DEVELOPMENT OF SCIENTIFIC REASONING IN PRIMARY AND EARLY SECONDARY SCHOOL PUPILS

by

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"I dedicate this Research to my brother, Safdar Hussain; who did so much to encourage me towards getting Higher Education. His untimely death in 1990 deprived me of a most delightful personality. His memory will always remind me to encourage and support his family".

TO MY PARENTS

"MY LORD! BESTOW ON THEM THY
MERCY EVEN AS THEY CHERISHED
ME IN CHILDHOOD"

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CONTENTS

CHAPTER THREE

3- RESEARCH METHOD-II

CHAPTER FOUR

4- RESEARCH METHOD-III

CHAPTER FIVE

5-DEVELOPMENT OF ACTIVITIES

CHAPTER SIX

6-RESEARCH METHOD-IV

CHAPTER SEVEN

7- SUMMARY, CONCLUSIONS, DISCUSSION

AND

RECOMMENDATIONS

REFERENCES

APPENDICES

ABSTRACT

This study focuses on the development of scientific reasoning chains in Primary and early Secondary school pupils. Overall 798 pupils at Primary and Secondary levels (age 8-14) participated in the empirical part of the research and were selected from four primary and three secondary schools in Glasgow city. Different techniques such as, interviews (in groups of two), structured questionnaire, and stations technique with an expert at each station for 1:1 interview were employed. A digit span backward test was also used for the measurement of the psychological factor (Working Memory span), a possible factor affecting the performance of the pupils.

To start with, alternative concepts held by the pupils were explored at various age levels. The alternative concepts explored have been placed in five categories. It was found that the pupils as young as 8 years have developed the ability to make sense of the world and start constructing concepts about different natural phenomena. It was also found that the pupils concentrate on the aspects of any phenomenon which can be felt by the senses. The aspects which are hidden, are difficult for them to explain. They cannot deduce hidden aspects with the mere help of senses and, are quite slow in developing deduction/ inference skills. This study indicates that their ability for deduction/ inference skills may be related to their Working Memory span and that this ability i.e. length of reasoning chain held, is always within the Working Memory of the pupils.

This study indicates that the pupils from 8-14 years of age can hold a maximum length of reasoning chain up to 4 reasoning steps. Moreover, this study shows that the pupils at Primary level had developed two kinds of explanations; i, e. purely alternative and a mixture of alternative and scientific explanations whereas the Secondary school pupils had developed three kinds of explanations; i. e. alternative, scientific and a mixture of alternative and scientific explanations.

CHAPTER ONE

1- CONSTRUCTIVISM

1.1. COGNITIVE MODELS/ THEORIES OF LEARNING

Children's minds are not blank slates [(1)] to receive instructions in a neutral way: on the contrary, children approach experiences presented with previously acquired notions and these influence what is learnt from new experiences in a number of ways . Children form ideas and interpretations as a result of everyday experiences in all respects of their lives: through practical activities, talking with other people around them and through the media. Individuals internalise their experiences in a way which is at least partially their own; they construct their own meanings. These personal 'ideas' influence the manner in which information is acquired. Observations of events are influenced by the theoretical frameworks of the observer. The observations the children make and their interpretations are also influenced by their ideas and expectations. Children construct sets of expectations or beliefs about a range of natural phenomena in their efforts to make sense of everyday experiences.

1.1.1. From the very earliest days in its life, a child develops beliefs [(2)] about the things that happen in its surroundings. Initially, these are isolated and independent of one another. However, as the child grows older, all its experiences of pushing, pulling, lifting, throwing, feeling and seeing things stimulate the development of more generalised sets of expectations and the ability to make predictions about a progressively wider range of experiences. Different psychologists [(1)] have incorporated this notion as an integral part of their theories. What children are capable of learning depends on 'what they have in their heads', as well as on the learning context in which they find themselves. Ausubel, [(3)] has described a process of 'meaningful learning' which results in the' subsumption' of new knowledge. In this process, the new knowledge interacts with existing concepts and is assimilated into them, altering the form of both the anchoring concepts and the new assimilated knowledge. To Piaget [(4)] learning is essentially an active process in which the learner constructs his knowledge through interaction with the environment and the resolution of the cognitive conflict which may occur between expectations and observations. What is assimilated depends not only on the environment, but on the learner's existing cognitive structure as well. If the dissonance is too great, assimilation will not take place at all. If there is no dissonance between an experience and a learner's cognitive structure then the information is assimilated without a change in the structure taking place. A view of learning as equilibration or adaptation between the learner and the environment places the learner in an active role. The child is seen as the architect of its own knowledge.

1.2. PIAGET'S THEORY OF (INTELLECTUAL) COGNITIVE DEVELOPMENT

1.2.1. Piaget's theory of intellectual development [(5)] has two components, one cognitive and the other affective. Piaget saw cognitive acts as acts of organisation of and adaptation to the environment. Piaget asserted that the basic principles of cognitive development are the same as that of biological development. From the biological point of view, organisation is inseparable from adaptation; they are complementary processes of a single mechanism, the first being the internal aspect of the cycle of which adaptation constitutes the external aspect. For Piaget, intellectual activity could not be separated from the "total" functioning of the organism. Thus, he considered the intellectual functioning to be a special form of biological activity. The processes responsible for cognitive development are assimilation and accommodation. Assimilation is the cognitive process by which a person integrates new perceptual, motor, or conceptual matter into existing schemata or patterns of behaviour. When confronted with a new stimulus:

a) a child can create a new schema into which he can place the stimulus (a new index card in the file),

b) he can modify an existing schema so that the stimulus will fit into it.

Accommodation accounts for development (a qualitative change), and assimilation accounts for growth (a quantitative change); together they account for intellectual adaptation and the development of cognitive structures. A state of "equilibration" between assimilation and accommodation is as necessary as the processes themselves. Equilibrium is the self-regulatory mechanism necessary to ensure the developing child's efficient interaction with the environment.

1.2.2. Piaget viewed cognitive development as having three components: content, function, and structure. For Piaget, all knowledge is physical knowledge, logical-mathematical knowledge, or social knowledge [(6)]. For conceptualising cognitive growth, Piaget divided intellectual development into four broad stages. Long periods of development can be subdivided into periods of shorter lengths to analyse and conceptualise development more efficiently. This does not in any way deny the continuity of development over its entire course, nor does it mean that the stages are selected without a rationale. Piaget broadly summarised the stages of cognitive development as:

1. *The stage of sensory-motor intelligence. (0-2 years).* During this stage, behaviour is primarily motor. The child does not yet internally represent events and "think" conceptually, though "cognitive" development is seen as schemata are constructed.
2. *The stage of operational thought (2-7 years).* This stage is characterised by the development of language and other forms of representation and rapid conceptual development. Reasoning during this stage is prelogical or semilogical.
3. *The stage of concrete operations (7-11 years).* During these years, the child develops the ability to apply logical thought to concrete problems.
4. *The stage of formal operations (11-15 years).* During this stage, the child's cognitive *structures* reach their greatest level of development and the child becomes able to apply logical reasoning to all classes of problems.

The chronological ages during which children can be expected to develop behaviour representative of a particular stage are not fixed. The age spans suggested by Piaget are normative and denote the times during which a typical or average child can be expected to display the intellectual behaviours that are characteristic of the particular stage. The age at which the stages occur can vary with the nature of both an individual's experience and his or her heredity potential. Progress through stages is not automatic. One aspect of Piaget's theory which is "fixed", however, is that every child must pass through the stages of cognitive development in the same order. Nevertheless, the rates at which children pass through the stages may not be identical because of experiential or heredity factors. Piaget suggested four broad factors that are related to all cognitive development; (1) maturation, (2) active experience, (3) social interaction, and (4) a general progression of equilibrium.

1.3. **Criticism**: Brainerd has raised certain theoretical problems with the Piagetian position on stages of cognitive (logical) development [(7)].

1. Piaget's stage concepts are largely descriptive rather than exploratory, because the conditions that explain or predict a child's behaviour in a particular stage are not known or specified.

2. The concept of structures cannot be used as an independent criterion for stages. The concept of structures has been criticised in that it describes tasks and not behaviour .

3. The Piagetian concept of stages is sometimes not supported empirically. Results discrepant with the theoretical position are reported for the Piagetian stages of sensory-motor functions, pre-operational thought, concrete operations and formal operations.

4. Piagetian theory assumes that manipulation of objects is important in the development of cognitive ability, particularly during the sensori-motor period. The co-ordination of reaching and looking is an example of a process that is important for cognitive development. The case of a child is reported [(7)] who was born with the complete absence of any limbs and whose interactions with objects consisted of "looking and listening and batting and rolling objects with his head and trunk". In spite of the very limited interaction with the environment, which was based entirely on distance receptors, this child showed normal cognitive and language ability at the age of three. A case of a woman is also discussed. She was in her early 40s with a head the size of an adult's, a body the size of an infant's, with completely non-functional limbs. This woman could read and talk well and was considered quite intelligent. This degree of non-interaction should retard cognitive development,

which, according to Piaget's theory, would never advance past the early sensori-motor stage.

5. Piaget's theory has led us to believe that the young child is egocentric, that is, it does not understand another's point of view. But Siegel et al (7) have reported a task in which a child knew something different from his or her mother. Because of immediate information, the two-year-olds did not understand the task and the three-year-olds had difficulty with it. However, the four-, five-, and six-year-olds behaved non-egocentrically and generally expressed understanding of what their mothers did and did not know, although they often could not justify their responses. Similarly, a game-like situation has been discussed in which children as young as nine can operate with a complex logical system and display formal operational structures.

6. Donaldson (8) argues that the evidence now compels rejection of a certain features of Piaget's theory. In her book, Children's Minds, she contends that young children's powers of reasoning are far greater than some of Piaget's claims would lead us to believe.

1.4. COMPARISON OF DIFFERENT COGNITIVE THEORIES. Piaget's theory focusses on logical operations a pupil can perform, whereas Ausubel's theory concerns the structuring of the content. Driver (4) makes a very important distinction, between these two complementary considerations. If learning new ideas depends primarily on what ideas a child already has, then it should be possible with a suitably designed sequence of instruction to teach any idea to a child at any age. If, however, there are structures of thought which only develop with age and experience, then it could be inappropriate to give instruction in those ideas at too young an age. According to the model introduced by the cognitive scientists, 'the information is stored in memory in various forms and that everything we say and do depends on the elements or groups of elements (schemes) of this stored information. This is a particular view of learning; a view in which learning is seen to take place through the interaction between a learner's experience and the 'mental entities', 'the ideas' or 'schemes' used to interpret and give meaning to those experiences.

1.5. INFORMATION-PROCESSING

1.5.1. People have written about human cognition for more than 2000 years. Only in the last 100 years, however, has cognition been studied scientifically. In the last 35 years, knowledge about human cognition has greatly increased. Cognitive psychology is presently dominated by the information-processing approach, which analyses cognitive processes into a sequence of ordered stages. Each stage reflects an important step in the processing of cognitive information [(9)].

1.5.2. It is clear that we can process certain signals selectively to the exclusion of others. A classical example of this ability is the cocktail-party phenomenon [(10)]. In a huge gathering, where everybody is talking, one can easily hear and respond if anybody calls one's name. An early awareness of this limitation (as mentioned by Reynolds)[(10)] was reported by Boring in 1950. During the nineteenth century astronomers attempted to time the crossing of stars by coordinating the visual event and the beat of a clock; this phenomenon became known as *the law of prior entry* and is often cited as indicating that only a single signal can be processed at a time. The law of prior entry suggests that the human organism has certain constraints on the number of signals, or the amount of information , that can be processed concurrently. Reynolds [(10)] has also reported a study which indicates that even when so instructed, subjects cannot successfully process two messages simultaneously. The role of attention is to control the allocation of this limited capacity among the incoming signals. The greater the attention devoted to a particular signal, the greater the capacity allocated and the more detailed processing the signal receives. These findings indicate some type of "bottleneck" in the processing system; a number of signals can have impact upon and actually enter the system, but at some point the structure of the system is such that not all may pass on to receive further processing.

1.5.3. An alternative approach to cognitive development has been [(11)] presented which uses the theory of information processing as the model which attempts to cast light on the processes of mental activity. In this model 'memory' is used as one of key concepts. It might be assumed that in order to handle the variety and quantity of incoming stimuli the human being must possess innate processes which enable a search for consistency and structure in the information received by the senses. This makes the process of coping with large quantities of information easier because it can be 'chunked'. These innate capacities are believed to be a discrimination process activated by the flow of stimuli from the environment, processes for the detection of regularities in structures and problem-solving processes.

1.5.4. The Information-Processing approach, firstly, views those activities which make up mental events as reflecting a flow of information. When one acts in a particular way as a result of seeing something (such as calling for help if there is an accident), the entire sequence of events is seen as flow of information: data are received by the senses, interpreted with the aid of what is stored in the memory, translated into a goal to produce a certain response, and then the goal is realised by recourse to mechanisms responsible for appropriate language production. Secondly, such an approach implies a rather mechanistic view of the mind: it is seen as a rule-governed system [(12)].

1.6. SEQUENCE OF LEARNING: To understand how learning takes place, one will have to consider the sequence of events which occurs in the learning of a single skill [(13)].

i. *Perception/ Input.* The first stage involves the apprehension and selective filtering of sensory input. It requires focussing the attention to the material to be learned, concentrating, and attempting to ignore other, potentially distracting events, so that only a limited amount of relevant material is perceived and registered in the nervous system. This information is encoded, usually verbally, in the limited capacity, short-term, working memory, STM.

ii. *Practice/ Rehearsal/ Storage.* Learning material must be practised or rehearsed until it becomes stabilized in memory. The transient store of short-term memory can allow for rehearsal into the more permanent and durable long-term memory, LTM. Here storage is now further organized and the material heavily influenced by its meaning in relation to past experience.

iii. *Access to learned material/ Retrieval.* We must have ready access to the learned material for future reference. The access of memory for required information is either organized for the output of an overt response or utilised in internal cognitive activity.

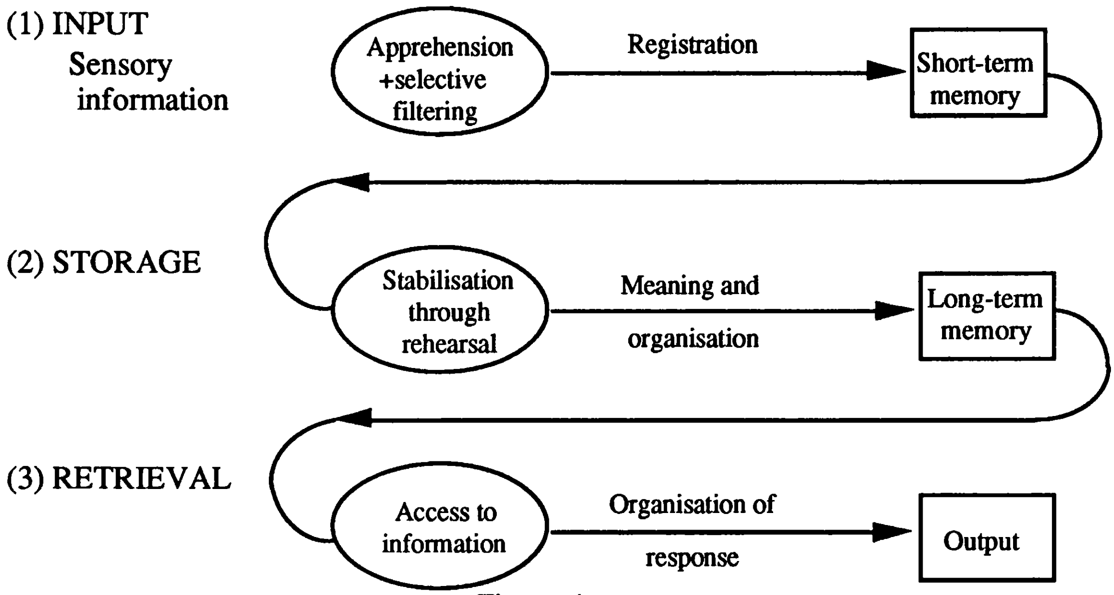


Figure-1

1.7. MAJOR FACTORS AFFECTING ATTENTION. There are different factors that influence attention/ perception which also must be considered for understanding learning. These factors are motivitation, set, contrast and novelty [(14)].

a) Motivitation. A stimulus which affects one's own needs, desires or concerns will capture attention and this heightens the perceptual sensitivity.

b) Set. This means readiness to perceive, which might increase or decrease the probability of stimulus attracting attention.

c) Contrast. It means size, intensity, movement, loudness etc. might affect attention. Wingfield [(14)] has mentioned research work which shows that an irrelevant message similar in content to the relevant message produces greater difficulty than an irrelevant message of dissimilar content.

d) Novelty. It can be seen as a combination of psychological contrast against a background of expectancy. It is highly dependent on individual motivation and experience.

1.8. **INFORMATION-PROCESSING MODELS.** It will be useful to examine some of the early information-processing models to understand the present achievments in the field:

1.8.1. Dennis [15] has discussed that at the beginning of the 20th century, James' work had generated considerable interest and attention among psychologists. Experimentation was not his strong point, but his insights into the processes of attention and perception served until early 1950s.

1.8.2. Gagné [16] presented an information-processing model, graphically, by sets of boxes and lines interconnecting them. Sometimes the boxes represent functions or states of the system and the lines represent transformations of information as it moves from one state to another. According to this model:

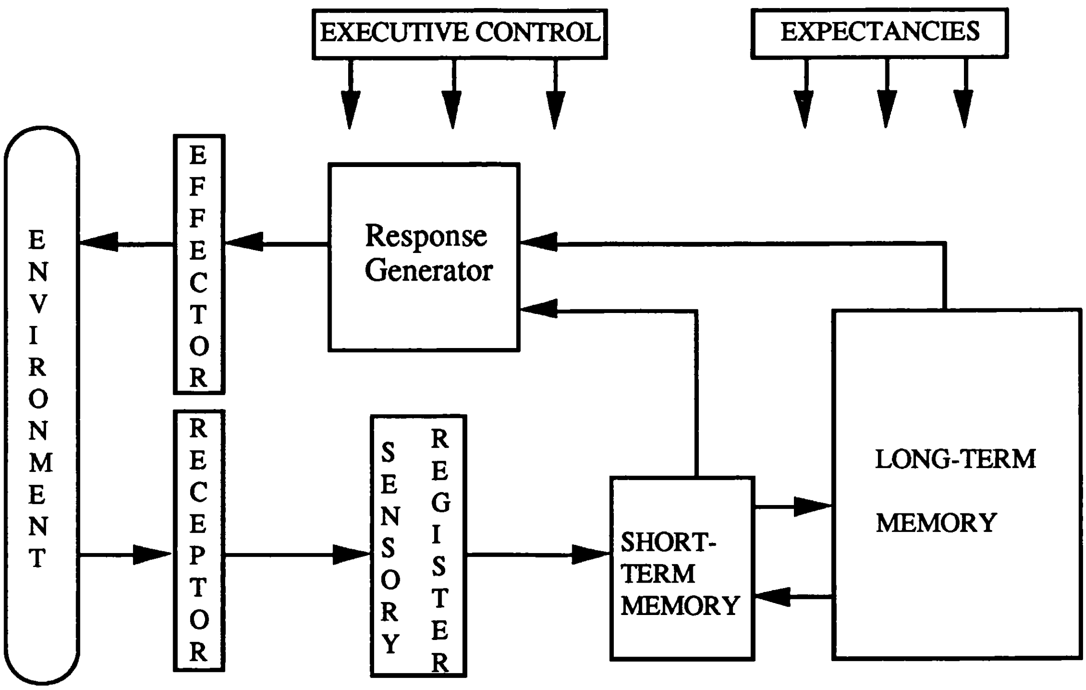


Figure-2

1) Events are described in terms of transformations of information from input to output.

2) Information is initially received by *receptors* and is registered centrally in sensory register. A portion of all information that is in the sensory register is transferred to *working memory*, but the rest is lost.

3) Working memory is limited in capacity and, if information in it is neither rehearsed nor coded, it will be lost. Coded information goes into *long-term memory*, which has a very large capacity.

4) Stored information may be retrieved. It is then organised by the response generator into a performance pattern that guides the effectors into a sequence of actions.

1.8.3. Broadbent's filter theory [17] of learning (theory of selective attention): Broadbent postulated the presence of three components in the processing system: a selective filter, a limited capacity channel, and a detection device.

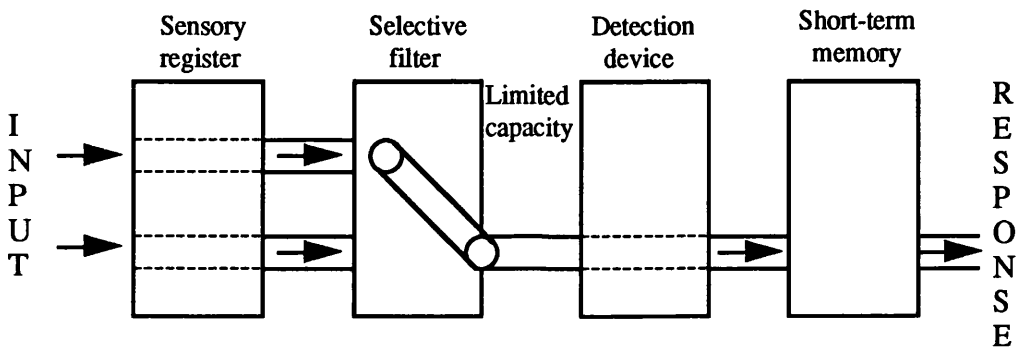


Figure-3: from Reynolds and Flagg (1983), Cognitive Psychology, [10] p.21.

The sensory register was assumed to have no definite capacity limitations and to accept concurrent signals in parallel. All the incoming signals were assumed to be retained momentarily in this store as a literal representation, much like a tape recording. While in this momentary store, the signals undergo a crude analysis of physical features such as sensory modality, loudness, spatial location, and shape. Using the the results of this *preattentive* analysis the selective filter screens out all those signals that are not to receive further processing. This filter can be viewed as a simple switch, much like a radio dial, which can be "tuned" to any one of a number of possible signals. Only information arriving in the selected signal or over the attended channel receives further processing. This further processing was assumed to be serial in nature, and the amount of time spent processing the signal depended on its information content. Thus two concurrent signals would be processed sequentially and the second would be processed only if it were still available in the sensory information store after processing of the first was completed. If two concurrent signals arrived, the system could process them both "simultaneously" only by serially switching attention between the two. Once it has passed through the filter and entered the detection device, the selected signal receives further analysis for meaning, for relationships with other material, or for any of a number of other possibilities. Information present on a non-attended channel or in a nonattended signal was assumed in Broadbent's theory to decay in a few seconds and to receive no processing beyond the initial preattentive analysis. Thus, "proponents of early selection [10] argue that selection among channels is based entirely on physical properties of the sensory information and meaning is extracted only from those signals which are selected for further processing".

1.8.4. Treisman's attenuation theory of learning [18]: Treisman argued that the filter does not act as a simple all-or-none switch, but rather serves to *attenuate* the irrelevant or unattended signals. Treisman also asumed that each sensory signal activates a "dictionary unit" in memory and that a threshold associated with the unit must be exceeded before the signal is actively perceived.

