.  Significance
        36        37.8868          4       .0000
```

```
Cases
 = 0 = 1  Variable

  19  17  BAAWA
  34   2  BBAWA
  28   8  BCAWA
  34   2  BDAWA
  32   4  BEAWA

       Cases      Cochran Q       D.F.  Significance
        36        26.5333          4       .0000
```

GRAVITY ***WORSE***

OBJECTS

Example with rocket - - - - - Cochran Q Test

```
Cases
 = 0 = 1  Variable

   27   9  WABIG
   33   3  WBBIG
   28   8  WCBIG
   23  13  WDBIG
   29   7  WEBIG

       Cases      Cochran Q       D.F.  Significance
        36        9.4545           4       .0507
```

```
Cases
 = 1 = 0  Variable

  22  14  WAEXI
   9  27  WBEXI
  16  20  WCEXI
   9  27  WDEXI
   7  29  WEEXI

       Cases      Cochran Q       D.F.  Significance
        36        21.8333          4       .0002
```

```
Cases
 = 0 = 1  Variable

   19  17  WAHEA
   30   6  WBHEA
   33   3  WCHEA
   26  10  WDHEA
   34   2  WEHEA

       Cases      Cochran Q       D.F.  Significance
        36        24.0645          4       .0001
```

```
Cases
 = 0  = 1   Variable

  21   15   WASHA
  35    1   WBSHA
  23   13   WCSHA
  26   10   WDSHA
  35    1   WESHA

       Cases       Cochran Q       D.F.   Significance
        36         26.6667          4        .0000
```

Appendix 7.8 Cochran Q Test for transmission of heat

```
TRANSMISSION OF HEAT    ***BETTER***
FEATURES
Example with glass - - - - - Cochran Q Test

 Cases
 = 1 = 0  Variable

 14  24  BABIG
  0  38  BAEXI
  6  32  BAHEA
  1  37  BAQUI
 11  27  BASHA
  8  30  BAAWA

     Cases      Cochran Q      D.F.  Significance
      38        29.4805         5      .0000


 Cases
 = 0 = 1  Variable

 36   2  BBBIG
 31   7  BBEXI
 37   1  BBHEA
 29   9  BBQUI
 35   3  BBSHA
 33   5  BBAWA

     Cases      Cochran Q      D.F.  Significance
      38        14.3939         5      .0133


 Cases
 = 0 = 1  Variable

 33   5  BCBIG
 37   1  BCEXI
 33   5  BCHEA
 31   7  BCQUI
 26  12  BCSHA
 36   2  BCAWA

     Cases      Cochran Q      D.F.  Significance
      38        17.8462         5      .0031


 Cases

 = 0 = 1  Variable

 38   0  BDBIG
 36   2  BDEXI
 37   1  BDHEA
 31   7  BDQUI
 36   2  BDSHA
 31   7  BDAWA

     Cases      Cochran Q      D.F.  Significance
      38        16.1494         5      .0064
```

Column 1 = The number of children who chose this feature
Column 0 = The number of children who did not choose it

B = Making the example better
OR
W = Making the example worse

AWA = away
BIG = bigger
EXI = not exist
HEA = heavier
QUI = quicker
SHA = shape

A= glass
B = air
C = gas stove
D = hand
E = heat

```
- - - - - Cochran Q Test

 Cases
 = 0 = 1  Variable

 25  13  BEBIG
 35   3  BEEXI
 38   0  BEHEA
 29   9  BEQUI
 34   4  BESHA
 36   2  BEAWA

     Cases      Cochran Q      D.F.  Significance
      38        28.5200         5      .0000
```

```
TRANSMISSION OF HEAT    ***WORSE***
 Cases
 = 0 = 1  Variable

 29   9  WABIG
 21  17  WAEXI
 30   8  WAHEA
 35   3  WAQUI
 20  18  WASHA
 24  14  WAAWA

     Cases      Cochran Q      D.F.  Significance
      38        22.0130         5      .0005
```

```
Cases

 = 0 = 1  Variable

  36   2  WEBIG
  21  17  WEEXI
  34   4  WEHEA
  31   7  WEQUI
  33   5  WESHA
  30   8  WEAWA

       Cases       Cochran Q        D.F.   Significance
        38         26.5287           5         .0001
```

TRANSMISSION OF HEAT ***BETTER***
OBJECTS
Example with glass - - - - - Cochran Q Test

```
Cases
 = 1 = 0  Variable

  14  24  BABIG
   2  36  BBBIG
   5  33  BCBIG
   0  38  BDBIG
  13  25  BEBIG

       Cases       Cochran Q        D.F.   Significance
        38         28.0690           4         .0000
```

```
Cases
 = 0 = 1  Variable

  38   0  BAEXI
  31   7  BBEXI
  37   1  BCEXI
  36   2  BDEXI
  35   3  BEEXI

       Cases       Cochran Q        D.F.   Significance
        38         12.6957           4         .0129
```

```
Cases
 = 0 = 1  Variable

  32   6  BAHEA
  37   1  BBHEA
  33   5  BCHEA
  37   1  BDHEA
  38   0  BEHEA

       Cases       Cochran Q        D.F.   Significance
        38         12.6957           4         .0129
```

```
Cases
 = 1 = 0  Variable

  11   27  BASHA
   3   35  BBSHA
  12   26  BCSHA
   2   36  BDSHA
   4   34  BESHA

        Cases       Cochran Q        D.F.  Significance
          38        19.8222           4        .0005
```

TRANSMISSION OF HEAT ***WORSE***
OBJECTS
Example with glass - - - - - Cochran Q Test

```
Cases
 = 0 = 1  Variable

  29    9  WABIG
  35    3  WBBIG
  31    7  WCBIG
  27   11  WDBIG
  36    2  WEBIG

        Cases       Cochran Q        D.F.  Significance
          38        11.6078           4        .0205
```

```
Cases
 = 1 = 0  Variable

  18   20  WASHA
   5   33  WBSHA
   9   29  WCSHA
  11   27  WDSHA
   5   33  WESHA

        Cases       Cochran Q        D.F.  Significance
          38        23.0400           4        .0001
```

```
Cases
 = 1 = 0  Variable

  14   24  WAAWA
   3   35  WBAWA
  13   25  WCAWA
  15   23  WDAWA
   8   30  WEAWA

        Cases       Cochran Q        D.F.  Significance
          38        14.0556           4        .0071
```