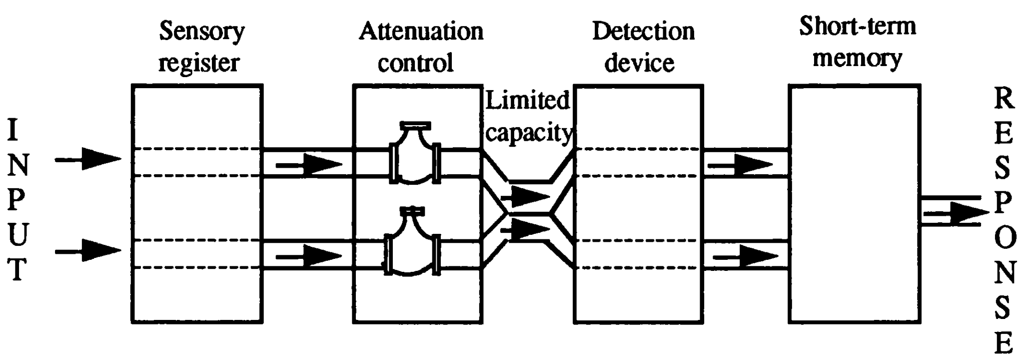


Figure-4: from Reynolds and Flagg (1983), Cognitive Psychology [10], p.21.

Generally the unattended message is lost if not probed for immediately. However this does not necessarily imply that the unattended message has no effect on the listener. Attenuation theory allows (although it does not presume) processing of several signals in a parallel manner, several at the same time, assuming the demands on the capacity are not too great.

1.8.5. Ninio and Kahneman's (1973) [19] experiments showed that the human being has a fair ability to deal with both messages. Norman [20] reported that performance of the relevant task presumably did not require all the capacity available, and the excess was used to further process the "unattended" message beyond the initial crude preattentive analysis.

1.9. INFORMATION-PROCESSING MODEL PROPOSED AT CENTRE FOR SCIENCE EDUCATION AT GLASGOW UNIVERSITY

This model gives an account of the processes and steps for an effective learning situation. According to this model, the learner has to filter out the useful information (signal) which is to be processed, and can also limit, or even exclude the extraneous, distracting information (the noise) [21]. The working memory is that part of the brain where we hold information (within short-term memory, STM), work upon it, organise it, and shape it before storing it in long-term memory for further use [22].

The important factor is that working memory is severely limited in its size and is capable of processing 5 to 7 pieces of information at a time [23] whereas STM has a capacity of 7 ± 2 chunks (according to Miller) [24].

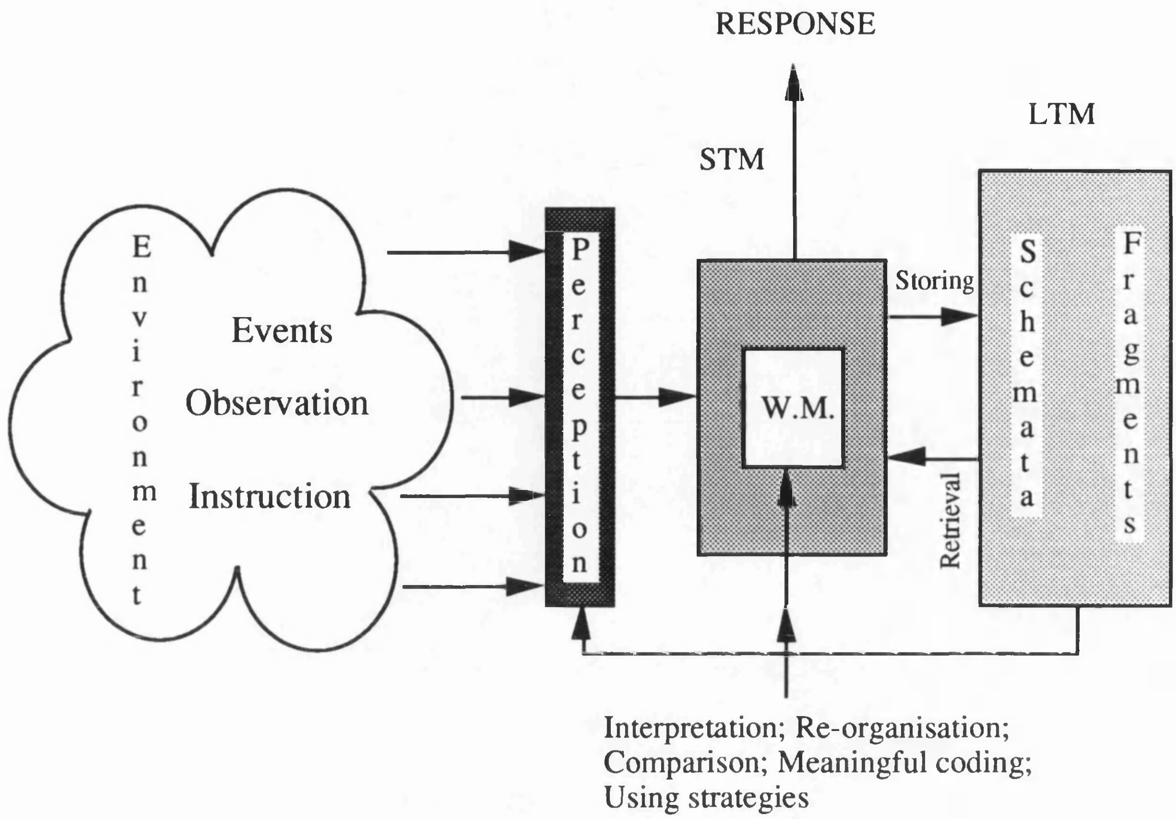


Figure-5: Model currently used at the Centre.

1.9.1. Science has special characteristics that make some issues more, and others less, prominent than they would be in a general description of learning. Especially important is the way in which the information presented and is filtered through a system of beliefs that the learner has established from observation of the world, a process that can lead to rejection or amendment of the information or to a change in beliefs (25). Therefore, the Information-Processing approach seems to be more appropriate for studying the learning of science and doing practical science in the laboratory.

1.9.2. The Information-Processing approach also seems to be appropriate for a constructivist approach to learning. An Information-Processing model takes full account of the learning processes; perception, attending to the signals, avoiding the noise, functions in the working memory and schemes and storage in long-term memory, LTM. Constructivism describes only the process of perception and the dissonance in the schemata or the misconceptions held in the LTM. Furthermore, the presence of alternate frameworks is one aspect of constructivism. So, in a sense, alternate frameworks are a subset of constructivism which in itself is a subset of Information-Processing. A constructivist approach is based on the assumption that the learner is active and purposeful during the learning process. He or she is actively involved in bringing prior knowledge to bear in order to construct meanings in new situations.

1.10. ALTERNATIVE FRAMEWORK. The belief that learning is an active construction process on the basis of the already existing conceptions has a long-standing tradition. The German educator Diesterweg (1790-1866) [(26)] pointed out that it is of utmost importance to start instruction from the student's point of view and that it is necessary for the teacher to investigate a student's preconceptions. The process of assimilation and accommodation are necessary for cognitive growth. Of equal importance are the relative amounts of assimilation and accommodation that take place. Whereas, everything must be assimilated by a child, the schemata the child uses may not be in harmony with those of adults (like classifying a cow as a dog), but the child's placement of stimuli into schemata is theoretically always appropriate for his or her level of conceptual development. There is no "wrong" placement. There are just better and better placements as intellectual development proceeds. These kinds of child's schemata, when they are not in harmony with those of the adults' might be termed as alternative frameworks [(27)]. Students' conceptions which are different from those generally accepted by the scientific community have been called[(28,28A)] 'misconceptions', 'preconceptions', 'alternate frameworks', or 'children's science'. These ideas and beliefs have also been given a variety of other names such as 'naive conceptions', 'spontaneous ways of reasoning', 'conceptual inventories', 'naive beliefs', 'naive knowledge', 'intuitive physics', 'children's beliefs', and so on. Driver describes these mental entities as 'intuition', 'intuitive notions', 'children's models' and alternative conceptions as well. Recently a number of studies [(29)] have highlighted the substantive aspects of children's and adults' thinking concerning Aristotelian ideas and beliefs. Some of these studies (as mentioned by Beno Boeha)[29] include: Viennot (1979), Osborne and Gilbert (1980), Watts and Zylbersztajn (1981), exploring the aspects of concept of force; Saltiel and Mulgrange (1980), Trowbridge and McDermott (1980) about velocity; Nussbaum and Novak (1976), Gunstone and White (1980) about gravity, and so on. Ricardo Trumper [30] also describes many of children's ideas on energy. He has also mentioned a bibliography updated by Pfundt and Duit (1988) which now contains more than 1500 research articles on children's and adults' ideas and beliefs in different areas of science subjects. Beno Boeha [29] reports some of the students' beliefs in mechanics, in particular about the topic of force. The results of this study support previous assertions such as:

"1. People, young and old, have descriptive and explanatory systems for scientific phenomena that develop before they experience the formal study of science.

2. These naive descriptions and explanatory systems differ in significant ways from those which students are expected to learn in their study of science;

3. The naive descriptive and explanatory systems show remarkable consistency across diverse populations, irrespective of age, ability or nationality;".

4. The naive systems are remarkably resistant to change by exposure to traditional instructional methods.

1.10.1. To those who have constructed them, misconceptions are not recognisable as different from any other explanatory knowledge. They are formed by the same process, take part in the generation of new knowledge and consequently are difficult to replace. As with construction, replacement involves the process of equilibration[31].

1.10.2. There is evidence that the same child may have different conceptions of a particular type of phenomenon, which are equivalent from a scientist's point of view, and even switching from one sort of explanation to another for the same phenomenon. It is often noticed that even after being taught, students have not modified their ideas in spite of attempts by a teacher to challenge them by offering counter-evidence. The students may even ignore counter-evidence, or interpret it in terms of their prior ideas. The student's interpretations and conceptions are contradictory, but none the less stable. Driver has documented [(1)] a number of children's ideas in different areas of science, such as, the studies in the area of student's conceptions in dynamics; Gunstone and Watts about force and motion; Nussbaum about the views of the Earth and particulate nature of matter in the gaseous phase; Tiberghien, the ideas about heat; Guesne, light; and Shipstone about electricity. These studies have been undertaken in a number of countries. The findings of these studies paint a consistent picture with students' early experiences of phenomena dominating their thinking. Driver has mentioned a number of studies [(32)] undertaken by Pfundt and Duit, 1985; Jung et al, 1982; Helm and Novak, 1983; Gentner and Stevens, 1983; Driver, Guesne and Tiberghien, 1985, which indicate that children develop ideas about natural phenomena before they are taught science in school. In-depth investigations have indicated that such ideas are to be seen as more than simply pieces of information; children have ways of constructing events and phenomena which are coherent within domains of experience yet may differ substantially from the scientific view. Studies also indicate that these notions may persist into adulthood despite formal teaching. Students' prior ideas are an important factor in their understanding of school science. Students make observations and inferences about phenomena which differ from those intended because of their different interpretive schemes. Observations are selected or rejected on the basis of their 'fit' with expectations. Children's conceptual schemes also infuence their investigations, the questions they ask, the variables they consider as influential or non-influential and the way results are interpreted. Children's schemes also influence their understanding of science texts; children construct meaning by relating what they read to what they already know and may therefore construct meaning other than those intended by the writer. Possible outcomes of the interactions between students' conceptions and science instruction have been suggested by Gilbert, Osborne and Fensham [(33)]. Solomon [(34)] has suggested that rather than trying to relate what is taught to their prior ideas, students may maintain them as separate domains, the 'life world' and the 'science world' each relevant to its own range of contexts. Harlen [35], while commenting on children's ideas, states that children form ideas about things around them before they are 'taught' about them in school. She has mentioned the work carried out at primary level by the Science Processes and Concept Exploration (SPACE), a joint project based at Liverpool University and King's College, London. She has reported some of children's explanations (ideas), listed in the *Space research reports* about the phenomena of Growth, Evaporation and Condensation, Sound, and Light. Kruger and Summers [36] have also reported research carried out under the SPACE project. This research shows that the scientific thinking of many teachers resembled that of children reported by many researchers during the last dacade. A number of teachers focussed on the properties of substances rather than on systems interacting. Andersson [37] mentions that "recent studies have shown not only that pupils have everyday conceptions of matter and its transformations that differ markedly from those in school syllabus, but these everyday conceptions largely persist even after their compulsory education has been completed". He further mentions "I have tried to characterise student's conceptions of matter in such a way that the *description* is communicable and leads to further development". He also mentions the very essence of student's reasoning as taking place within non-scientific frameworks. Baxter [38] has documented children's concepts about "day and night, changes in the Moon, Sun, stars and seasons". Prieto, Blanco and Rodriquez [39] describe the ideas held by Spanish students about solutions and the process of dissolution. It was found that, in general, these ideas relate to student's everyday experiences and that they are only marginally affected by the science instruction received. In attempting to explain the phenomena of one substance dissolving in another, students usually focus on the solute, whilst assuming a 'passive' role for the solvent. Osborne and Cosgrove [40] have investigated children's conceptions about familiar phenomena associated with water, e.g., evaporating, condensing, boiling, and the melting of ice, using a clinical interview technique. The results of the research indicate that children do have ideas about the changes of state of water which are quite different from the views of scientists. Champagne, Gunstone, Klopfer [(41)] and Gilbert and Watts [(42)] and Palacios, Cazorla and Cervantes [43)] have also documented a number of children's concepts in different areas of science. Driver and Easley [(44)] have mentioned different studies, such as, in a study of unfounded beliefs, Boyd (1966) showed that common misconceptions were held by secondary school pupils and that they appeared to be as prevalent among students studying science as among those who did not; reference is made to studies undertaken by Doran (1972) who studied the occurence of common misconceptions related to the kinetic theory of matter by 7-12 year old pupils; Za'rour (1975) in his study of science misconceptions among high school and university students in Lebanon isolated twenty misconceptions in the areas of Physics, Earth Science, Chemistry and Biology. Studies have also been undertaken by Jones and Lynch [(45)]; Mohapatra [(46)]; Eckstein and Shemesh [(47)]; Russel,Harlen and Watt [(48)]; Driver [(49)]; Bliss, Ogborn and Whitelock [(50)]and Longden, Black and Solomon [(51)].

1.10.4. A series of studies have been undertaken in Scotland by Johnstone, and his students, on selected conceptual areas in chemistry which indicates specific difficulties and misunderstanding arising in the course of instruction. Duncan and Johnstone [(52)] analysed the difficulties of 14-15 year old pupils in 9 schools. They reported three areas of difficulty including, for example, the misapprehension that one mole of a compound will always react with one mole of another. Johnstone and Mughol [(42)] noted that students (at all secondary school age levels) are familiar with basic symbols of electrical circuits but that there is also considerable confusion (again at all ages) for the meaning of common electrical terms like voltage and power. Similarly, Johnstone, MacDonald and Webb [(53)] studied misconceptions in the area of thermodynamics with 98 Higher Grade chemistry students. The results indicated 8 major misconceptions.

The studies reported here are an indication of the existence of a problem; pupils develop misconceptions which can persist despite instruction. However the development of a taxonomy (classification) of such misconceptions does not yield interpretive power. Not until the reasons for the misconceptions are understood will progress be made in instructional terms.

1.11. DISCUSSION. The studies mentioned above provide evidence that children develop alternate concepts about different natural scientific phenomena. Driver, Guesne and Tiberghien [1] have reported a variety of children's responses (from different researches) regarding different natural phenomena. For example,

i. In one study a large group of 12-16 year-olds was asked to say in a couple of sentences 'what heat is'. Although some of the 16-year-old pupils described heat in terms of energy, most of the younger ones and about one-third of the older pupils equated the idea of heat with a hot body or substance or described it as being given off from a heat source and such as, 'heat is energy; when it heats something up it will transfer the heat energy to what it is heating up; heat is warm air; heat is a warming fluid or solid....when you touch it, it feels hot-----if anything has got heat in it'.

ii. In another study, children aged 10-11 (P5-P6) and 13-14 (S1-S2) were interviewed in daylight and, in a sunny room. The children were asked 'Where is there light in this room'? Some children responded 'everywhere' or 'in space'; but the others replied:

- 'On the ceiling...light is there, but it isn't on (pointing to electric light bulb)'.
- 'In the bulbs; It is the bulbs that light up'.
- 'There (pointing to the ground)'.

Interviewer. Why do you say that?

Pupil. Because the sun beats down and you can see that it's lighter than in the shadow.

iii. On another occasion the children 13-14 (S1-S2) years old were asked to explain what a shadow is, and how a shadow is formed. The responses are:

'(A shadow) ...It's reflection but...it's a darker light'.

Interviewer. Is there any light on the chairs in the room?

Pupil (14 years): On some of them, there isn't any, because they are in the shade....Under the tables....(there's shade)....because there are...tables which hide the light....(A shadow)...it's the reflection of a person or a thing...You can't really see the person...You just see the shadow...the light shines on the person...behind the person, reflects his shadow.

iv. In various studies carried out by Nussbaum, the children from 8-12 years were interviewed about the shape of the Earth. The studies showed that the children believed the Earth they live on is flat and:

a. The Earth's roundness is just the roads' curves.

b. The Earth's roundness is just the mountain's shape.

c. The globe represents some other planet in the sky.

d. Is surrounded by ocean. This is what enabled Columbus to go round it.

e. Is surrounded by ocean. The round shape of this flat Earth is seen in photographs taken from space.

Having considered different researches Driver, Guesne and Tiberghien [(1)] noticed some common features of the children' ideas:

i. Pupils initially base their reasoning on <u>*observable*</u> *features in a problem situation.*

ii. Children consider only limited aspects of particular physical situations <u>*(the observable)*</u>*, with the focus of their attention appearing to depend on the saliency of particular perceptual features.*

iii. Children focus their attention on change <u>*(observable)*</u> *rather than on steady state situations.*

iv. While explaining changes <u>*(observable)*</u>*, children's reasoning tends to follow a causal linear sequence.*

v. Children use different ideas having a range of connotations which can be different and considerably more extensive than those used by scientists.

vi. Children make statements about a phenomenon depending upon the context.

vii. Ideas held by the children in one area influence the concepts in the other areas.

Apparently, all these features deal with the common factor "observation" in the children's responses.

1.11.1. Similarly, Harlen [35], reports some general features of children's ideas. Children's ideas:

i. emerge from a process of reasoning about experiences, rather than from childish fantasy or imagination;

ii. would not, however, stand up to rigorous testing against evidence that was often available for the children to use had they wished to do so;

iii. sometimes required additional evidence to be made available if they were to be tested in practice;

iv. were influenced by other information than that which came from media, conventions of speech and of ways of representing things, influential adults and peers;

v. were often expressed in terms of words which seemed scientific, yet had, for the children, a meaning which was ill-defined, difficult to pin down and not apparently consistent with the scientific meaning.

These features emphasise the main characteristic of the children's responses in that they emerge from experience.

1.12. **DIFFERENT TECHNIQUES OF RESEARCH REFERRED TO IN LITERATURE.** The techniques/ methodologies used during these researches, were test questions and interviews. Interviews were held on a 1:1 basis showing pictures and drawings. But difficulty of ensuring good communication, both through written words and through drawings, has been reported. This type of confusion may not present to the child the same real events as those intended. There was also the possibility that the child may not have previously had the experience to think about the situation they are suddenly confronted with and asked to comment upon.

1.13. Science is a major area of human mental and practical activity which generates knowledge, knowledge that can be the basis of important technological applications as well as of intellectual satisfaction. It is an important part of the education of all, not just of scientists, to be aware of the status and nature of scientific knowledge, how it is created and how dependable it is. Almost all scientific phenomena have two basic aspects a) observation and b) explanation (inference), but, none of the studies mentioned above has examined the children's responses on both of these bases. Moreover, alternative frameworks are a subset of constructivism whereas constructivism in itself, is a subset of Information-Processing. Working memory may play a major and primary part in the construction of the children's ideas (frameworks). No research, until now, has dealt with the development of the children's concepts as a function of or related to the working memory.

1.14. **AIM OF THIS RESEARCH.** This study sets out to explore different features of children's concepts for the explanation of different phenomena and to explore a possible relation, if any, with working memory capacity within the framework of the Information-Processing model.

CHAPTER TWO

2. RESEARCH METHOD-1

2.1. INTRODUCTION. Learning is an outcome of various influences of needs, perception of knowledge, abilities and attitudes. At the same time, learning rebounds on these factors by producing new knowledge, abilities and attitudes which in turn affect perceptions and needs [25]. During this process of learning children construct sets of expectations or beliefs about a range of natural phenomena in their effort to make sense of everyday experiences [2]. There is a huge body of research on misconceptions of students in a variety of science subjects [30]. The usual methods for obtaining information about students' misconceptions have been by questionnaires and individual student interviews. Osborne and Gilbert [54] and Watts[55] have described a variety of interview formats or procedures. Another line of research on misconceptions uses multiple choice tests. Linke and Venz [56,57] and Halloun and Hastenes [58] have used diagnostic tests in areas of Physics, and Haslam and Treagust [59] and Peterson [60] developed and used tests to identify misconceptions of years 11 and 12 (ages) students about covalent bonding and chemical structure.

When scientific explanations conflict with children's concepts, it might stop the learning process. To integrate new concepts, children may have to re-organise their ideas in a radical way. As a result of this conflict, children may have a revolutionary change in thinking. Even when this happens, new and old ideas may co-exist [61].

The present research work has its origins in children's alternative concepts. The ultimate aim of this study is to contribute to the exploration of general features of children's misconceptions and to explore a possible relation between alternative frameworks and the working memory span of the children. The immediate aim, however, is to attempt to understand how children think about some specific situations.

2.2. PILOT STUDY

There are several techniques mentioned in the literature which can be used for the exploration of children's ideas [62-66]. Each of these techniques has its specific advantages and disadvantages.

2.2.1. INTERVIEW

An interview is a technique for gathering useful information about individuals. When its purpose is mainly of data collecting, it may be referred to as a survey or fact-finding interview.

Advantages of interview:

i. It provides an opportunity to question thoroughly certain areas of inquiry and it permits greater depth of response than the questionnaire technique.

ii. It enables a researcher to get information concerning feelings or emotions in relation to certain questions.

iii. A trained interviewer can put the interviewee at ease and so to obtain his full co-operation.

iv.The interviews can be recorded for later use/ reference.

Disadvantages of interview.

i. It is a very time consuming procedure and, in terms of time spent, it is expensive to use.

ii. The interviewer might have to travel to and from the interviewee's home or workplace or school and so it can be expensive in terms of money.

iii. Its effectiveness depends greatly upon the skill of the interviewer, for even in the presence of a skilled person some subjects will not respond freely and accurately.

Types of interview:

1. Structured (respondent) interview. This type of interview means that:

a) Each subject interviewed will be asked the same questions in the same manner and order.

b) It is likely that the introductory and concluding remarks will be the same for each subject interviewed.

c) The answers given may have to fit some standard scoring system or procedure.

d) It provides important controls. The purpose of the interview is to satisfy the researcher's questions.

2. Unstructured (Informant) interview. This type of interview means that:

a. The purpose of interview is to gain some insight into the perceptions of a particular person (or persons) within a situation.

b. The interviewer attempts to help the interviewee express his or her own concerns and interests without feeling unduly hampered.

c. The researcher does not want to place restrictions on the questions asked or the responses given.

d. This flexible approach permits the interviewer to pursue certain responses as for as is necessary, to follow up important clues and to change the course of the interview when it seems advisable to do so.

e. In some situations the subject being interviewed may be asked very few questions and encouraged to express himself freely.

f. Questions can range narrowly or broadly and the records that result from different approaches are useful for different purposes (for making different sets of knowledge claims).

2.2.2. QUESTIONNAIRE

When the researcher is interested in acquiring data relative to attitudes, opinions, feelings, experiences and so on, he might collect the most useful information by devising an appropriate questionnaire. The questionnaire consists of a series of questions or statements to which individuals are asked to respond. Moreover, the questionnaire may be of an open-form or closed-form according to the needs of the research.

ATTRIBUTES OF A QUESTIONNAIRE.

a. It can be used conveniently when large numbers of respondents must be reached;

b. It requires little time to administer when compared with the interview.

c. It permits respondents to remain anonymous when they answer the questions.

d. It presents an even stimulus, potentially to large numbers of people simultaneously, and provides the investigator with an easy (relatively easy) accumulation of data.

e. If the questionnaire is mailed, the number of returns may be small.

f. The respondents may not answer all the questions asked; or, if they do, they may not answer them completely;

g. Carelessness, faulty memory, faulty perception and lack of interest may adversely affect the quality of responses.

h. There can be little assurance that all of the responses will be truthful.

i. Questions might be misinterpreted by the respondents.

2.2.3. CHECK LIST

The check list is a series of phrases or sentences that are to be checked in order to indicate the presence, amount, frequency, or order of occurrence of certain kinds of behaviour, characteristics or conditions.

ADVANTAGES:

a. Check lists are relatively simple data-collecting devices that are easy to construct and administer.

b. Provided the researcher wishes to limit responses in order to facilitate the analysis and tabulation of data, and provided that items can be constructed to cover all the areas of inquiry, the check list can be very useful tool for research.

c. Check lists present a good method of obtaining relevant data, which can be easily recorded, analysed and tabulated.

DISADVANTAGES:

a. The responses being restricted, may be a limitation in some kind of research.

b. The researcher cannot be sure that the responses are accurate and truthful.

2.2.4. OUTCOME. Keeping in view the advantages, the interview techniques were chosen for use during this phase of research. Moreover, it was decided to interview the children in groups of two in the hope that they would stimulate each other to talk and to avoid the embarrassment of 1:1 interviewing. This was considered necessary to involve children actively in the process.

Keeping in view the researcher's background, to make the research sample homogeneous and to make the research work directly applicable in the researcher's country, it was decided to include an equal number of children with Scottish background and with ethnic minorities background. Initially, expertise in interviewing both Scottish and ethnic minority pupils had to be developed. This was accomplished by visits to three local secondary schools. Approximately two visits were made to each of these schools and in each visit six children were interviewed. Thirty six children were interviewed in all at secondary 1 level. These interviews were audio recorded and transcribed afterwards.

2.2.5. SCHOOL PUPIL SAMPLE: The sample was selected randomly, with the help of class teachers, from three local secondary schools as shown below:

SERIAL. No.	NAME OF THE SCHOOL	NO. OF CHILDREN
1	Hyndland Secondary school	12
2	Hillhead Secondary school	12
3	Woodside Secondary school	12
Total number of children interviewed		36

table-1

2.2.6. **EMPHASIS OF THE PILOT STUDY**. The whole process was concerned with gaining expertise in the interviewing technique. Some information was also gained about the knowledge of the pupils' naive/ alternative explanations of natural phenomena. The topics chosen for the purpose were about the change in the size of the Moon, the Moon's eclipse, the rotation of the Earth , reflection, refraction, air-resistance, balance and change of day and night. Paper and wooden models such as paper planes, paper wind-mills, wooden aeroplane, paper kite, etc were used during the interviews. Different pictures were used to illustrate the phenomena in different ways for every group of children. (appendix-1). This helped the children to understand the questions and describe the phenomena. Some of the questions asked and children's responses are quoted here to give an idea about the concepts that they have at early secondary level.

1. A picture was shown to a group of children. In the picture a boy is skating in a half ramp. After asking some questions about skating, the researcher asked one pupil:

R (Researcher). Where do you skate normally?

P (Pupil). Just down the street.

R. But how do you skate on the street?

P. Put one foot on it and push with the other and go on the street.

R. If the street goes upward like this ramp then....?

P. You go back down.

R. Why?

P. Because gravity pulls it down.

The pupil has the idea that gravity pulls things only if they are on the slide or (might be) raised above from the ground.

2. While asking a series of questions about balance, the researcher asked:

R. While sitting on the chair, are you balanced?

P. Yes, because if it has one instead of four legs, I will fall back.

The pupil, on the basis of everyday experience, had developed the concept that a chair can be balanced only if it had four legs.

3. The researcher shows different mirrors (looking glass, convex mirror and concave mirror etc.) to a group of children. Convex and concave mirrors are of the same size. The questions asked and the answers of the children were like this:

R. When you look in these (convex and concave) mirrors what do you see?

P. This (convex) makes smaller image and this (concave) makes larger.

R. Why?

P. This (concave) has got more power in it. This (convex) is thicker and heavier.

The children had the idea that the concave mirror had some kind of power in it which enlarges the image and thickness and weight of the other (convex) mirror that reduces the image.

2.3. FIRST PHASE

2.3.1. INTRODUCTION. For getting on with the actual research, it was necessary to expand the list of topics on natural phenomena related to everyday life experiences. The topics of evaporation, energy, forces, gravity and conduction were added. Moreover to make the interviews more interesting for the children, practical situations were created by using a toy helicopter, models made of card, a wooden hammer, a silvered spoon, a polished drum, a car-mirror, ordinary mirrors, compact mirrors, different convex and concave mirrors, a dental mirror, different convex and concave lenses, a spinning top, an air freshener, a can-opener, a water game (in which a monkey moves by pressing a button), an echo killer which gives different sounds while pressing different buttons, a spray bottle, a water pistol, different contact lenses, a magnifying glass, a pair of spectacles and a toy motor-bike. The pictures, models, toys used for the interviews are given in appendix-1. To encourage the children to take an active part in the interviewing process, they were again interviewed in pairs. The questions asked of the children were very simple, e.g. What do you think about this picture? or will this model (of kite/ aeroplane) work? or how is some specific situation possible?

2.3.2. THE SCHOOL PUPIL SAMPLE. To explore the development of naive/ alternative ideas/ concepts with younger children, the interviews were extended to primary school and children from P6 and P7 (ages 10, 11). Three children from P5 (age 9) were also included. The number of children at each level in different schools is shown below (Table-2) :

SERIAL No.	NAME OF THE SCHOOL	NO. OF CHILDREN		
		P5	P6	P7
1	Willowbank Primary school	0	12	12
2	Dowanhill Primary school	3	10	8
3	St.Charles' Primary school	0	5	7

Table-2

2.3.3. **THE PROCEDURE FOR SELECTION OF THE SAMPLE.** The selection of the sample was completed by the teachers concerned. Care was taken to include an equal numbers of children with Asian and Scottish background and equal numbers of male and female pupils. Every group was interviewed for more than one phenomenon (topic). The number of children interviewed for different topics is given below.

SERIAL No.	PHENOMENON	NO. OF CHILDREN			
		P5	P6	P7	Total
1	Refraction	3	5	10	18
2	Reflection	0	8	14	22
3	Rotation of Earth	0	0	2	2
4	Balance	0	4	2	6
5	Force	0	2	2	4
6	Evaporation	0	6	4	10
7	Pressure	0	8	0	8
8	Energy	0	2	2	4
9	Conductivity	0	0	6	6

Table-3

2.3.4. ADMINISTERING THE INTERVIEWS. To administer the interviews properly the permission of the Strathclyde Education Authority, the parents and teachers was sought.

As a result, contact was made in Willowbank Primary, Dowanhill Primary, St.Charles' Primary and Anderston Primary schools. This phase started in early 1990. Overall 57 children at three primary schools were interviewed. The duration of each interview was about 15 minutes and the interviews were held in groups of two. All the interviews were audio-recorded and then transcribed.

2.3.5. DESCRIPTION OF RESULTS. General results are reported here but will be discussed in detail later.

1. **Refraction.** Three children at P 5, six at P6 and ten at P7 were interviewed for this topic. Only 3 out of 18 children could use the word 'refraction' and no one could give a scientifically correct explanation of the phenomenon. Instead, most of the children gave alternate concepts which are reported on the following pages. There was only one child who had some concept about the curvature of the lens.
2. **Reflection.** Eight out of 22 children at P6 and P7 could use the word 'reflection' but no one could explain it scientifically correctly. All of the children offered their own constructed concepts which are reported on page 33 onward.
3. **Rotation.** The only two children interviewed for the topic could state that the Earth revolves around the Sun but with no further explanation. No one could give a scientific explanation for the change of day into night or vice-versa or the change in the size of the Moon or about the change in weather. The children were lost for words most of the time. That is why no more children were interviewed for these phenomena.
4. **Balance.** The explanation for the concept of 'balance', as given by many children was quite good and they could explain 'balance' to some extent. The children's explanations will be described later.

5. **Force**. Two out of four children could use the word but did not have any idea about force as used in science.

6. **Evaporation**. Three out of ten children could use the word 'evaporation' but with no further scientific explanation.

7. **Pressure**. Four out of eight children could just use the word but could not give any further explanation.

8. **Energy.** All of the four children interviewed were able to use the word 'energy' but were unable to give any scientifically correct details about the phenomena.

9. **Heat**. Six children at P7 were interviewed for the topic. For the concept of heat, no child could say how heat is transfered from one object to another.

2.3.6. All the children who could recognise different phenomena (although they could not explain them) were able to do so due to the fact that the pictures/ photographs/ models and toys used during the interviews were quite familiar to them, e.g:

REFRACTION. Spectacles and magnifying glass.

REFLECTION. Mountain reflection in a lake, shaving mirror, make-up mirror, a person standing in an "Echo valley", a car mirror and a dental mirror.

BALANCE. A boy skate boarding on a ramp and girls doing gymnastics.

FORCE. A can opener, a man breaking a pile of slabs with his hands, people pulling/ pushing a car, a car driver applying brakes.

EVAPORATION. A woman drying her hair with hair-drier.

PRESSURE. Water pistol, washing liquid spray, a dropper filled with water.

ENERGY. A spinning top, a burning candle, battery, heat from the Sun, plants being used as food, a man using his strength and a water dam.

2.3.7. During the interviews, however, (for the majority of the above phenomena) certain *naive /alternative concepts* were noted. Some of the sample responses are given below:

REFRACTION

1. Two beakers are presented to a group of P7 (12 years age) children. One beaker is half filled with water and the other is empty. A pencil seems to be broken when dipped in the beaker having water in it (Fig. 6).

FIRST GROUP (P7)

I (Interviewer). What about this? When the pencil is dipped in one beaker (having water in it), it appears to be broken, and when put in the other (empty), it is seen straight?

P (Pupil). No....o. it is just water effect.

Figure-6

SECOND GROUP (P7)

I. Can you see this pencil (when the pencil is dipped in the water)?

P. It looks like bent, because you kept it like that (vertical), I will hold it and it will look straight. (The child tries and fails and is worried).

I. But why is that part seen (dipped in water) thicker than the other part?

P. Because we cannot see for the water, that's why that looks thicker.

2. A fisherman is fishing. The water seems shallow but when he enters it is quite deep. The fisherman is astonished (Fig. 7).

Figure-7

FIRST GROUP (P7)

I. Can you tell me about it?

P. Just a swimming pool,... Amm. The water is not really that deep but when you jump into it, it comes up to your neck.

I. Why?

P. Just the water has its effects.

3. A picture (Fig. 9) is shown in which there is a glass with a long stem. On one side of the glass, there is a handkerchief with a glass slab on it. The handkerchief looks as if it is torn.

Figure-8

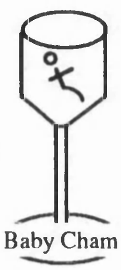


Figure-9

IST GROUP (P7)

I. Why does this (handkerchief) look torn?

P. Because of the mirror (glass slab).

Now another glass with a long (Fig.8) stem, full of water is presented to the children. On one side, it had a picture of a deer and at the foot of the stem was written "baby cham". While looking through the glass full of water, the words and the picture are seen bigger.

I. What causes them (words and picture) to become bigger?

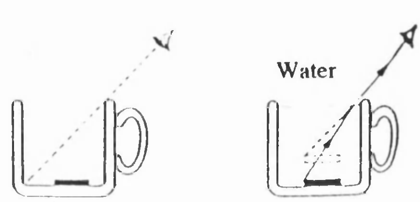
P. Water.

SECOND GROUP (P7)

I. Why do the picture and the words, when seen through the glass, look bigger?

P1. Thickness of glass and how much water is in it.

4. A small drinking glass (container) with a coin at the bottom is shown to children. (Fig.10) Water is put in the container and the coin is seen to be bigger.



IST GROUP (One girl from P5)

I. What happens to its size (after water is poured in the container)?

P. It looks bigger.

I. What is the reason?

P. The reason...... because I think the coin has got the reflection coming in, so it looking bigger..reflection.

I. Reflection. What is causing the reflection?

P. Due to water, I think so.

Coin is put in a rectangular container, with water in it, and the interview goes on.

I. If we put water in this container, can you see any difference in the size of the coin?

P. I think that (change) may be due to the glass because it was the shape of the glass that reflection was coming.

I. If we put this coin into this glass, then? (The coin is put in the empty container).

P. The shape of the glass and the water. If there is water and shape is like that, the coin will be seen bigger (the child rectifies the idea after the experiment).

SECOND GROUP (P7)

I. What happened to the coin (after the researcher poured water in the container)?

P. Gets bigger.

I. Why this is so?

P. Because of water the coin is magnified.

5. A line diagram of a person wearing glasses, while sitting on a table, is shown to the P7 children (Fig.11). On one side of the person in the diagram, there is a table lamp, and he is reading a book.

I. Why he is sitting (like that) straight on the chair?

P1. He is blind or something.

P2. Reading Braille with his fingers or like that.

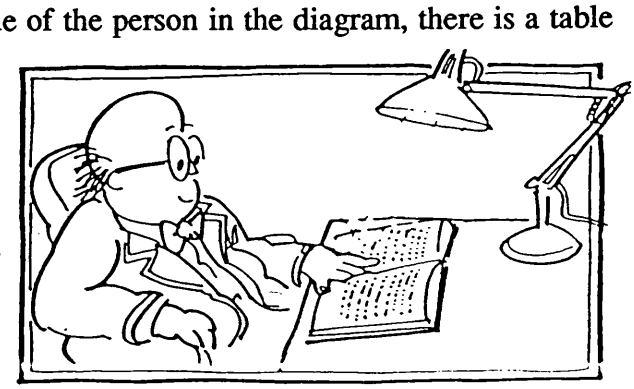
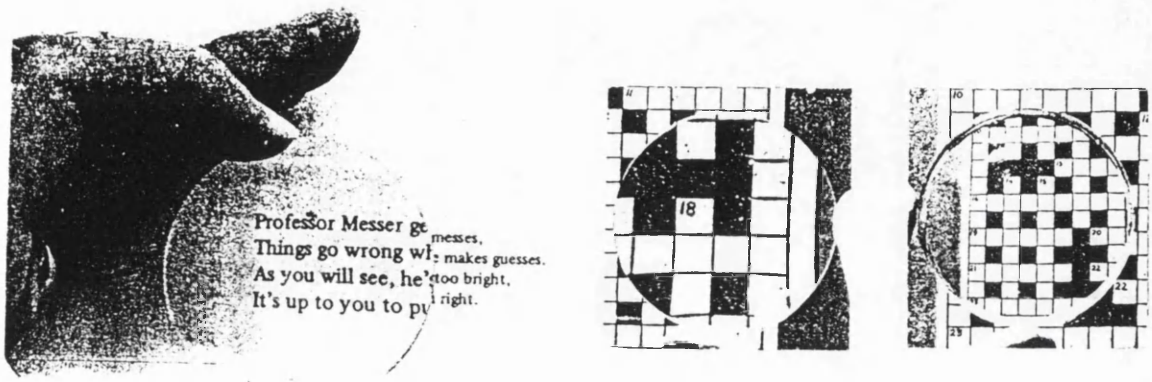


Figure-11

P1. May be kind of glasses like those that Steavie Wonder wears, who also look into eyes; walk amazing as he is blind, seems wonderful.

6. A pair of concave and convex lenses is shown to the children (Fig.12). They are asked to read some writing through these lenses. The words are seen of different size through different lenses.



FIRST GROUP (P5)

Figure-12

I. What is the cause of this (why does the size of the writing change)?

P2. (Sighs). This is because this is bigger than this and this is more big than this.

I. So this is the bigger glass through which the words are seen smaller?

P2. No. Through smaller glass the words are seen smaller.

P1. The big one, you see, bigger and smaller because this is thicker (points to the thickness).

P2. Because the glass are shaped differently.

I. What do you mean by shape?

P2. This is round one and a thin one, and this is a round and thick one and this is a round and very small. This one is just like square (refers to glass slab), and this one is rectangle (refers to a transparent piece of glass).

SECOND GROUP (P6)

I. Why are the words seen to be of different size in different glasses (lenses)?

P2. The way that they are made like that (the child shows by touching the surface; refers to the curvature of the lens).

P1. Yes and from thickness.

THIRD GROUP (P6)

I. Why are the words seen through this (concave lens) smaller and through this (convex lens) bigger?

P. Because that one is thicker and that one is thinner. The glasses have different magnifying power; because all the glasses are different, that becomes smaller, that becomes much bigger, width and type of glass.

7. A magnifying glass is shown to the children. The children see words bigger through this.

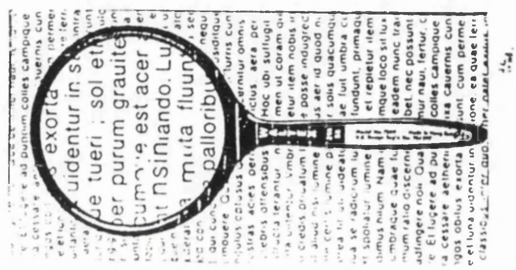


Figure-13

FIRST GROUP (P5)

I. What makes the words become bigger?

P2. Because the glass is very big.

8. A glass slab is put on writing in front of children . The words seem to come up towards the viewer (Fig.14).

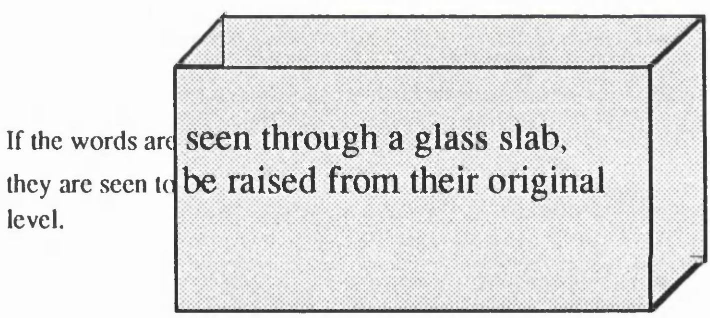


Figure No.14

FIRST GROUP (P5)

I. What about the words?

P. They are bigger, I think. These words are coming nearer. We can see the near things. This can be used for the people whose eye-sight is weak for nearness.

SECOND GROUP (P6)

I. What makes them (the words) come up?

P1. I think is a chemical inside the glass (slab).

9. A girl wearing glasses is interviewed.

ONE GIRL (P5).

I. What is used in these glasses to make you able to read?

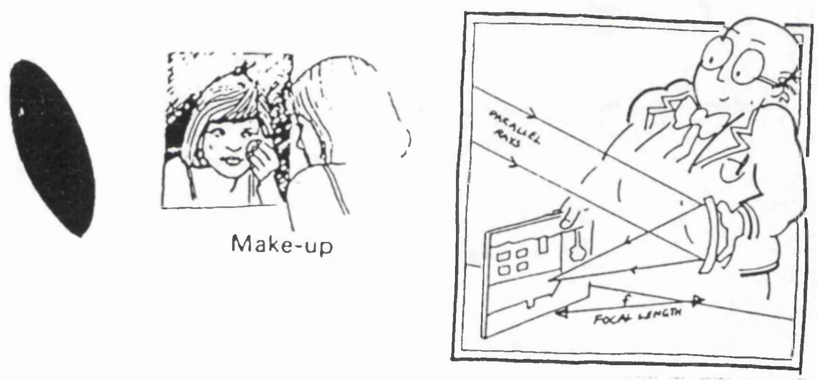
P. These are lenses and they are very powerful. All the glasses are not of the same power, there are many powers.

I. What do you mean by power?

P. (The child gives the whole story, the doctor has told her but could not explain what the power is).

REFLECTION

1. Convex and concave mirrors and a rectangular normal looking mirror are shown to the children. The children see their images of different sizes in the mirrors.



FIRST GROUP (P5)

Figure-15

I. What makes the images different while looking in different pieces of glass?

P1. Well I think it (refers to concave mirror) does have glass over here (behind), It is covered (refers to the paint at the back).

P2. This one is smaller, that one bigger. This is a big one but has a cover (paint on one side) behind it . So it makes the face smaller . But it is smaller and it also has cover behind it . But if we see through this I can see my face bigger.

I. So, what makes it different?

P2. The cover at the back (paint at the back).

SECOND GROUP (P6)

I. What makes the images bigger or smaller?

P1. May be a better kind of glass.

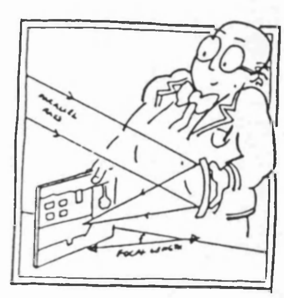



Figure-16

P2. Different kind of glass, that may be different from that.

THIRD GROUP (P7)

I. Why is your face seen to be smaller in this?

P. Could be a smaller mirror.

I. Can you see your image in this (a concave mirror but of the same size)?

P. That is much bigger image.

I. Then what makes different pictures in two mirrors of the same size?

P. This is heavy, this is thick one, and that is a thin one. There is something got into it. I have seen this kind of a big one. That is bigger, that is heavier.

FOURTH GROUP (P7)

I. You see, the mirrors are of the same size but why in one is there a smaller image and in the other a very large one?

P2. May be it is made. It is made a different kind.

P1. Just made of some sort of different material.

2. A line diagram of a person shaving in front of a mirror is shown (Fig.17). The name of the person is written on his vest but through the mirror that is seen to be reversed.

FIRST GROUP (P5)

I. Can you read his name?

P1. I can read with the help of a mirror (and the child reads his name).

I. Why do you do that ? You look in the mirror and you read it, why?

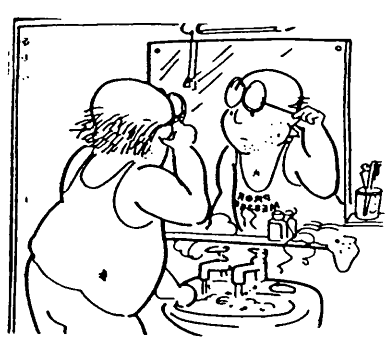


Figure-17

P1. Because if we look in a mirror we need another mirror.

I.Why?

P1. I have done an experiment in school.

SECOND GROUP (P6)

I. can you read his name for me?

P2. Pro....o...fe.....prof....professor. ...... mess.......

I. Why it is difficult to read?

P2. Oh, it is through the mirror...

P1. And (continuing the statement) it is backward and its' going over like that, and you can only see some of that, not all of it.

P1. Reflects that was turned round.

P2. The mirror turns them round.

THIRD GROUP (P6)

I. Can you read his name?

P2. P...r...a...n...kk. (He could not read it).

P1. John.

I. Why you can't read it?

P1. It is upside down.

I. Why?

P1. Because of the mirror. If we see in the mirror, it goes upside down.

I. Is it the mirror that makes the words upside down?

P. Ya.

I. How do you know?

P. We did it last time in P5.

3. A picture is shown to the children. One person is seeing his magnified eye image in a concave mirror and the other a reduced image in a convex mirror (Fig.18).

FIRST GROUP (P6)

I. What do you see in this?

P2. That one makes it bigger and that one makes it smaller.

I. What about this (about concave mirror)?

P2. This is magnifying glass, like a telescope.

P1. Must be something in the mirror, makes it bigger and smaller.

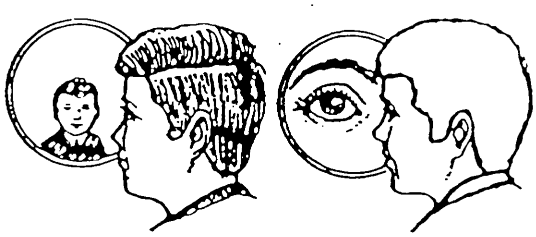


Figure-18

4. A normal looking glass of larger size as compared to convex and concave lenses) is presented to the same group.

Figure-19

FIRST GROUP (P6)

I. What about this?

P2. Yes, I can see bigger.

I. Is this the same in which that person is seeing his full image (bigger)?

P2. Ya, magnifying glass.

I. What makes different images in different glasses?

P1. Different shape, this is thicker and this is thinner.

P2. I think there is something inside it, and at the top there is kind of glass. There is a mirror behind and a glass at the top of them.

5. A compact (make-up) mirror is shown to the children. In the normal mirror, a normal image is seen whereas in the concave mirror a magnified image is seen.

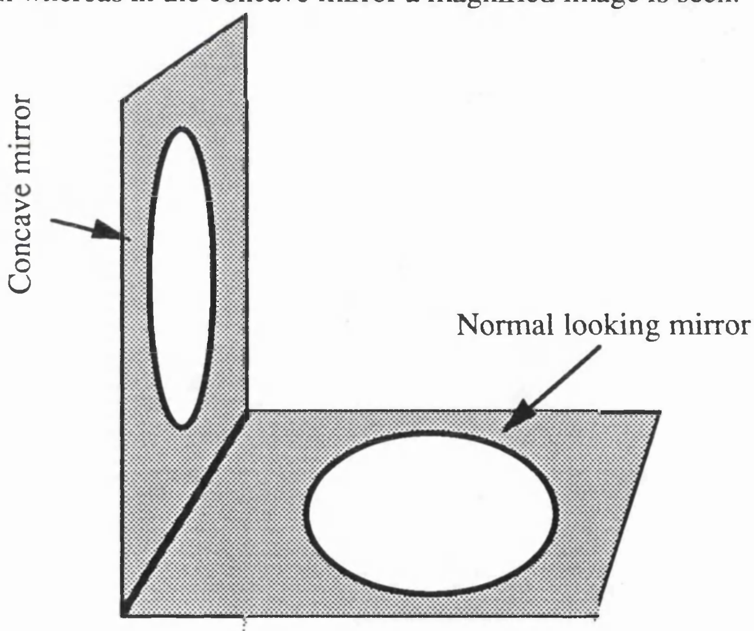


Figure-20

FIRST GROUP (P6)

I. What makes your image normal in one mirror and enlarged in the other?

P1. It is due to the mirrors together your face is going bigger; may be shining one to the other.

I. If they are separated, then?

P1. That will not be bigger.

SECOND GROUP (P7)

I. What makes the size of these images different from each other?

P1. Colour (paint on the back) makes it different.

P2. May be, put a black background behind it and a silvery background behind it. Put silvery angled, somehow it is made the figure......something behind the glass (mirror).

THIRD GROUP (P7)

I. Why is one image seen normal and the other magnified?

P1. There is a mirror underneath and a magnifying glass on the top.

6. A line diagram of a Lollipop lady (Fig.21) is shown to the children at P6 level. She is wearing a white coat and a white cap with a white sign "stop" in her hand.

I. Why is she wearing white coat and white cap?

Figure-21

P. Because she is a lollipop lady. She liked it and bought it ; She is outdoors.

7. A line diagram of a person in an "echo valley" is presented to the children of P7 (Fig.22).

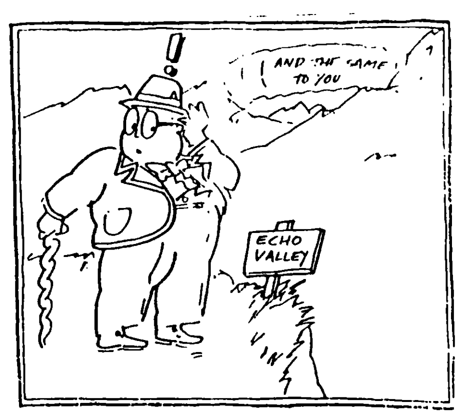


Figure-22

I. What do you think about this picture?

P1. I think the valley is steep, going down, and someone talks. I think the mountain is bigger, so the mountain can reflect; say the same back.

P2. He said hello, and see, the mountain says, same to you, so we joke.

I. What kind of reflection is taking place here?

P1. The voice.

I.The voice! So voice can be reflected?

P1. Yes.

While continuing a series of questions about reflection:

I. In addition to water, is anything, that can be used for reflection?

P1. A mirror......a piece of glass in which you look at.

P2. Something silver, gold, clean, polish, you can see through it.

ROTATION

Different photographs are shown to the children at P7 level.

1. A photograph of sun-set is shown. The scenery shows it to be autumn.

I. Before Sunrise, why it was night?

P1. Because it was dark.

I. Is day and night here (in U. K.) of equal length?

P1. No. Because sometimes a longer day and sometimes shorter.

P2. In winter it gets dark straight away at 4.00 o'clock and in summer it goes till 8.00 o'clock.

Figure-23

I. Why it is sometimes longer and sometimes shorter?

P1. The Earth moves.

I. Why is it sometimes winter and sometimes summer?

P1 & P2. No response.

2. A photograph is shown in which trees and flowers of different colours are seen.

I. How can you see different colours?

P1. No response.

I. Can you see these colours at night?

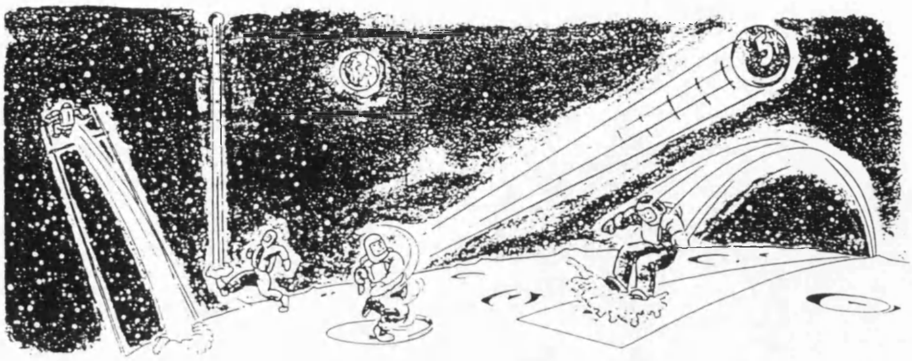
P2. No, it is dark.

I. It is dark. So, how do these colours appear?

P1. From the Sun.

3. A photograph is shown. Some astronauts are playing games on the Moon(Fig.24).

I. You see, a man throws far away, a footballer can kick very high, and an athlete can jump so long; how this all is possible?



P1. Because of the small gases in the Moon.

Figure-24

I. How does the Moon change its shape?

P2. The Sun causes it. It is small behind the Sun; Because it only moves a wee bit at a time.

4. A photograph about tides in the sea is shown (Fig.25).

I. Have you seen that water comes up and then goes down on a beach?

P2. Tide, waves.

I. Why does that happen?

P1. The wind causes it.

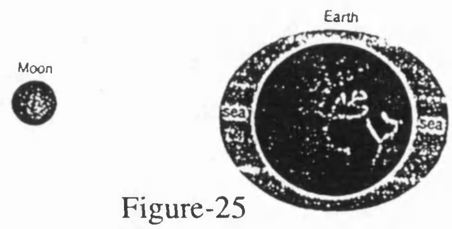


Figure-25

BALANCE

1. A picture is shown in which a child is skate-boarding on a half ramp. There is a rod on one corner of the ramp. At present the boy is near the top of the corner of the ramp and is holding his arm out (Fig.26).

FIRST GROUP (P6)

I. Why does he come back down?

P1. He may have to go home or somewhere else.

Figure-26

I. O. K; But you see, at this moment, he is holding his arm like this. Why?

P2. I think he is going to hang on to there.

SECOND GROUP (P7)

I. Why does he come down?

P. Because gravity pulls down.

I. What do you mean by gravity?

P. No response.

2. A picture is presented in which an acrobat is standing on a rope (Fig.27). He is holding a plank on his head on which two girls are standing. He is holding a long pole in his hand.

FIRST GROUP (P6)

I. Why he is holding the pole in his hand?

P1. So he won't fall; to give him balance.

P2. Because, you know, that ladies, if they move one step here, you know, the balance would go on this side. So, you know, all three of them, will fall.

The researcher showed them three photographs and asked, whether they could explain balance.

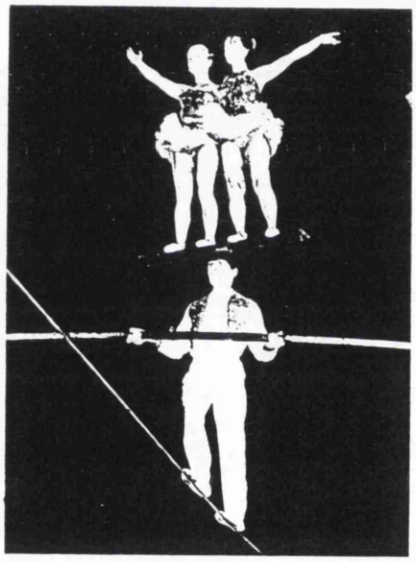


Figure-27

I. So, with the help of these three photographs, can you tell me what balance is?

P1. A....a , the meaning of balance......

P2. Ya. Keep things straight.

SECOND GROUP (P6)

I. How they can stand like this (like the acrobat standing on a rope)?

P1. It is a camera trick.

I. Why he is holding the pole in his hand?

P. So he can hold on it just in case he falls.

THIRD GROUP (P7)

I. You see, how they are standing?

P2. They have got a balance (the child points to the pole as balance).

3. A picture of a girl doing gymnastics is shown to P7 children (Fig.28).

Figure-28

I. Why she is keeping her legs apart like this, separate?

P. To keep balance.

I. Can she keep her balance if she puts both legs together on one side?

P. One side will be heavier than the other.

I. With the help of three pictures (skate-boarding on a ramp and the girls doing gymnastics) can you tell me about balance?

P. Say you were walking along a wall, step by step, you would have to put your arms out and keep your balance. Similarly, when he is going up the wee skate board he keeps one foot behind the other to keep his balance. So that when he is going down there, then he is okay. So that he cannot go flying off there. Because he could fly off that side. If she (in the case of girl doing gymnastics) puts her legs on one side she would have too much weight on one side and she would fall off. That's how she has to keep her balance on her head.

4. A picture in which two persons are carrying ladders on their shoulders, is shown to the children (Fig.29).

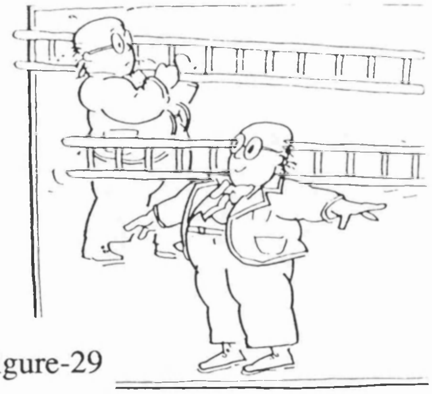


Figure-29

FIRST GROUP (P7)

I. You see, here (one person) is carrying a ladder on his shoulder but he is holding it with both hands. While here (the other) he is not holding the ladder at all. Why?

P2. He can show that he is carrying without touching. While the other is carrying with hands. He can show that he is better than him.

P1. Like this (pointing with hands), the ladder may be balanced.

SECOND GROUP (P7)

I. What kind of impressions you get from their faces?

P. That man seems to be in trouble, and this seems to be easy.

I. Why?

P. Because he has got more weight on that side and he has got the ladder balanced.

I. What do you mean by balance (while showing pictures of two persons carrying ladders on their shoulders, one person climbing on a ladder and a girl doing gymnastics)?

P1. Weight on each side is even.

P2. Weight on each side is equal.

5. A strip of paper is lying on the table in front of a child sitting in the chair.

FIRST GROUP (P6)

I. Is this strip lying on the table balanced?

P. No.

I. Are you balancing while sitting on a chair?

P. No.

A picture is presented in which a child is sitting in a chair with his arms folded (Fig.30):

Figure-30

I. If you sit on a chair and fold your arms like that, can you stand up on the chair?

P2. You can stand up if you are in the middle . If you are not, you will fall.

I. Why you will fall?

P2. Because of weight in front.

I. If the chair has got three legs, can you sit on it?

P2. No..o. It can't stand.

I. If it has one leg?

P2. It will fall.

SECOND GROUP (P7)

I. When you are sitting on chair, are you balancing?

P2. No.... ha..n. We do not need any balance. You can just sit. Even if we part our legs, you know, this space for the chair is enough to sit (as compared to the space needed to stand in the ramp), you know, this seat (chair) has got more space under it. That boy (refers to the picture in which a boy is skating on a ramp) will obviously fall because he is standing on his toes. But on straight (on plain and levelled ground), balance is no where, no here, no there (There is no need of balance on flat ground). So I will be on the place.

6. A photogrph is presented in which two firemen are spraying water on a fire (Fig.31). The firemen are leaning forward while spraying.

FIRST GROUP (P7)

I. Can one man hold the hose like that?

P1. There will be so much power in water.

P2. Ya, you know, like a...as the water has too much power. There will be so much power in water you cannot spring in out from the ground, straight on to the fire. So two men have to control up.

Figure-31

I. But if, you see, the water stops suddenly, what will happen then (to the firemen)?

P2. A....a.. the fire will probably be out by then. Then they stop the water. They draw up the hose and go back. They can get another fire engine and have some water in it.

P1. You know, the water hydrants, may go to the hydrants somewhere else (to get more water). (The question is totally misunderstood)

SECOND GROUP (P7)

I. If the water stops suddenly, what will happen then (to the firemen)?

P. They will fall over.

I. Why are two persons holding the hose?

P. It is quite heavy and water is coming out.

7. A picture is shown to P7 children in which a person is climbing up a ladder. The base of the ladder is too close to the wall (Fig.32).

Figure-32

I. Will he be able to climb up?

P. To reach the top he will have to put the ladder farther.

I. Why?

P. Because to reach the top he will fall backward because the weight is on that side, because I have seen it.

8. A picture is presented to P7 children.

A man is hanging a heavy bag on the handle of a pram (Fig.33).

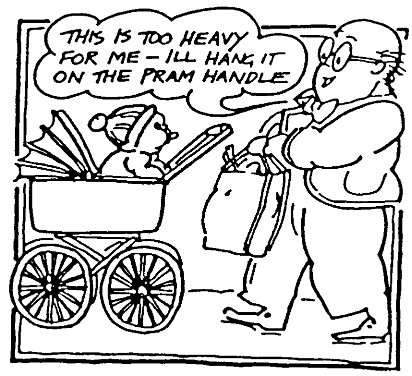


Figure-33

I. What will happen? Will it be O. K.?

P. No. It will turn over because the bag is too heavy.

EVAPORATION

There are three separate groups of P6 children. Some pictures are shown to them and some activities are performed in front of them.

i. Paraffin is poured in a dish. After a few seconds the children smell it (while sitting at the other corner of the table).

I. How does its smell reach you when the liquid is here?

P2. Because it is a kind of strong Paraffin.

ii. A magic mushroom deoderant (air freshener) is put in front of children. After a few seconds they sense its smell (Fig.34).

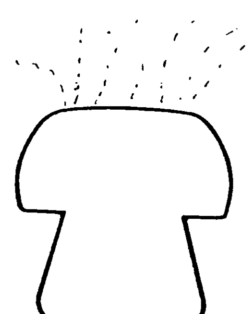


Figure-34

I. How does its smell reach you?

P1. Because it soaks up in the air and keeps smelling.

iii. A picture is shown to the children. In one part of the picture, it is morning, it is raining, there are puddles of water, there is no wind and a man walking with an umbrella. In the other part of the picture, it is now in the afternoon, the sun is shining, there are no puddles and the wind is blowing (Fig.35).

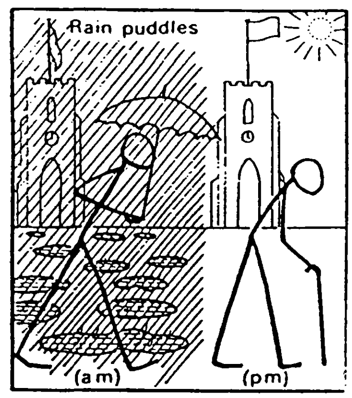


Figure-35

I. What is happening in this picture (morning)?

P1 & P2. It is raining and there are puddles.

I. And then in the afternoon?

P1. The Sun has dried them up.

I. How are these dried up?

P1. Sun. A..heat.

P2. Dries on the ground.

I. What does the Sun do to these puddles?

P2. Dry them up.

iv. A picture of a person just coming out of a swimming pool is shown to the children. He is shivering with cold (Fig.36).

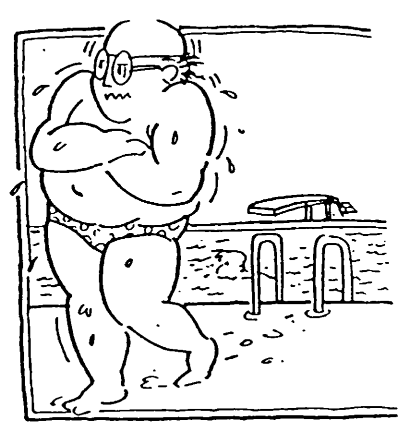


Figure-36

I. What happens in this picture?

P2. It is cold.

I. Why?

P1. Because he just came out of water.

I. Why he is feeling cold?

P1. Because water is warmer inside than outside. So he comes out of water and it is cold.

I. If the water is colder (than outside) then..?

P1. Still will be cold.

v. A picture is shown to the children in which a woman is drying her hair with a hair-drier (FIg.37).

I. What is going on here?

P2. Spray drying her hair.

I. What does the hair-drier do?

P2. Hot air comes out and dries up the hair.

I. Where does the water from the wet hair go?

P1. The water comes off.

P2. Evaporates (laughs).

Figure-37

I. What does the word 'evaporate' mean?

P2. A....disappear in the air, become steam and it is evaporated.

I. Steam also evaporates?

P2. Ya.

vi. A perfume is presented and sprayed on the hand of one child.

I. What do you feel ?

P2. Wetness......cold.

I. Why?

P2. Skin is warm and that is cold.

HEAT

For exploring the concept of heat among children, containers of different materials e.g. made of plastic, polystyrene, paper coated plastic, container with two walls apart and a decoration inside, were presented.

GROUP (P6)

I. If you pour equally hot coffee (say at 70 ^{o}C) in all these cups, which of these will be the easiest to drink with?

P1. That one (made of glass).

P2. That one (made of glass).

I. Why?

P1. That has handle and is smoother.

P2. I do not think so, glass will be hot.

I. Why?

P1 &P2. Because that is glass and that is plastic.

TWO GROUPS (P7)

I. If we pour equally hot coffee in cups made from different material, which of these will be hotter?

P2. This should be hotter.

I. Why?

P2. It's made of polystyrene and rest are made of plastic.

P1. Its lighter, It is not very good made.

I. Which will feel colder?

P1. This will be colder (Pointing to the container with two walls).

P2. Its stronger made.

ENERGY/ ENERGY CONVERTERS

A top is shown to the children. When it turns, a small bulb lights in it, and the top continues spinning for some time.

FIRST GROUP (P6)

I. Why it is moving for such a long time?

P1. I do not know.

P2. You gave it so much energy.

I. Where did this energy go? Is energy moving it?

P2. No.

I. What makes the bulb light?

P2. It may be the wind, it turns so quick the light comes up.

P2. Wind; light comes over. May be pressure makes it push.

I. What do you mean by pressure?

P2. Like some special energy.

I. Can you explain what do you mean by energy?

P2. Energy may be.... wind... like inside; make it go and make it turn.

SECOND GROUP (P7)

I. When I turn this top, am I using some kind of power?

P1. You are using your fingers, joints. They all turn it.

P2. It is your muscles and fingers that make it turn.

I. Is the kind of power that I am using here and the power used in helicopter the same (referring to a toy helicopter)?

P2. I think that is different.

I. What do you mean by power?

P2. Well! Like a muscular power; spent in a bat while playing tennis; using muscles

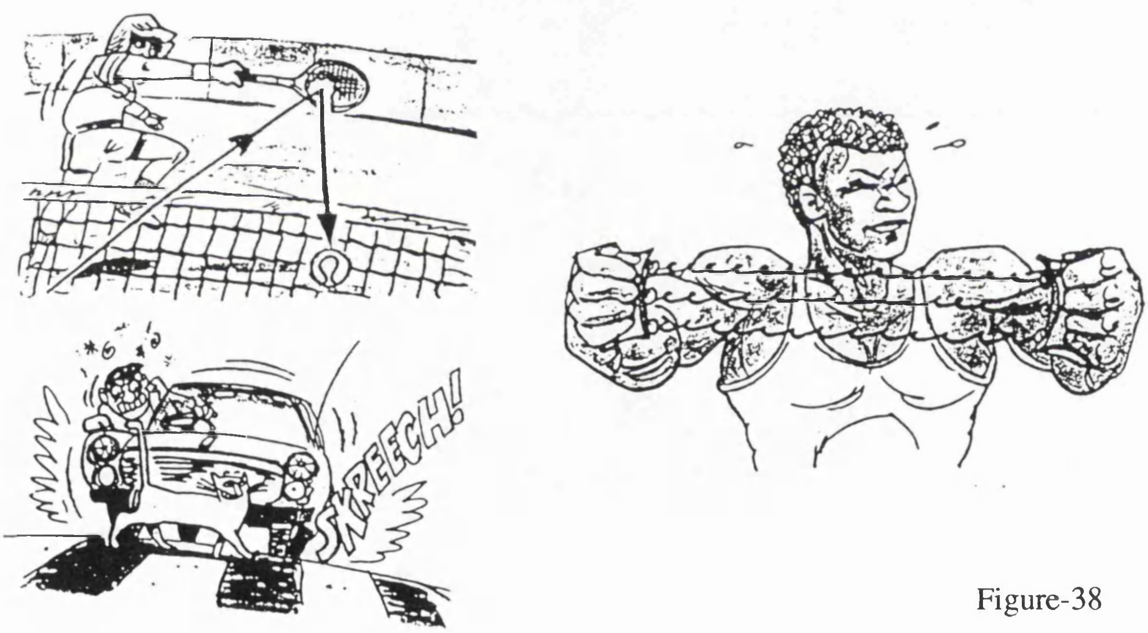


Figure-38

in the elbow to go out (while stretching the spring doing exercise) or using muscles in legs to stop a car; something like that.

I. Do you think this is the same kind of power being used in the helicopter?

P2. The same sort of power; but that one comes from petrol or diesel like that (in cars) inside engine is a car battery.

I. So, petrol is also a power?

P2. Ya.

P1. I think that sort of power is made from many things; power from petrol and diesel, and a power from food and drink that we need.

2. Pictures of a burning matche and a burning candle are shown to P6 children (Fig.39,40). Some of the questions and answers about these were like this:

I. If you put your hand over the flame, do you feel anything?

P. Heat.

I. If you burn it at night, what do you notice?

P. Light.

Figure-39

I. For producing heat and light, is burning necessary?

P. Yes.

I. Without burning, light and heat cannot be produced?

P. Ya.

Figure-40

I. What do you think, (in the case of a burning candle) is this candle being changed into light and heat ?

P1. No, wax is another thing and light and heat is another thing.

3. Then a small torch is presented to P6 children.

I. What is used in it ?

P2. Battery.

I. What is produced ?

P1. Light .

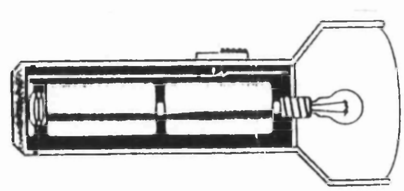


Figure-41

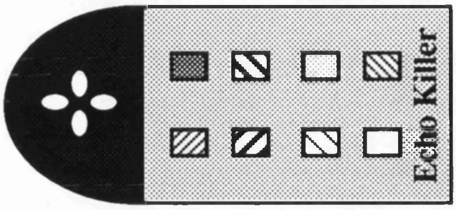
I. What is the difference in the light produced by burning matches, burning a candle and that of battery?

P2. That's electrical and that's non-electrical.

4. Different toys and pictures are presented to P7 children.

i. A small torch and a small toy (echo killer) which produces different sounds, are presented to P7 children (Fig. 41 & 42).

Figure-42



I. What is used in this torch?

P1. Battery.

I. What does it produce?

P1. Light and heat.

I. Do you think that this battery and light are the same things......two shapes (forms) of one thing?

P1. No.

I. What is used in it (echo killer)?

P2. Battery.

P1. Ya.

I. What do you think, the battery here is used for producing light and heat (in the torch) and here produces sound?

P1. Aha that has got power in it.

I. Do you think that light and sound are the same things?

P1. No.

I. Are heat and light different things?

P1 & P2. Yes.

I. Do you think that to produce some kind of sound a battery is necessary?

P2. We can use electricity.

I. Otherwise you can't produce any sound?

P2. No; people speak.

I. What do they use?

P1. Voice.

I. If I drop a penny on the floor, does it produce any kind of sound (noise)?

P1. Yes.

I. So, what is used here?

P1. When it goes down, it makes noise.

P2. When it goes down, gravity..........

I. If you don't eat for a long time, can you speak?

P2. No, because we don't have energy.

I. Do you think this battery has energy?

P1&P2. It has got power.

I. And what about sound?

P1. Battery supplies power and sound comes.

ii. A battery-operated toy helicopter is presented to the same group (Fig.43).

I. What is used in it?

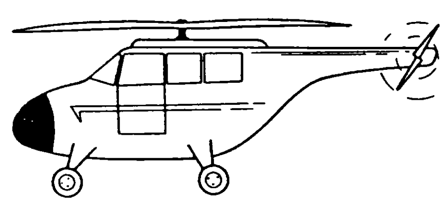


Figure-43

P2. Battery.

I. So, what happens?

P1. The battery supplies energy, and the helicopter moves.

I. But what about trees and leaves; when they move (swing)?

P1. The wind makes them to move.

I. If I turn this spinning top (referring back to the spinning top)?

P1. This is your energy that turns it round.

iii. A picture of woman drying her hair with hair-drier is presented to the same group (Fig.44).

I. When you switch it on, what comes from the plug?

P1. Energy, electricity.

I. Electricity is energy?

P1. Yes.

I. Electricity produces air or air comes from outside?

P2. No; when mixed, the fan turns round and makes the air stronger.

Figure-44

iv. A picture of a waterfall is shown to the same group.

I. You were telling that to produce movement, some kind of energy is used; what kind of energy is used in the movement of this water (Fig.45)?

P1. Natural energy and pressure of the water.

I. What kind of pressure does water have?

P1. When wind moves, water moves.

I. What do you mean by energy?

P2. It is power.

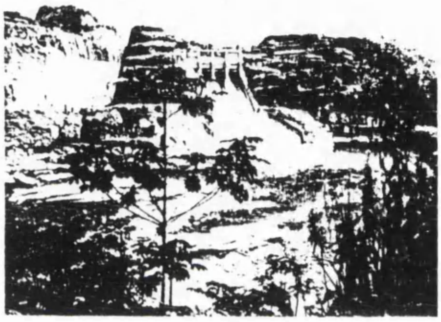


Figure-45

2.3.8. **DISCUSSION**. After analysing the responses of the children, the following main points emerged:

1. **Many phenomena either go by unobserved or pupils are content to accept them without explanation.**

You know the wind blows; tides rise and fall; the moon waxes and wanes; day follows night. They are so obvious that they don't need explanation. You do not have to explain breathing (unless you have nearly suffocated) or walking or talking. Children accept things for what they are. For example,

i) In an answer to a question "Why it was night before the sunrise"?, the children at P7 said, " because it was dark".

ii) Paraffin was poured in a dish in front of P6 children. They were asked, how does its smell reach them? They replied "because it was a parraffin".

iii) The children were asked why the different flowers have different colours. They answered "Different colours of the flowers appear (come) from the Sun".

iv) When coffee is poured in different containers, the polystyrene container feels hotter than the others "because it is made of polystyrene".

v) Similarly, the children just accept that a helicopter moves "because it has a battery in it"; a torch lights up "because it has a battery in it"; and an echo killer gives different sounds "because it has batteries in it".

vi) When the children were interviewed about a picture of acrobats doing an incredible feat, they considered it as a camera trick and accepted it without any further reasoning.

2. **Personal experience plays a very important part in generating explanations.**

Children have their own logic. For example,

(i) When the children were asked, 'how does the tide happen', some children had the concept that the wind causes tides (because it is often windy at the beach).

(ii) They have the experience that when things are carried in such a way as to keep the weight equal on each side, they can be carried very easily and things don't fall.

The children are shown a picture in which two persons are carrying ladders on their shoulders. The children pointed out that the person carrying the ladder at the centre and without touching it, has the ladder more balanced than the person carrying the ladder at one end. Similarly, one child explained balance with an example and related skate-boarding with his personal experience. When (he said) someone is walking on a wall, he will have to walk step by step keeping his arms stretched out to keep balance. Similarly when he is going down the ramp, he keeps one leg behind and his arm out to keep balance. In the case of the girl doing gymnastics, he added, when the weight on one side is more than the other, she will fall.

(iii). The children who had already done the experiment, knew that the mirrors turn the words round but there was no explanation.

(iv). A coin was put in a small drinking glass full of water. When a girl was asked why the coin seemed bigger, she said that the coin got the reflection coming in. But when the coin was put in a rectangular container full of water and the coin was not seen as bigger than before, she rectified the idea and said, "it might be due to glass because it was the shape of the glass reflection was coming".

(v) A man coming out of a swimming pool is shivering with cold. The children were more than satisfied with their everyday description that the water inside the pool is warmer than the air outside that is why he is feeling cold.

3. The children mix up description with explanation (many scientists do this too).

i. Some children had the concept that the Lollipop lady wears a white coat and white cap "because she liked it and bought it". Similarly she carries a white circular sign (stop) "because she is Lollipop lady".

ii. A pencil, a pen or a spoon dipped in water seems broken because of water or the shape of the glass or both water and the shape of glass.

iii. Big lenses produce bigger images and small lenses produce small images. Similarly heavy and thick lenses produce enlarged images whereas thin lenses produce small images.

iv. Writing seen through a glass slab seems to be raised from its actual level because of the thickness of the glass.

v. A picture is shown to the children. There is a handkerchief in the picture on which a glass slab is placed. The handkerchief seems to be torn. The children said, "it seems torn because of the glass slab on it".

vi. A perfume was sprayed on the hand of a child and asked how he felt. The answer was that he felt cold because the hand was warm.

4. If, however, the children are prodded in an interview they will come up with something to please the interviewer. They are probably not serious attempts at explanation.

i. When the children at P7 (age 11) were asked about the change taking place in the size of the Moon, they responded that the sun causes these changes. One child said that the Moon is behind the sun and it moves a bit; that's how the size of the Moon changes very slowly.

ii. A swimming pool or a fishing lake seems to be shallower than expected due to "the water effect".

iii. Words seen through a bowl of water are seen bigger "because of the water".

iv. The children at P6 (age 11) had the concept that there is something inside the mirror which makes the image smaller or bigger. They also mentioned (another concept about the same process at the same time) that there is a glass on top of the mirror. Similarly one child said that "there is a mirror behind and a glass on top that causes the images to be different. Another child said that if a mirror has a black or silvery background (because different mirrors had different paint at the back), that will produce images of different sizes.

v. In the case of the compact mirror (make-up mirror which has one normal plane mirror and the other a concave mirror), the children said that the plane mirror shines on the other (concave mirror), that's why the image in one mirror is seen to be bigger. When the mirrors were separated from each other, the children slipped in to another concept and said that the colour of the case and the colour of the paint behind the mirror causes the change in size of the image.

vi. The images in different mirrors are seen of different sizes because the mirrors are of different diameters. Some children thought the weight of the mirror and others considered the material used in the mirrors as the reason for producing images of different sizes.

vii. The children are asked what makes the image different in lenses of the same diameter. They replied, "This is heavy, this is the thick one, and this is thin one; there is something got into it". Another child said that "there is a mirror underneath and a magnifying glass on the top", that's why different mirrors produce different images.

viii. Writing seen through a glass slab seems to be raised from its actual level because "there is a chemical in the slab which gives the effect".

5. **Only things that need explanation are explained:-**

Why wear clothes? You will get cold if you don't.

Why drink? You will get thirsty if you don't.

But why images invert in mirrors or a spoon is seen to be bent in water are not important to them. They are a sort of curiosity but not really important in the business of living, for example:

a. A girl at P5 (age 9) knew much about lenses because she had an eye-sight problem. She had glasses and she knew about the effects of long-sightedness and short-sightedness.

b. A picture was shown to a group of P6 children in which a boy is sitting in a chair with his arms folded. The children were asked that, while sitting like that, could they stand up. The answer was that they could not stand up because the weight will be shifted in the front. But when the same children were asked whether they needed any kind of balance when sitting in chairs, they replied in the negative. Similarly when they were asked whether a piece of wood lying on a table was balanced, they said," No".

c. When the children at P7 (age 11) were asked whether they were balancing when sitting in chairs; they replied," We do not need any balance".

2.4. COMPARING THE RESULTS OF THE FIRST PHASE OF THIS STUDY WITH THOSE OF PREVIOUS RESEARCHES:

All these results are in agreement with the previous studies. Children develop/ construct naive concepts as a result of everyday experiences. The same child can have different explanations for the same phenomenon and use them differently under different circumstances. It is also quite evident from the interviews that, if a child is taught formally, he constructs some explanations, e. g.

in the case of reflection, the children at P5 and P6 (age 9 &10) knew that the mirrors turn the words round but could not offer any scientifically correct explanation. They could be behaving just like parrots in giving set descriptions and responses with no understanding. Similarly, in the case of the girl in P5 is who wears glasses, the doctor told her that the lenses have different powers; some lenses are used for long-sightedness and some for short-sightedness, but she could not explain the process in a scientific way.

2.5. PROBLEMS FACED DURING THE FIRST PHASE:

These interviews were conducted over a period of two school terms and finished in May 1990. During this research, many problems had to be faced.

i. The researcher had to travel long distances to different schools.

ii. It took almost three months (after the interviews were over) to transcribe the interviews. The interview technique is very successful for exploring the children's concepts but it is very time consuming .

iii. It was too tedious to listen to and to transcribe the interviews. It was quite difficult to understand and make sense of children's language. Sometimes the children spoke in such a tone that one could not hear correctly and the researcher had to ask for help from others. Most of the children ignored grammatical requirements. Sometimes, while talking about one picture, children jumped to another picture illustrating another phenomenon. So it was difficult to connect the concepts together when listening to the tape later.

2.6. ABOUT THE INTERVIEW TECHNIQUE:

Keeping these difficulties in view, the researcher decided to discard the interview technique meantime and search for another more convenient method.

CHAPTER THREE

3. RESEARCH METHOD-II

3.1. INTRODUCTION. Keeping in view the results of the previous interview phase, changes were made in the approach for the investigation of children's alternative frameworks. It was thought that an open-ended test, as a second choice, might prove better for the purpose. Different new areas of natural phenomena were chosen. The topics or phenomena selected were familiar to the children either informally or indirectly, often presented in a scientifically correct way e.g. through T.V., radio, videos, newspapers, cartoons and comics etc. The topics had not been formally taught at school.

The questions included were about dissolving or extracting a gas from a liquid (Coca Cola bottle); the shape of the Earth; clouds on Earth; rain; people living on Earth; seeing the Moon at night; winter and summer seasons and rotation of day and night.

3.2. SCHOOL PUPIL SAMPLE. Overall 20 children at P5, 75 children at P6 and 67 children at P7 were tested (from 9+ to 11+ year old). The sample was compromised of equal numbers of girls and boys and of equal numbers of children with Scottish and ethnic minorities background in each age group. No specification was made for the selection of the children. On the other hand, the researcher depended entirely on the teacher concerned and the availability of the children. The school distribution is shown below (Table-4).

SERIAL No.	NAME OF THE SCHOOL	NO. OF CHILDREN			
		P5	P6	P7	Total
1	Anderston Primary school	20	28	24	72
2	St.Charles' Primary school	x	26	21	47
3	Willowbank Primary school	x	21	22	43

Table-4

3.3. The questions about the gas dissolved in a liquid (a plastic Coca Cola bottle) were asked only in Anderston Primary School. Every child was tested for more than one topic and so, the number of children tested varies for each phenomenon as given under:

Serial No.	AREAS EXPLORED	Anderston Pry.school			St.Charles' Pry.		Willowbank Pry.School		Total
		P5	P6	P7	P6	P7	P6	P7	
1	Gas dissolving in and extracting out of a Coca Cola bottle.	20	28	24	x	x	x	x	72
2	Shape of the Earth, People living on Earth, and rain on Earth.	20	28	24	26	21	21	22	162
3	Change of day and night.	x	28	24	26	21	21	22	142
4	Seeing the Moon at night.	x	x	x	26	21	21	22	90
5	Warmth in Summer and Cold and winter.	x	x	x	26	21	21	22	90

Table-5

3.4. ADMINISTERING THE TEST. The headteachers of the schools mentioned above were contacted. A general information letter was sent to the parents describing the purpose of the study. The children and the parents were assured that the information supplied by the children would not be used for other than research purposes. The required copies of the questionnaire were mailed to the school concerned. In spite of the busy schedule of the schools, almost one hundred percent answers were received well in time. All the requirements of confidentiality were fulfilled to the entire satisfaction of the teachers, parents and the children.

3.5. DESCRIPTION OF THE RESULTS. The general results of this phase are reported here, but will be discussed in detail later on page 74. While reporting the results, some kind of grouping had to be made. Different explanations offered by different children giving the same impression were grouped under one category. Similarly, within one expression, the sign (;) and a dot (•) also separates one explanation offered by one child from the explanation given by the other. All the results are described here for the general interest of the reader.

QUESTIONS ASKED AND DESCRIPTION/ EXPLANATIONSO FFERED	P5/20	P6/28	P7/24
INSTRUCTIONS: At the side of each question, there is picture of a bottle with some Coca Cola in it. Your answers could be a drawing on the bottle or you might prefer to answer in words.			
Q. When the cap (of the bottle) is opened:			
a. What do you hear?			
(i) Hissing sound.	60%	31%	63.5%
(ii) Gas coming out.	40%	60%	37.5%
(iii) No explanation.	0%	9%	0%
b. What do you see?			
(i) Bubbles formed by the gas rising.	35%	71%	58%
(ii) Gas coming out.	30%	18%	29%
(iii) Foam.	35%	11%	0%
(iv) The ginger evaporates; the bottle gets steamed up.	0%	0%	8%
(v) No explanation.	0%	0%	5%
c. What does the bottle feel like now?			
(i) Soft.	100%	100%	100%
Q. How do you explain what you have heard?			
(i) Gas coming out of the bottle.	45%	36%	38%
(ii) Hissing sound.	5%	61%	54%
(iii) No explanation.	50%	3%	8%
Q. How do you explain what you have seen?			
(i) Gas; gas coming out; gas escaping; ginger rising.	45%	36%	21%
(ii) Foamy; foam; bubbles; white stuff; bubbles missing; rising bubbles.	40%	64%	54%
(iii) The coke rising because the air came out.	15%	0%	25%
Q. How do you explain that the bottle has gone soft?			
(i) Gas rushes out and there is hardly any air; air comes out; no gas left in; when you opened it all the air was released.	70%	79%	75%
(ii) Because we opened the bottle; we took the lid off; because the cap is removed; lid is absent.	25%	7%	21%
(iii) No explanation.	5%	14%	4%

Q. You found that the bottle had gone soft;			
a. What would you do to make it hard again?			
(i) Tighten the cap and shake it.	95%	89%	96%
b. Explain why you would do this?			
(i) To make it hard again.	40%	11%	29%
(ii) Because it puts air in it; I would do this so that the gas could go back in.	15%	4%	0%
(iii) To keep the gas in; to stop the gas coming out; because the gas could not escape.	10%	36%	33%
(iv) No explanation.	35%	49%	38%
Q. You noticed that the bottle became soft when you took the top off. If you replace the top and shake the bottle, it becomes hard very quickly. Why do you think this happens?			
(i) Because more gas goes in; the gas come back by shaking; because the gas is coming in; air is put back in.	30%	14%	27%
(ii) Because no air gets out; the air has been trapped; because the cap helps us not to remove gas; because the gas is blocked.	25%	25%	38%
(iii) The gas comes on and the bubbles come up as well; the gas builds up; it makes more gas to fill up; because the air comes out of the drink.	10%	18%	25%
(iv) No explanation.	35%	43%	10%

QUESTIONS ASKED AND DESCRIPTION/ EXPLANATIONS OFFERED	P6
Q. Explain with a drawing and words why it gets dark at night and then becomes light in the morning again.(Total No of children:75)	
(i) • The Sun spins round the Earth, so half of the Earth is light(day) and the other is dark (night). • It becomes dark at night as well due to the Moon and light (day) due to the Sun. • It becomes dark at night and light in the morning when theWorld turns right. • It becomes dark at night because another planet goes near the Earth and then the planet goes round and then it becomes light. • Dark is at night and Sun in the morning. • As the Sun rises in the morning, later on in the day, it starts moving round the Earth, although you can not see, it does move and at night it is so far round you cannot see. • Because when it is dark, you have to go to sleep because you cannot go out and in the morning you have to wake up so can go out and play and go to school.	49.3%
(ii) • Because the Earth circles round the Sun and the Sun hits half of the Earth and the other half is dark. • Because the Earth moves round and covers the Sun up.	12%
(iii) • The clouds cover the Sun, it becomes night. • The clouds in the sky change colours, move another place.	5.3%
(iv) • When the Earth goes round the Sun, the Moon goes round the Earth and the Moon covers the Sun's brightness. • The Sun moves away, the Moon blocks the Sun's rays of heat and light so it becomes night.	6.7%
(v) No clear idea.	26.7%
Q. Why can you see the Moon at night? Draw a picture of the Moon, the Earth, the Sun and yourself and use them to explain your idea. (Total No. of children:47)	
(i) A picture showing that the Moon and the Sun are on the either side of the Earth but not in straight line.	2.1%
(ii) Just picture showing that the Moon and the Sun are on opposite sides of the Earth and all in straight line.	2.1%
(iii) It is night due to the Moon and day because of the Sun.	14.9%
(iv) The Earth moves and the Sun and the Moon come alternately.	21.3%
(v) Because the world turns round, the Moon stays there and the half faces the Moon and we see it.	6.2%
(vi) We cannot see the Moon in the morning because the Earth moves round covers the Moon up.	2.1%
(vii) • The Sun has moved away and the Moon has moved into the Sun's place and the Sun shines through it. • The Moon is brightly coloured white so we cannot see the Moon in day light. • Because it (Moon) is all white. • Because it is a planet and it is bright. • It is dark at night and Moon is seen because it is bright and white just like a black paper and a white spot in it.	31.9%

QUESTIONS ASKED AND DESCRIPTION/ EXPLANATIONS OFFERED		P6
(viii)	When the Earth gets nearer the Moon, it gets dark.	2.1%
(ix)	I think it is because the clouds move away at night and you can see space and I think the Moon is in space.	2.1%
(x)	No clear idea.	14.9%
Q.	Explain with a diagram and words why it is warmer in summer than in winter. (Total No. of children: 47)	
(i)	• Because the Sun is closer to the Earth and because we are half way through the year and snows in winter. • The Sun is closer during summer and away during winter and it is raining during winter. • When the Sun is nearer, the Earth gets warmer.	38.3%
(ii)	Because in winter the Sun goes down and the Moon comes up.	4.3%
(iii)	• Because in summer it is warm, in winter it is cold. • Because in winter the snow falls and in summer the snow does not fall.	19.1%
(iv)	Because the Sun faces the summer part than the winter part.	2.1%
(v)	Because there is more of the sun in the summer.	2.1%
(vi)	The Sun is getting hot and hot in summer, in winter it is windy and cold.	2.1%
(vii)	Because the Earth moves round and on one side it is summer and the other time it is winter.	6.4%
(viii)	It stays in the north pole for six months and the six months are hot over there and cold over here.	2.1%
(ix)	No clear idea.	23.1%
Q.	Think of yourself sitting in a space shuttle, looking out of the window towards the Earth; draw a picture of the Earth as seen to you. Draw some persons living on different parts of the Earth. Also draw some clouds and rain on those persons. (Total No. of children: 75).	
EARTH.	1. The Earth almost round.	93.3%
	2. The Earth like an Ellipse.	1.3%
	3. The Earth just like Moon (Crescent).	2.7%
	4. The Earth just like table (with four corners).	1.3%
	5. No idea.	1.3%
PEOPLE.	1. People living within the Earth (upright).	85.3%
	2. People living within the Earth in different directions.	6.7%
	3. People living on the surface of the Earth (only towards North and only towards South).	2.7%
	4. People living on the surface of the Earth (all around the Earth).	1.3%
	5. No idea.	4%
CLOUDS.	1. Around the Earth and towards the Earth.	6.7%
	2. Clouds and rain within the Earth.	70.7%
	3. Clouds within the Earth as well as outside (towards North, towards East or South).	14.7%
	4. Clouds above the North only and rain covering whole of the Earth.	5.3%
	5. No idea.	2.7%

QUESTIONS ASKEDAND DESCRIPTIONS/ EXPLANATIONS OFFERED	P7
Q. Explain with a drawing and words why it gets dark at night and then becomes light again in the morning?(Total No. of children: 67)	
1. • The Earth goes round and round but the Sun stays at the same place. • The world turns. • The Earth round the circle and turns on itself. • The Earth will turn. • The Earth circulates the Sun. Night comes when a side of the Earth is not facing the Sun and day comes when the Earth is facing the Sun. • The Earth rotates round the Sun. • Because the Earth turns around the Sun. • It becomes dark because the Earth has turned 12 times(hours), it becomes dark. • Because the Earth turns round. • The Earth revolves around the Sun, seasons also change due to this fact.	34.3%
2. • The world moves around and when the darkness hits any country it becomes dark and slowly the world moves and the Sun shines hits our country then it becomes morning. • It gets dark because the Earths are equal to some country (two halves) that looks at the Moon and the half of the Earth is opposite to the Sun. • It becomes light with the Sun shining. • When the side hits the Moon, it becomes dark; the same with the Sun. • If it is dark you come from, the Sun is not facing you (it is night). • It is light in the morning because the Sun goes up and its' dark at night because the Sun goes down. • While it is light people have to go to work and darkness outside helps the people to sleep, to take rest. • When the Earth faces the Sun it is day; when it turns to the Moon, it is night. • Because the Sun moves around the Earth and at night it is at different place of the Earth, so it gets dark and persons go to sleep. • The Sun goes down. • The Sun goes down so you can see the stars.	25.4%
3. • The Earth stands and the clouds come and go off the Earth, the Sun come for light . Half of the Earth has light and half has dark. • The clouds cover the Sun, it becomes night, when the Sun comes out it becomes day.	13.4%

QUESTIONS ASKED AND DESCRIPTIONS/ EXPLANATIONS OFFERED	P7
• It gets dark at night because the clouds covering the light. It gets light in the morning because the clouds are moved away from the Sun.	
• When the Earth moves around, some parts of it go past the Sun and that is when it is morning. When some parts go past the clouds that's when it is night.	
• It gets dark at night because dark clouds move together and stop the light coming on the Earth.	
4 • The Moon revolves around the Earth. The Earth revolves around the Sun. Every time the Moon goes around the Earth, it will at one point cross the Sun's path and it will therefore bar the Sun's light, people go to sleep at this point. When the Moon moves away, the Sun will come out again and people will awake.	4.5%
• As the world goes round, it comes across the Moon and the Sun.	
5 • No idea.	22.4%
Q. Why can you see the Moon at night? Draw a picture of the Moon, the Earth, the Sun and yourself and use them to explain your ideas. (Total No. of children: 43)	
1. • The Sun is not visible at night but its rays bounce off the Moon and make it glow brightly in the darkness.	6.9%
• I can see the Moon at night because the Moon always faces the dark side of the Earth and it reflects the light of the Sun; so it shines.	
• Because the Moon revolves round the Earth and when it is night on our side of the world, the Sun from behind us shines on the Moon and make it glow.	
2. • The Earth moves around and the Sun is at the other side of the Earth.	11.7%
• When the Earth turns we can see the Moon.	
• Because the Earth turns and it gets dark so you can see lots of things (stars and Moon).	
3. • Because the Sun goes down.	34.9%
• The Sun and the Moon move around the world at the same time and while the Sun is at different place, the Moon is here when we are sleeping.	
• We cannot see the Moon in the morning because it is light but at night we could see the Moon.	
• Whenever it is night on one side of the Earth, the Moon comes out, But when the Sun comes out it fades away and goes to the other side.	
• Because at night the Sun goes down and the Moon comes up.	

QUESTIONS ASKED AND DESCRIPTIONS/ EXPLANATIONS OFFERED	P7
4. • Because the Moon goes right in front of the Sun, so, the Sun's light goes through the Moon and lights up but not too bright. • At night the Moon crosses the Sun's path so that the Sun brights up the Moon. • The Sun shines on the Moon so you can see it. • The Moon is bright at night. • You can see the moon in the night because it is very dark and the Moon is like a bulb for the whole world. It is just looking at a lighted bulb in the dak. In the day you cannot see it because it is light and because it is hidden and you cannot see it. • The Moon is bright and gleams so in the day the Moon blends in with the rest of the sky but at night the Moon shows itself because light does not blend with dark.	30.2%
5 • No idea.	16.3%
Q. Explain with a diagram and words why it is warmer in summer than in winter. (Total No. of children: 43)	
1. • Because the winter has no Sun and a lot of snow, summer is the opposite. • It is warmer in summer because we are facing to the Sun. In winter it is cold because we are facing the Moon. • In winter the Sun does not rise that good whereas it does rise a lot in summer. • The Sun draws nearer in summer, the cold goes away. • Because in summer the days become longer than in winter. In winter it snows, it rains and it hails. In summer the warmth comes and does not rain a lot, it does not snow or hail. • It is colder in winter because we do not see the Sun very often. In winter the Moon stays in the Sun's path longer than usual and it revolves quicker so that night comes earlier. Since we see so little of Sun, we get less warmth. In the summer the Sun is nearer the Earth so it gives off more warmth. • It is warmer in summer because the Sun goes hot after six months and then it starts cooling down and it is hotter nowadays (because this test was carried out in summer) because of the Green House Effect. • It is warmer in summer than in winter because in summer the Sun shines more and the days are longer and in winter you rarely see the Sun, so days are shorter. Because in winter the Sun does not come out that a lot.	48.9%

QUESTIONS ASKED AND DESCRIPTIONS/ EXPLANATIONS OFFERED	P7
2. • The Earth spins on an axis and in our summer time the Northern hemisphere is more facing the Sun than it is in winter.	6.9%
• When the Earth moves around, in the winter in some other country it is very hot. Then it becomes winter for them but it is warmer for us.	
3. • At the end of summer the Sun goes round the Earth and so when it is winter in some parts of the world, it is summer somewhere else.	13.9%
• In winter the Sun is in the other side of clouds because the Sun comes out why it is warm.	
4. • In winter; that is at the end of the year, the world goes round slower, so the wind would blow harder and in summer the world goes faster which gathers up heat to make it warm.	2.3%
5. • This is the same as the Sun and the Moon and the Earth goes round and there are five seasons surrounding the Earth and it goes round and round and it goes spring, summer, autumn and all that.	2.3%
6. • Because the Sun hibernates in winter and we do not get much sun so the animals know when to hibernate.	4.6%
7. • The Earth moving closer to the Moon and on the Moon it is cooler than the Sun.	2.3%
• No idea.	18.6%
Q. Think yourself sitting in a space shuttle, looking out of the window towards the Earth, draw a picture of the Earth as seen to you. Draw some person living on different parts of the Earth. Also draw some clouds and rain on those persons. (Total number of children:67).	
EARTH.	
• The Earth almost round.	98.5%
• The Earth like an egg.	1.5%
PEOPLE.	
• People living within the Earth (upright).	88.1%
• People living on the surface of the Earth.	8.9%
• No idea.	2.9%
CLOUDS.	
• Clouds and rain within the Earth.	55.2%
• Clouds and rain towards the Earth but from the North, East and the West.	40.3%
• Clouds around the Earth and rain towards the Earth.	4.5%

3.6. DISCUSSION. After categorising the results of this phase, despite the fact that the technique was changed, the same patterns emerged as from the interview phase.

1. **Many phenomena go by either unobserved or pupils are content to accept them without explanation,** e g;

• *The children are not worried about the shape of the Earth whether it is round; like a crescent; like a table or or like an egg.*

• *When the children were asked about the change of day and night, they answered, "The world moves around and when the darkness hits any country it becomes dark and slowly the world moves and the Sun shines hit our (U. K.) country then it becomes morning".*

• *When the children were asked how the seasons change, they described "this is the same as the Sun and the Moon and the Earth go round and there are five seasons surrounding the Earth and it goes round and round and it goes spring, summer, autumn and all that".*

2. **Personal experience plays a very important role in the development of the concepts**. For example,

a) It gets dark at night and light in the morning because:

• *When it is dark, you have to go to sleep because you cannot go out and in the morning you have to wake up, and can go out and go to school.*

• *When the clouds cover the Sun, it becomes night; When the Earth gets nearer the Moon, it gets dark.*

• *When the Sun goes up it is light in the morning and it is dark at night when the Sun goes down; When it is light people have to go to work and darkness outside helps the people to sleep, to take rest.*

b) Similarly, we can see the Moon at night because:

• *The clouds move away at night and you can see space and I (child) think the Moon is in space.*

• *The Earth moves, the Sun and the Moon come alternately (because they do not see the moon and the sun at the same time).*

• *The Earth turns and it gets dark so you can see lots of things (stars and Moon).*

• *The Sun and the Moon move around the world at the same time and while the Sun is at different place, the Moon is here when we are sleeping (because, mostly, one cannot see the Moon and the Sun at the same time).*

3. **The children mix up description with explanation and do not differentiate while describing or explaining a process.** For example,

i. When the children at P5, P6 and, P7 (age 9, 10, 11) are asked to describe and explain the processes of dissolving a gas in a liquid or a gas escaping out of a liquid (in the case of a Coca Cola bottle) they do not make any distinction between description and explanation. For all the questions asked about the Coca Cola bottle, whether the questions are about description or explanation, the children are describing the process throughout. There is no evidence of development in the concepts from P5 to P7 level. On the contrary, all the children concentrated on the observation aspect of the questions, such as, fizz, bubbles and, hissing sound etc. They do not see a need for explanation.

ii. In an answer to the question "Why does it get warmer in summer than in winter?" the children described the winter as having no sun and a lot of snow and the summer is the opposite, therefore it is warmer in summer. Some children said that it is warmer in summer than in winter because in summer the sun shines more and the days are longer and in winter you rarely see the sun, so days are shorter because in winter the sun does not come out that a lot.

4. **Children have ill formed explanations for many things based upon partially digested input from formal or informal sources. A few may be self generated**, e. g;

a) It becomes dark at night and light in the morning because:

• *Another planet goes near the Earth and then the planet goes round and then it becomes light.*

• The sun rises in the morning, later in the day, it starts moving round the Earth, although you cannot see it moving, it does move and at night it is so far round you cannot see it.

• When the Earth goes round the sun, the Moon goes round the Earth and the Moon covers the Sun's brightness.

• It gets dark at night because the clouds cover the light. It gets light in the morning because the clouds have moved away from the Sun.

• When the Earth moves around, some parts of it go past the Sun and that is when it is morning; When some parts go past the clouds that's when it is night.

• The Moon revolves around the Earth, The Earth revolves around the Sun. Every time the Moon goes around the Earth it will at some point cross the Sun's path and it will therefore bar the Sun's light, People go to sleep at this point. When the Moon moves away, the Sun will come out again and people will awake.

b. We can see the Moon at night because:

• The Moon goes right in front of the Sun, so, the Sun's light goes through the Moon and lights it up but not too brightly.

• It is very dark and the Moon is like a bulb for the whole world. It is just like looking at a lighted bulb in the dark.

• The Moon is bright and gleams so in the day the Moon blends in with the rest of the sky but at night the Moon shows itself because it does not blend with dark.

• We cannot see the Moon in the morning because the Earth moves round and covers the Moon up.

• We see the Moon because the Sun has moved away and the Moon has moved into the Sun's place and the Sun shines through it.

• The Moon is brightly coloured white so we cannot see the Moon in the day light. It is dark at night and the Moon is seen because it is bright and white just like a black paper with a white spot in it.

c. It is warmer in the summer than in winter because:

• The Sun draws nearer in summer, the cold goes away.

• *In winter the Moon stays in the Sun's path longer than usual and it revolves quicker so the night comes earlier.*

• *In winter the Sun is on the other side of the clouds and in the summer it comes out of the clouds that's why it is warmer in summer.*

• *In winter, that is at the end of the year, the world goes round slower, so the wind would blow harder and in summer the world goes faster which gathers up heat to make it warm.*

• *Because the Sun hibernates in winter and we do not get much sun so the animals know when to hibernate.*

3.7. **OUTCOME.** Keeping the above discussion in view, it is evident that the open-ended questionnaire technique is helpful in bringing out the alternative concepts but, it is of limited value in understanding the link, if any, in their reasoning. It is also quite evident from this phase as well that formal science teaching affects learning but the children may be behaving just like parrots, regurgitating rote learning without understanding, such as,

• *The Sun is closer to the Earth and because we are half way through the year and snows in winter.*

• *It stays in the North pole for six months and the six months are hot over there and cold over here.*

The children have been told that the Earth revolves around the Sun in one year and at the same time it moves on its axis which are basic reasons for the change of day and night and being hot in summer than in winter but they do not know how to explain these processes.

3.8. **ABOUT THE QUESTIONNAIRE TECHNIQUE.** At the same time, it was noted that the children pay more attention to the observation aspect of any phenomenon rather than explanation. It was decided to change the technique to help pupils to separate description and explanation. This forms the basis of the work reported in the next chapter.

CHAPTER FOUR

4. RESEARCH METHOD-III

4.1. INTRODUCTION. Keeping in view the results of the interview and questionnaire phases, a new technique had to be developed which could explore the responses of the children and help to categorise them in terms of their characteristics, shape, and length of the chain of reasoning from early Primary level. It was also considered important to know about the changes taking place in the alternative concepts of the children while going from Primary to Secondary stage. Therefore it was decided to include 8^{+} to 13^{+} year-olds (from Primary 4 to Secondary 2 level) children for the exploration of the development of alternative concepts in children. Moreover, to see the effect of formal science teaching while going from primary to secondary level, the concept of energy was considered the best because it was not formally taught at primary level but was taught at early secondary level in Scottish schools.

4.2. **DIFFERENT ACTIVITIES TO BE USED.** For the purpose, different practical activities based on the energy concept were devised, e. g;

Figure-46

1. Bow and Arrow (Fig.46)
2. A Dancing Monkey (Fig.47) (a game in which a model monkey moves in water when a button is pressed).

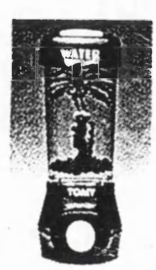
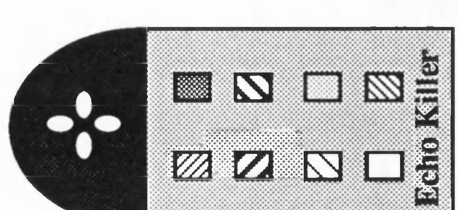


Figure-47

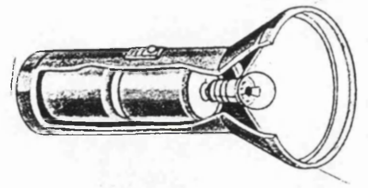
3. A Flute
4. An Echo Killer (which produces different sounds when different buttons are pressed). (Fig.48)

Figure-48



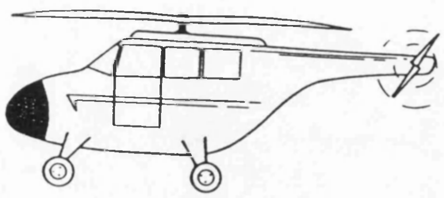
5. A Torch

Figure-49



6. A Toy Helicopter

Figure-50



7. A Liquid Timer (In which two immiscible liquids of different density are used; (Fig.51). There are two 'frictionless'

Liquid Timer

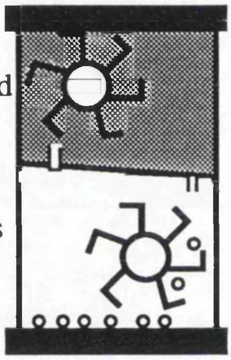


Figure-51

wheels inside the Timer. When the Timer is turned over, the wheels turn due to falling/ rising liquids)

8. A Windmill (turning above a burning candle)

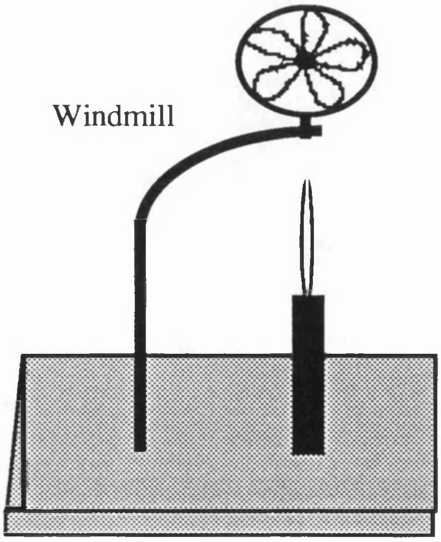
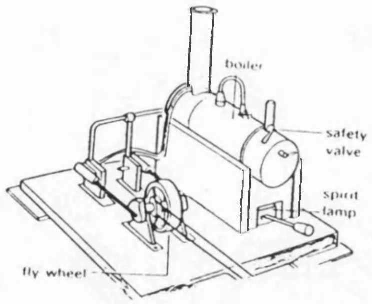


Figure-52

9. A Steam Engine

Figure-53



10. A Hand Dynamo (in which a handle turns a dynamo to light a bulb)

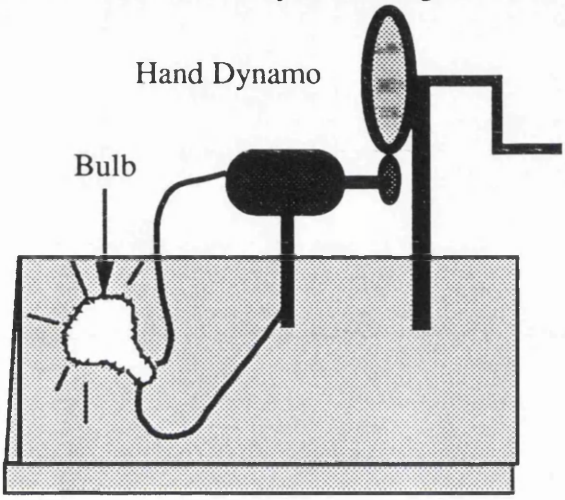


Figure-54

4.3. TECHNIQUE APPLIED. The open-ended questionnaire was considered suitable for quick data collection from large numbers. Moreover, considering the age level of the children, very simple questions were asked and for the most of the activities only two questions were asked:

i. *What happened*?

ii. *What made it happen*?

However, for the Liquid Timer and the Helicopter, three questions were asked for each activity. The questions asked for the Liquid Timer were:

i. *What makes the wheel turn round*?

ii. *What makes the blue liquid fall down*?

iii. *What makes the colourless liquid rise up*?

The questions asked for the Helicopter were:

i. *What happened*?

ii. *What made the propellers go?*

iii. *What made the helicopter move about?*

4.4. SCHOOL PUPIL SAMPLE. The selection of the sample was made by the teachers concerned. Only those children were included who were granted permission by their parents to join the test. Care was taken, again, to include an equal number of children with Asian and Scottish background and equal number of girls and boys. The children were organised, as previously, to work in groups of two with the hope they might encourage/ stimulate each other (as proved in the interview phase) to take part more actively. Overall 396 children were tested at three Primary and three Secondary schools. The distribution of the sample at each level/ school is given in table-6 below.

SERIAL No.	NAME OF THE SCHOOL	NO. OF CHILDREN					
		P4	P5	P6	P7	S1	S2
1	Dowanhill Primary school	24	13	18	18	x	x
2	St.Charles' Primary school	27	20	9	31	x	x
3	Willowbank Primary school	29	17	24	35	x	x
4	Hyndland Secondary school	x	x	x	x	20	20
5	Hillhead Secondary school	x	x	x	x	19	15
6	Woodside Secondary school	x	x	x	x	20	37
T O T A L (396)		80	50	51	84	59	72

Table-6

4.5. ADMINISTERING THE TEST. To administer the test different local primary and secondary schools in Glasgow city were contacted. A general information letter describing the purpose and duration of the test was sent to the schools and to the parents of the children. After the approval of the parents had been given, the schools were contacted to arrange the required visits, each of which was of one-hour duration. Four visits for each of the primary schools; one visit for Hyndland Secondary; one for

Hillhead Secondary and two visits for Woodside Secondary school were arranged. For carrying out the test, a stations technique was employed. All the activities were set on different tables. Questionnaires for each activity were supplied in separate envelopes at each station. The children were asked first to perform the activity and then to write the answers and "post" their responses in a box. Most of the children performed all the activities but some of them were not able to complete all the activities within the specified time. Some of the secondary school children had not been taught the concept of energy before this research was carried out, so these children were classified with P7 The data for (P7+S1) are plotted in the graphs which follow as P7. S1-E and S2-E are the children who had been taught the concept of energy before the research was carried out. So, the number of children for each activity varies as below:

SERIAL No.	ACTIVITY	NO. OF CHILDREN						
		P4	P5	P6	P7+S1 / P7	S1-E	S2-E	Total
1	Bow and Arrow	80	48	47	66+9	57	67	374
2	Dancing Monkey	75	48	50	70+9	56	72	380
3	Flute	79	47	51	70+8	58	70	383
4	Echo killer	76	49	51	66+9	57	72	380
5	Torch	73	47	52	64+7	55	62	360
6	Helicopter	79	50	51	67+9	57	70	383
7	Liquid Timer	77	47	52	66+9	58	63	372
8	Windmill	73	50	51	70+9	57	65	375
9	Steam Engine	78	50	52	74+9	57	63	383
10	Hand Dynamo	76	48	50	67+9	55	66	371
Maximum number of children tested at each level		80	50	51	75+9	59	72	396

Table-7

4.6. DESCRIPTION OF THE RESULTS. The number of children (%) who could fully describe and explain the activities is given in table-9. If a child could report all the steps which were detectable by the senses, these were considered as "description". If a child could report all the steps which could be deduced but which are not detectable by the senses; these were considered as "explanation". Some criterion had to be established before categorising the answers on the basis of full description and full explanation. So, provisionally, some possible processes had to be considered by the researcher which might be linked with each other for the full description or explanation of an activity. Different processes considered for the description and explanation of each activity are given below (Table-8):

Activity	DESCRIPTION STEPS	EXPLANATION STEPS
Bow & Arrow	1. Movement of the arrow. 2. Shape of the arrow.	1. Pulling force. 2. Bending of the bow. 3. String pushing the arrow.
Dancing Monkey	1. Pressing button. 2. Movement.	1. Force from hand. 2. pressure of button on water, jet of water pushing the monkey upward.
Flute	1. Blowing the Flute. 2. Putting fingers on the holes. 3. Music.	1. Breath/ air. 2. Sound travelling to the ear.
Echo Killer	1. Button. 2. Music/ noise.	1. Battery. 2. Wires. 3. Electricity. 4. Sound travelling to the ear.
Torch	1. Button. 2. Light.	1. Battery. 2. Circuit/ Wires. 3. Electricity. 4. Light comes on.
Helicopter	1. Movement of fan on the back/ movement of the propellers. 2. Movement of the air/ wind. 3. Movement of the helicopter.	1. Battery. 2.Circuit. 3. Electricity. 4. Fans blowing air. 5. String keeping the helicopter in a circle.
Liquid Timer	1. Blue liquid falling down and colourless liquid rising up. 2. Wheels turn.	1. Blue liquid denser. 2. Lower wheel turns because of falling liquid. 3. Colourless liquid rises up being less dense.
Windmill	1. Candle burns. 2. Heat produced. 3. Movement of the windmill.	1. Light/ heat. 2. Hot air rises. 3. Hot air turns the windmill.
Steam Engine	1.Burner/ heat. 2. Steam. 3. Movement of the engine.	1. Spirit burns and produces heat. 2. Steam. 3. Steam presses the piston. 4. The piston moves the engine.
Hand Dynamo	1. Movement of the handle. 2. Circuit, wires. 3. Bulb lights up.	1. Movement inside the dynamo. 2. Electricity produced. 3. Circuit. 4. Electricity changed into light.

Table-8

4.6.1. When the data were arranged on the basis of the criteria mentioned above, the percentage of the children who could describe and explain the activities fully are given below:

FULL DESCRIPTION VS FULL EXPLANATION

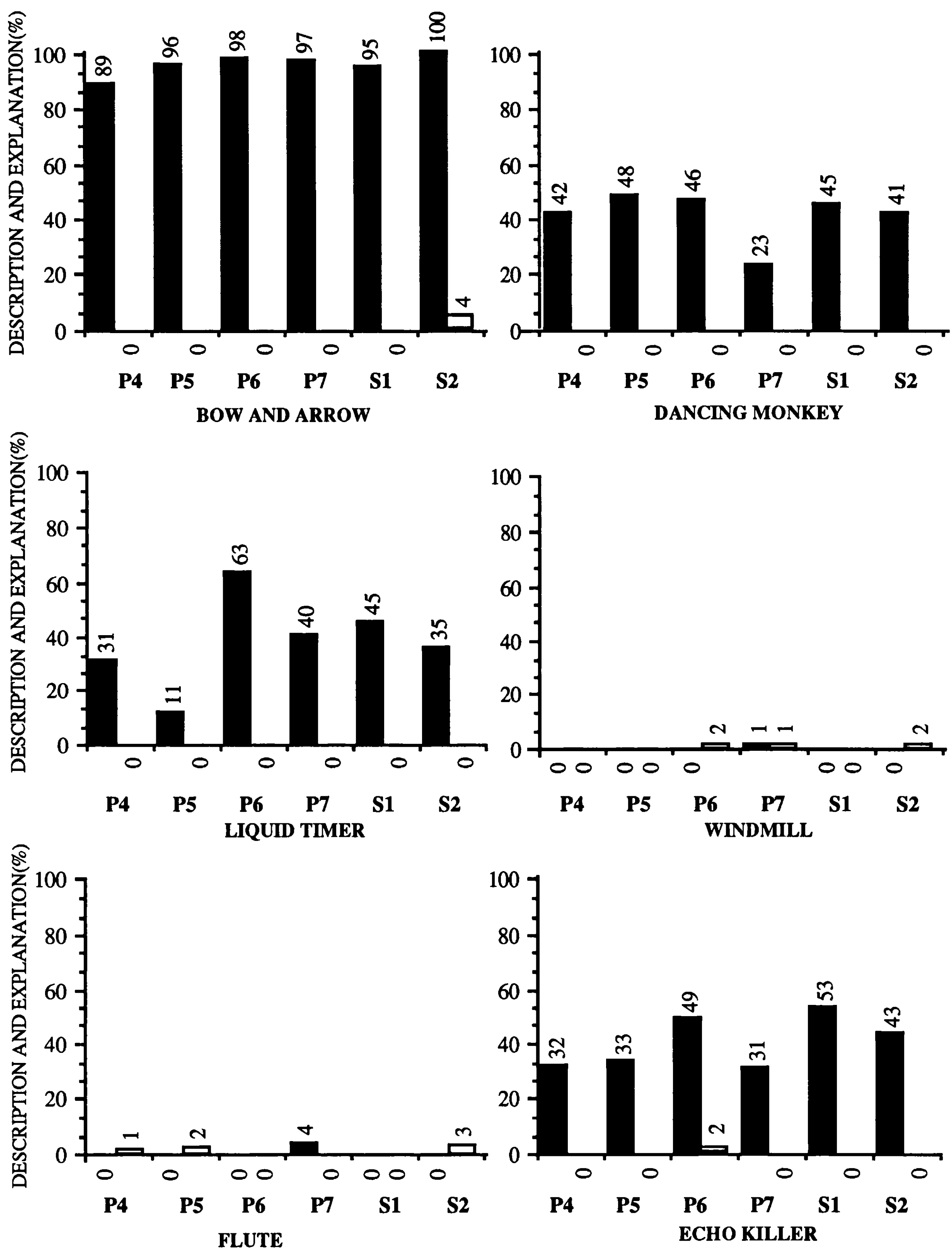
Activity	Description Explanation	P4	P5	P6	P7	S1	S2
Bow and Arrow	Description	89	96	98	97	95	100
	Explanation	0	0	0	0	0	4
Dancing Monkey	Description	42	48	46	23	45	41
	Explanation	0	0	0	0	0	0
Liquid Timer	Description	31	11	63	40	45	35
	Explanation	0	0	0	0	0	0
Windmill	Description	0	0	0	1	0	0
	Explanation	0	0	2	1	0	2
Flute	Description	0	0	0	4	0	0
	Explanation	1	2	0	0	0	3
Echo Killer	Description	32	4	49	31	53	43
	Explanation	0	0	2	0	0	0
Torch	Description	22	42	37	32	55	63
	Explanation	0	0	2	0	0	0
Hand Dynamo	Description	1	0	2	7	9	9
	Explanation	0	2	2	0	0	0
Steam Engine	Description	1	0	2	10	11	25
	Explanation	0	0	0	1	0	2
Helicopter	Description	0	12	2	3	4	14
	Explanation	0	0	0	0	0	0

Table-9

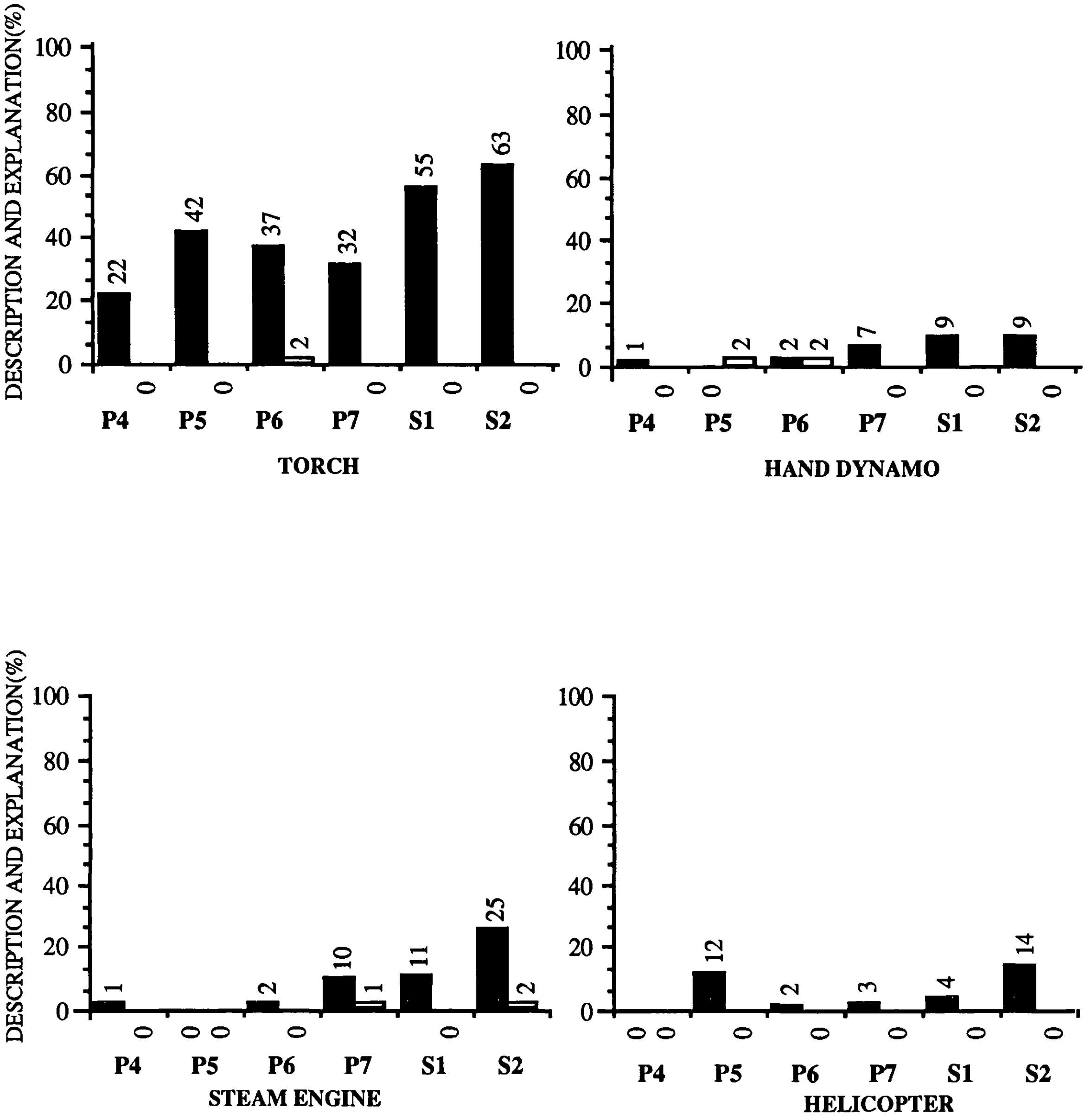
4.6.2. The graphs prepared (Figure-55) on the basis of the above data are given on the following pages. These graphs show that most of the children can describe an experience better than they can explain it. For most of the activities, the children were very poor at explaining the activities and in some activities they were not able to give any explanation at all. In the case of the Dancing Monkey, the Liquid Timer and the Helicopter, no one could explain the process fully (whole process).

Figure-55

FULL DESCRIPTION COMPARED WITH FULL EXPLANATION



☐ Children who could explain the full process of an activity
■ Children who could describe the full process of an activity
All numbers are percentages



□ Children who could explain the full process of an activity
■ Children who could describe the full process of an activity
All numbers are percentages

4.6.3. Most of the children described and explained the activities by separate bits of information. Some of the children described pressing the button as equivalent to an explanation for many activities. Others considered heat, light, water or candle as enough explanation for the activity. Similarly, some children considered themselves as the explanation of the activity, such as, when *I* blew the flute it made a noise; when *I* press the button the monkey dances. They had difficulty in detaching themselves from the phenomenon. Considering the thought processes/ steps (considered provisionally) it was noticed that, wherever, the number of steps was more than two, the description and explanation were unexpectedly very poor, e. g; windmill, flute, hand dynamo, steam engine and the helicopter.

4.6.4. The general results for each activity are reported here but specific results will be dealt with in the 'discussion' of this chapter. Within any sentence/ paragraph, the sign (;) separates different statements offered by different pupils.

ACTIVITY	QUESTION	COMMON ANSWERS
Bow & Arrow	When you pulled the bow and then released the arrow: i.What happened? ii. What made it happen?	a. The arrow flew away. b. It stuck to the wall (due to the suction caused by the rubber at the end of the arrow). a. When the arrow was left it flew away. b. The string. c. I pulled the string and let it go.
Dancing Monkey	When you press the button: i. What happened? ii. What makes it happen (what moves the monkey)?	a. The monkey moves/ dances. a. Button; b. Water; c. Battery; d. Wind blows through the hole (button) and moves the monkey. e. The monkey is holding the pole. f. Pressure of water/ jet of water.
Flute	When you blew the pipe: i. What happen-ed? ii. What made it happen?	a. A noise came out; b. Music/ sound/ melody. a. Breath/ air; b. Holes in the flute; c. Vibrations in the flute.
Echo Killer	When you press-ed the button: i. What happened? ii. What made it happen?	a. Noise/ music/ different sounds came. a. Button; b. Battery; c. Electricity; d. Speakers; e. Microchip; f. Machines; g. Records of different sounds.
Torch	When you press-ed the button: i. What happened? ii. What made it happen?	a. Light came out; b. The bulb lit up. a. Button; b. Battery; c. Power/ Current from the battery.
Helicopter	When you press-ed the button: i. What happened? ii. What made the propellers go? iii. What made the helicopter move about?	a. It moved/ propellers moved/ it flew. b. The helicopter flew round and round. a. Button; b. The battery in the helicopter. c. The wind; d. The machines; e. Electricity/ power from the battery. a. The fans and the blades/ propellers. b. Hook; c. String; d. The wind; e. Motor inside the helicopter; f. Weight of the helicopter; g. Battery; h. Stand on which the helicopter was hung; i. Electricity.

ACTIVITY	QUESTIONS	COMMON ANSWERS
Liquid Timer	When you turned the liquid timer upside down: i. What makes the lower wheel turn round?	a. Blue liquid, liquid falling down.
	ii. What makes the blue liquid fall down?	a. Turning the liquid timer upside down. b. Holes in the Timer through which the liquid falls; c. The wheels; d. Density of the blue liquid.
	iii. What makes the colourless liquid rise up?	a. The blue liquid. b. The wheels. c. Heat makes it rise up
Windmill	When you put the lit candle under the windmill: i. What happened?	a. It moved; b. Heat came out; c. The candle lit.
	ii. What made it happen?	a. The candle/ heat/ flame/ fire/ heat from the candle. b. Air/ wind; c. The heat from the candle went through the slots and made it happen. d. Light of the candle. e. Hot air; f. Energy made it move.
Steam Engine	When you put the burner under the tank: i. What happened?	a. The engine moved; b. All the bits moved. c. Spirit burned, flame came.
	ii. What made it happen?	a. Oil/ spirit/ flame/ heat/ burner. b. Steam; c. Hot air; d. Fan underneath. e. Belts, strings; f. Power.
Hand Dynamo	When you moved the handle: i. What happened?	a. Light goes on.
	ii. What made it happen?	a. Handle; b. Electricity; c. Machine/ dynamo. d. Rubber on the dynamo knob. e. Heat produced by the friction of handle with the knob of the dynamo.

Table-10

4.6.5. When the data were arranged on the basis of vocabulary used for each activity, an increase in diversity was noticed while going from P4 to P7 (many of the new words were of the children's own construction and were not always used correctly). More scientific words are used at secondary level which is an obvious effect of formal science teaching at this stage(appendix-2).

4.7. CHAIN OF REASONING. In view of the results obtained (Table-8 and Table-9) it was decided to arrange the data on the basis of the length of the chain of reasoning (thought steps) because each activity had a different number of steps at description and explanation levels. For example, while describing the procedure of lighting a torch two steps are used; a) button, and b) light comes up. (Button causes the torch to light up).

But on the explanation side there are many possible steps such as:

1. Chemical energy in the battery.
2. Battery produces current.
3. Current flows through the circuit to the bulb.
4. Bulb changes electricity into light.

The matter of splitting the full process of each activity was discussed with the colleagues in the Centre for Science Education (Glasgow University). Bearing in mind the age of the children, and children's responses, different closely inter-related steps were grouped together and considered as one step. Sometimes the children do not distinguish between description and explanation and use the same response for the both. So in such cases the same response is considered for both, description and explanation, such as, for the windmill. The number of steps (chain of reasoning as grouped by the researcher) in each activity is given below, the figures in brackets showing the number of thought steps for description and for the explanation of the activity.

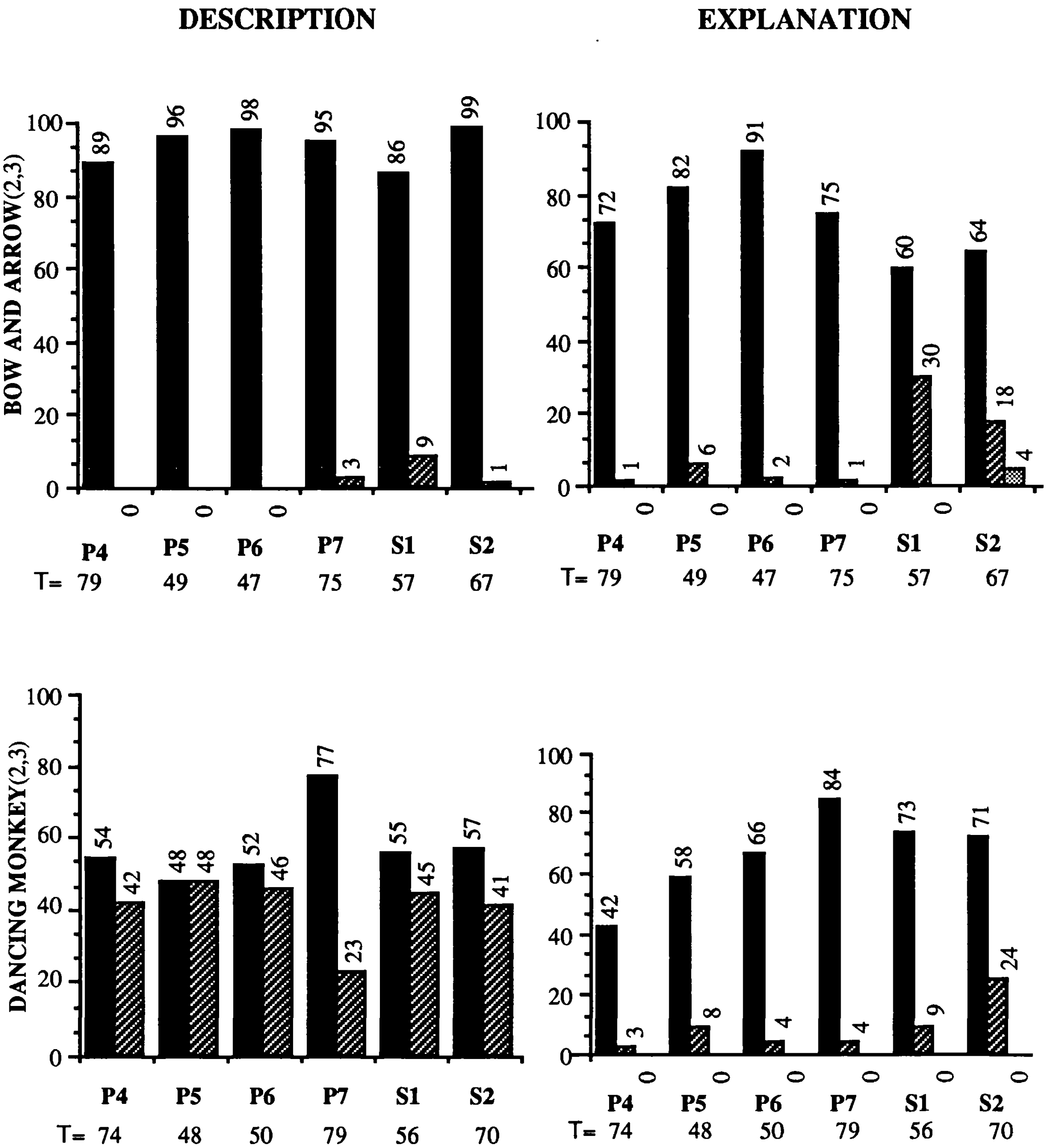
ACTIVITY	DESCRIPTION STEPS	EXPLANATION STEPS
Bow & Arrow (2,3)	1. Movement of the arrow. 2. Shape of the arrow.	1. Pulling force. 2. Bending of the bow, expansion of the bow, and force exerted on the string/ tension in the string. 3. String pushing the arrow.
Dancing Monkey (2,3)	1. Button. 2. Movement.	1. Force from hand. 2. Pressure of button on water, Jet of water going up, jet of water pushing the monkey upward. 3. Gravitational force brings monkey down.
Liquid Timer (2,3)	1. Blue liquid falling down. 2. Wheels turn.	1. Blue liquid denser/ heavier, falls under gravity, falls on one side because of level difference. 2. Lower wheel turns because of falling liquid. 3. Colourless liquid rises up being less denser.
Flute (3,3)	1. Shape of the flute. 2. Holes in the flute, change of note. 3. Music.	1. Breath/ air. 2. Vibrations in the pipe, change of pitch. 3. Sound/ vibrations travelling to the ear.
Windmill (3,3)	1. Candle/ fire/ smoke/ flame/ light/ heat. 2. Shape of the leaves. 3. Movement of the windmill.	1. Candle/ fire/ smoke/ light/ heat/ heat energy. 2. Hot air/ hot air rises. 3. Hot air pushes the leaves turn.
Echo Killer (2,4)	1. Button. 2. Music/ noise.	1. Chemical energy/ battery. 2. Circuit/ wires. 3. Electricity/ current/ (electrical) vibrations. 4. Speaker/ sound travelling to the ear.
Torch (2,4)	1. Button. 2. Light.	1. Chemical energy/ battery. 2. Circuit/ wires/ metallic plate (under the button) connecting button with the circuit. 3. Electricity. 4. Change of electricity into light.

ACTIVITY	DESCRIPTION STEPS	EXPLANATION STEPS
Hand Dynamo (3,4)	1. Movement of the handle, movement of the knob on the dynamo. 2. Circuit, wires. 3. Bulb lights up.	1. Movement inside the dynamo. 2. Electricity produced/ Electricity. 3. Electricity travels in wires/ circuit. 4. Electricity changed into light.
Steam Engine (3,4)	1. Oil/ spirit/ smoke/ fire/ burner/ heat. 2. Hot water/ steam. 3. Movement of the engine.	1. Spirit/ fire/ heat/ heat energy. 2. Steam/ steam energy/ pressure. 3. Pressure of steam on the piston. 4. Move of piston/ pulleys/ strings.
Helicopter (3,5)	1. Movement of fan on the back/ movement of the propellers. 2. Movement of the air/ wind. 3. Movement of the helicopter.	1. Chemical energy/ battery. 2. Metallic piece inside (connection) / circuit. 3. Electricity. 4. Motor/ Engine inside, movement of the fans, fans blowing air backward, air pushing the helicopter forward, upper propeller elevating the helicopter. 5. String keeping the helicopter in a circle.

Table-11

4.8. **RESULTS BASED ON CHAIN OF REASONING.** The results (Fig.56) prepared on the basis of reasoning steps (chain of reasoning held by the children at each level) showed that in most of the cases, children from Primary 4 to Secondary 2 tend to describe and explain an activity in two steps only. A few children from P7 (age 11) onward could describe and explain with 3 steps. There was only one child at Secondary 2, (one out of 396 children overall tested in this phase) who could explain using 4 steps for the Steam Engine.

Figure-56



Children describing two steps

Children describing only one step

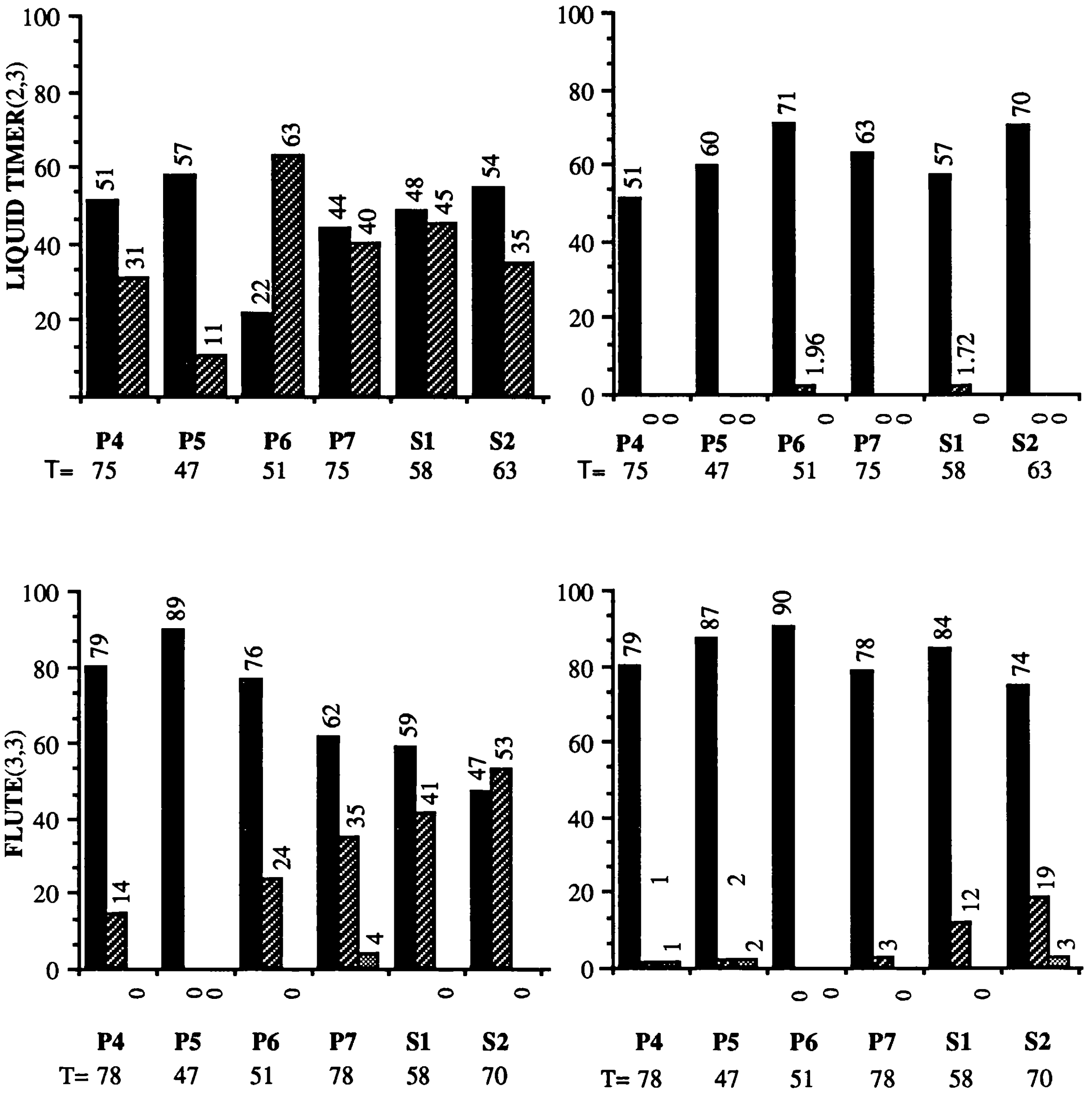
Children explaining three steps

Children explaining two steps

Children explaining only one step

T= Total number of children taking part in the activity
All the numbers used are in percentages.

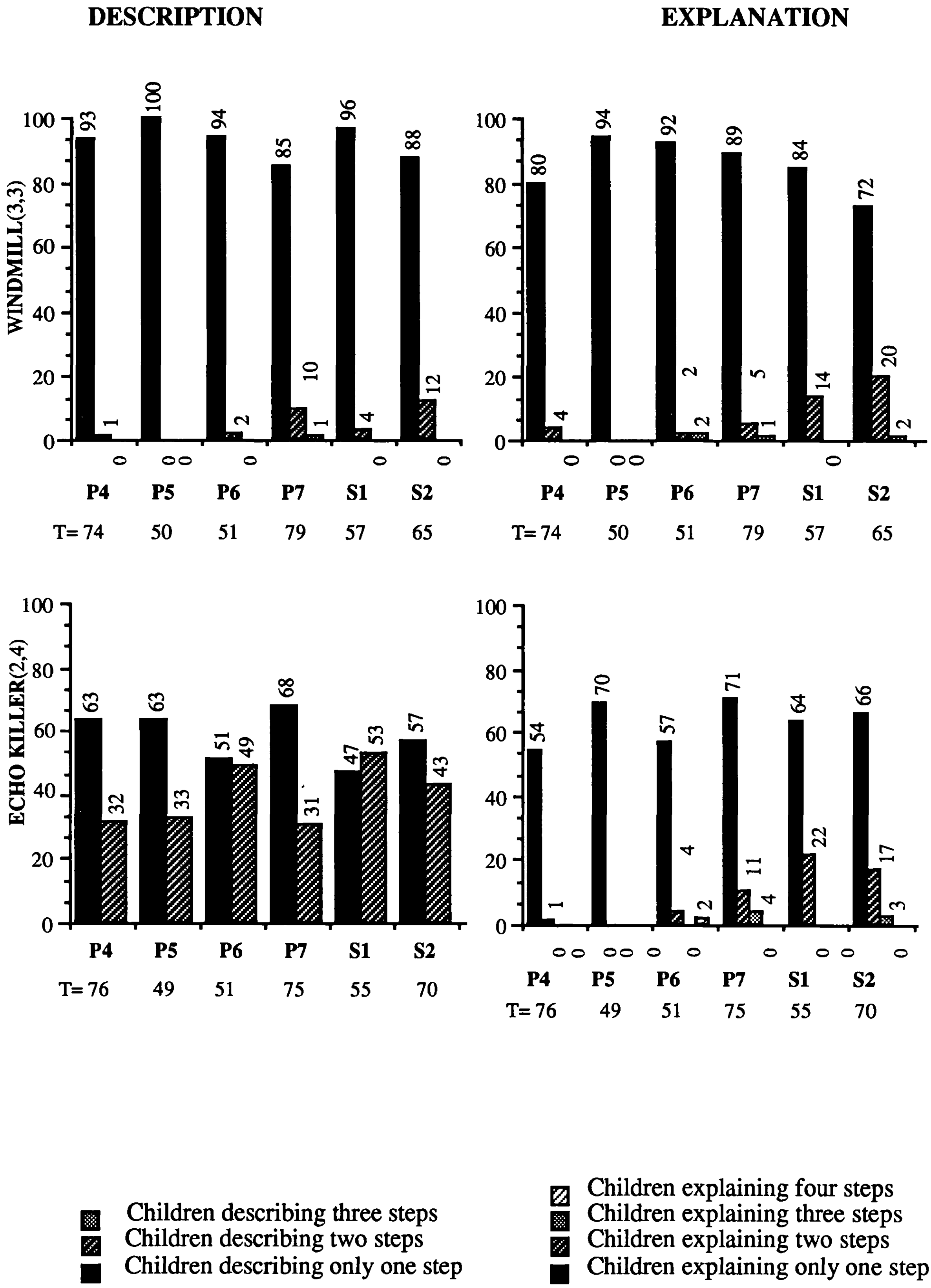
DESCRIPTION EXPLANATION



Children describing three steps
Children describing two steps
Children describing only one step

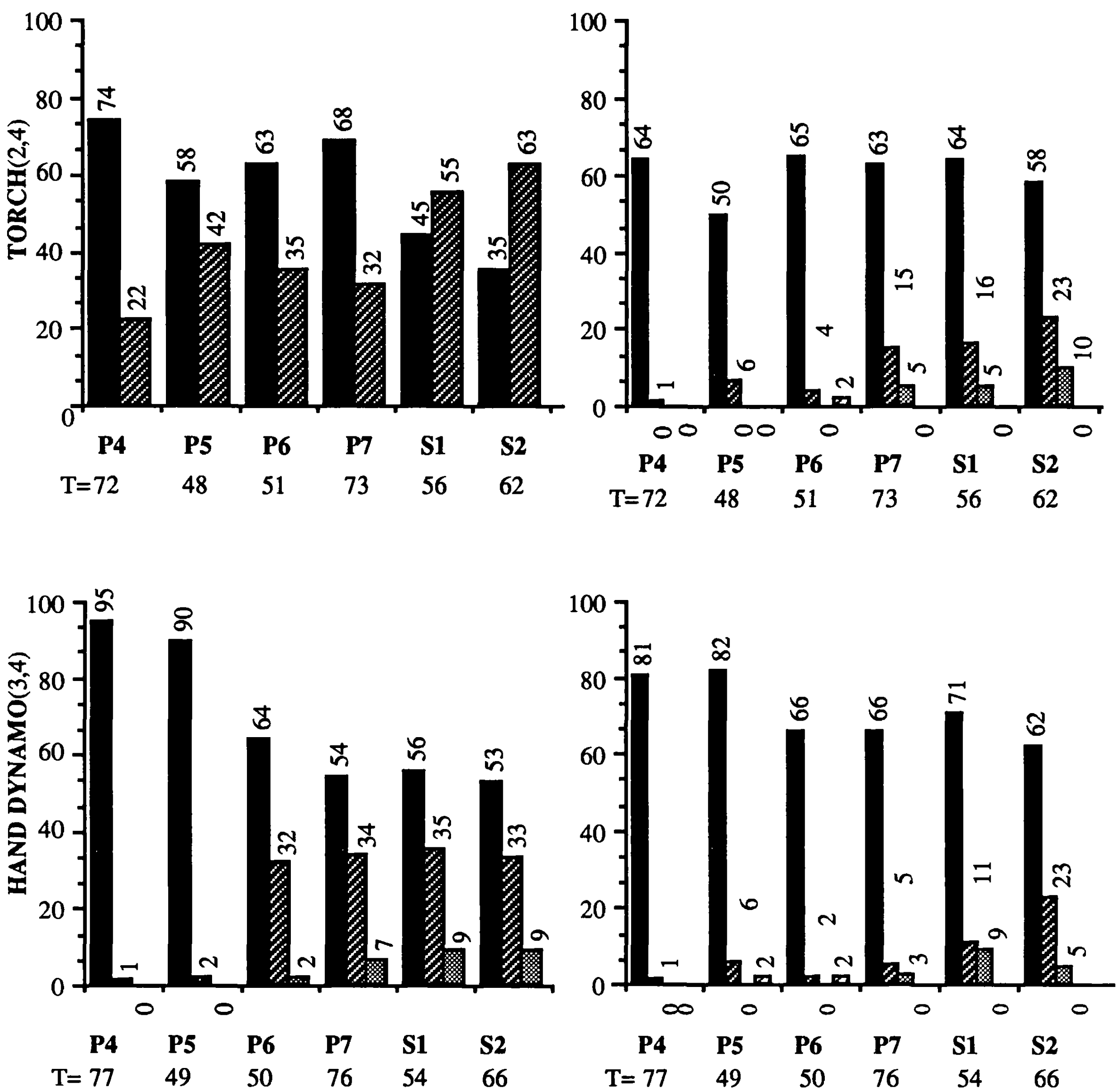
Children explaining three steps
Children explaining two steps
Children explaining only one step

T= Total number of children taking part in the activity
All the numbers used are in percentages.



T= Total number of children taking part in the activity
All the numbers used are in percentages.

DESCRIPTION **EXPLANATION**

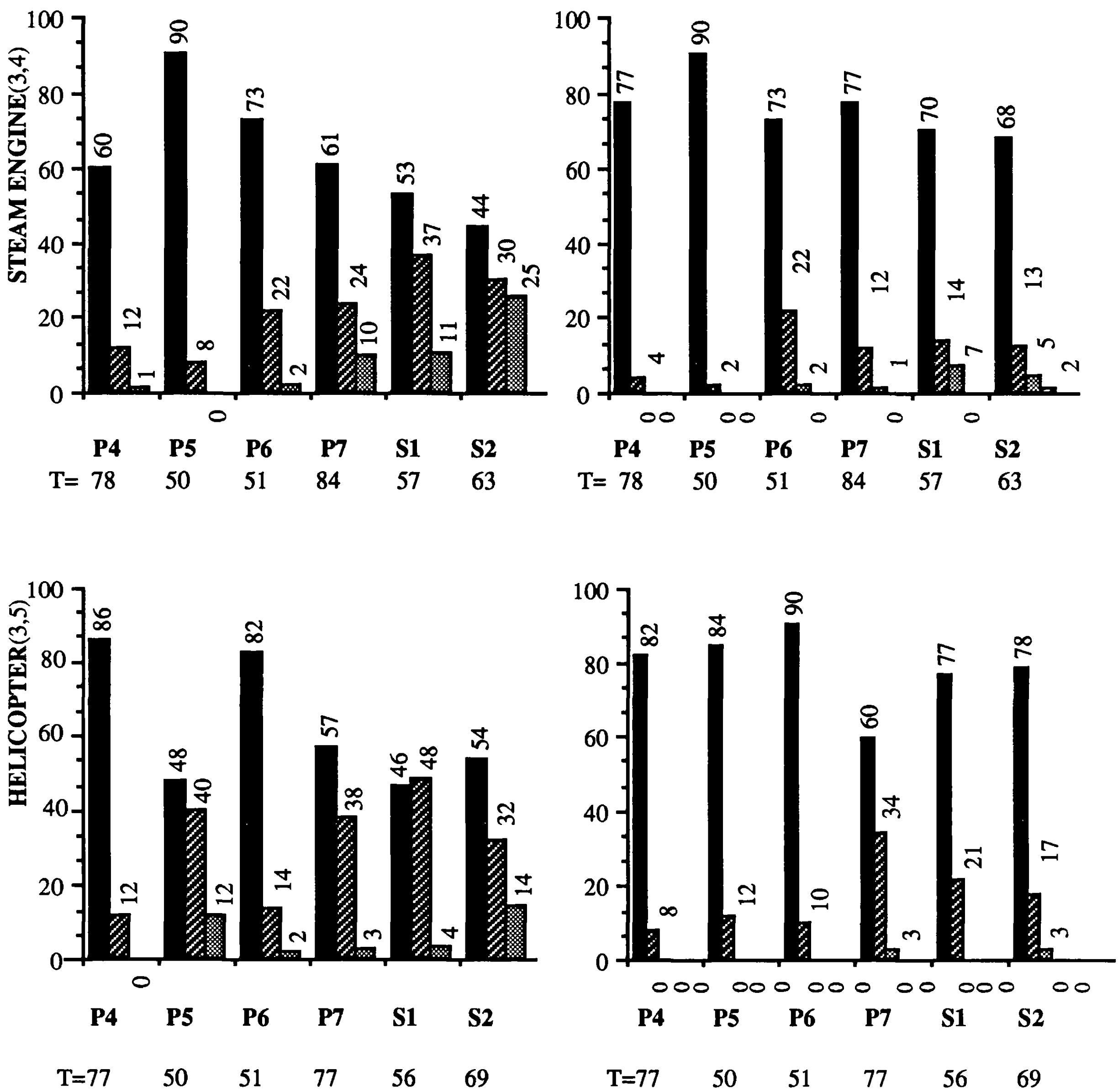


Children describing three steps
Children describing two steps
Children describing only one step

Children explaining four steps
Children explaining three steps
Children explaining two steps
Children explaining only one step

T= Total number of children taking part in the activity
All the numbers used are in percentages.

DESCRIPTION EXPLANATION



Children describing three steps
Children describing two steps
Children describing only one step

Children explaining five steps
Children explaining four steps
Children explaining three steps
Children explaining two steps
Children explaining only one step

T= Total number of children taking part in the activity
All the numbers used are in percentages.

4.8.1. It was also obvious from the results (Fig.56) that wherever the number of reasoning steps is greater than two, the performance decreases. The activities, such as, Windmill, Flute, Hand Dynamo, Steam Engine and the Helicopter have more than two steps in description and explanation processes and the number of children who could attempt steps more than two in an activity is very low. The results also show an improvement in performing some activities at P7 level (age 12). When the children (after P7) are confronted with formal science teaching at Secondary 1 level, the performance in these activities decreases. This sudden drop might be the effect of confusion happening with exposure to the formal science teaching and the concepts already developed through informal learning. This confusion seems to be absent, more or less, by the end of second year at secondary level.

4.9. AVERAGE LENGTH OF REASONING CHAIN FOR DESCRIPTION AND EXPLANATION BASED UPON CORRECT ANSWERS.

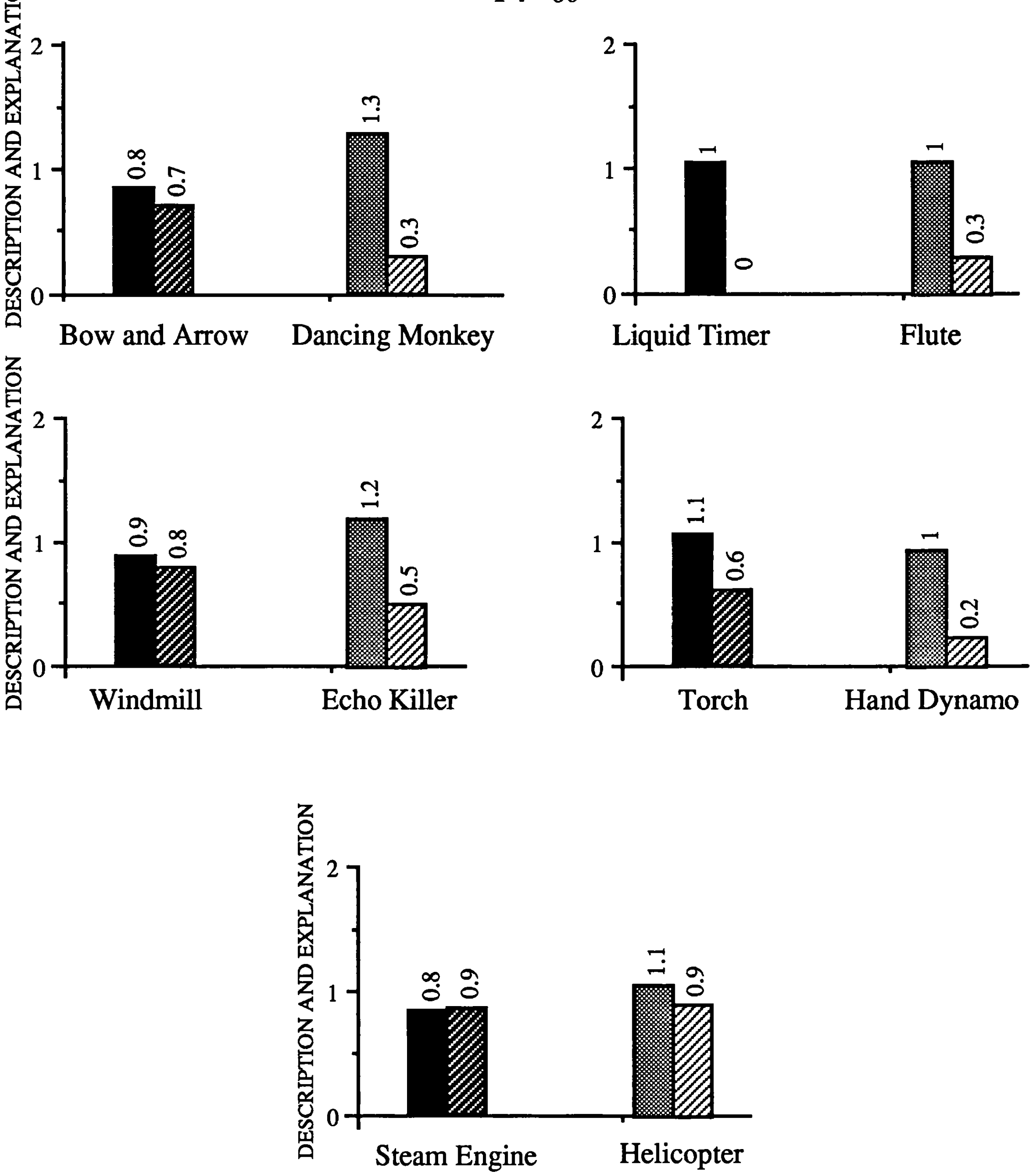
When the data were arranged on the basis of average performance of the children, it showed that in almost all the cases the average length of the reasoning chain for explanation is lower than the average length of chain for description (Fig.57). There is a very slow increase in explanation ability in going from Primary to Secondary level. Moreover, it showed that in the case of the Bow and Arrow, the Windmill, the length of reasoning chain for description and explanation is the same from P4 up to Secondary 2 level. These are the activities for which some of the explanation steps are quite observable. In all the other activities the explanation steps may have been hidden and the performance increases as the age increases.

4.9.1. In Figure-57, the data for each activity are presented in adjacent columns to show description and explanation. For accommodating more data on each page, data for two activities are fed in the computer at the same time. When the graphs are prepared by computer, all the four columns appear differently shaded; two for each activity.

Figure-57

Average Length of reasoning chain for describing and explaining the activities based upon correct answers

P4= 80

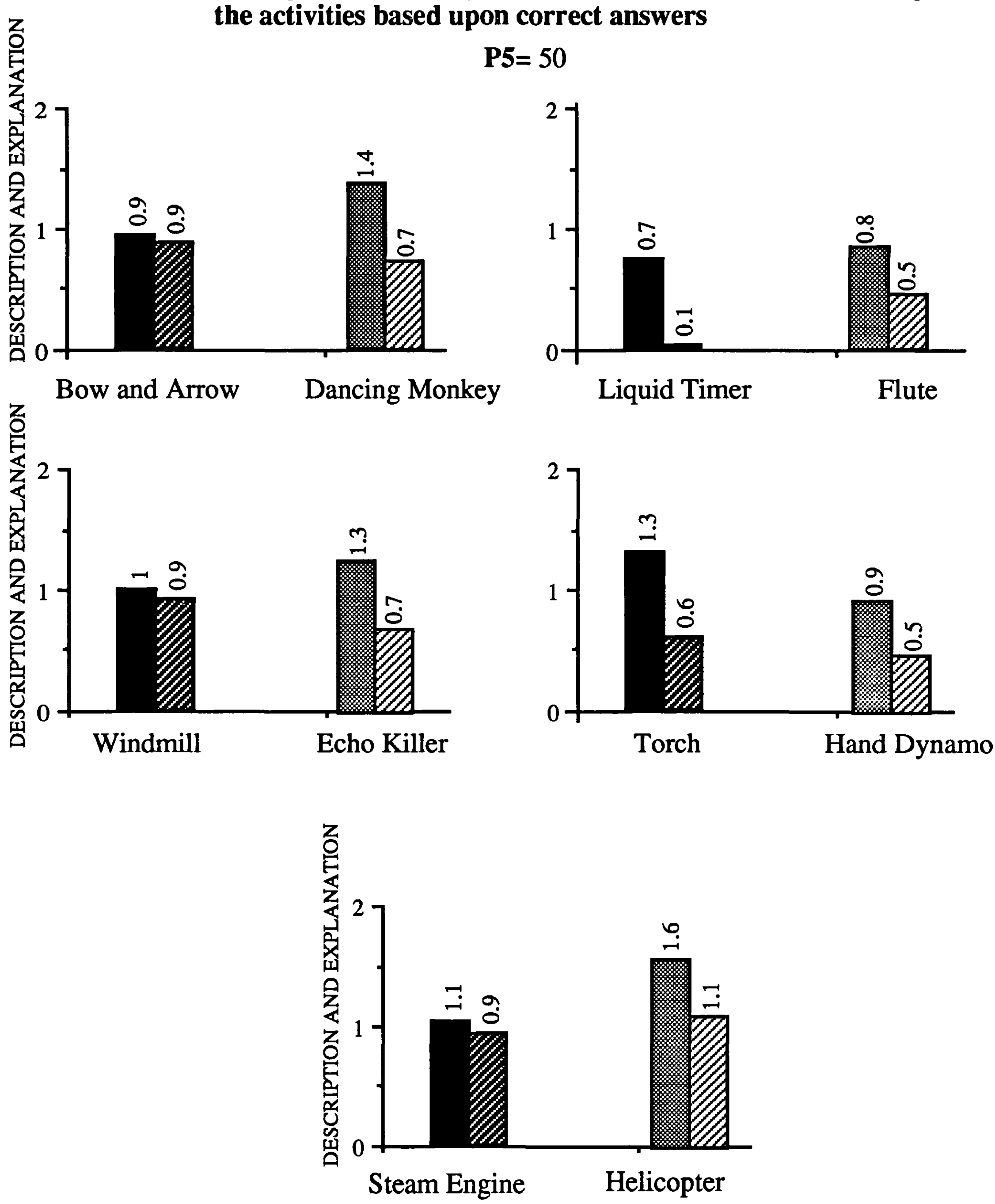


Average length of chain of explanation | Average length of chain of explanation
Average length of chain of description | Average length of chain of description

All numbers are actual

Average Length of reasoning chain for describing and explaining the activities based upon correct answers

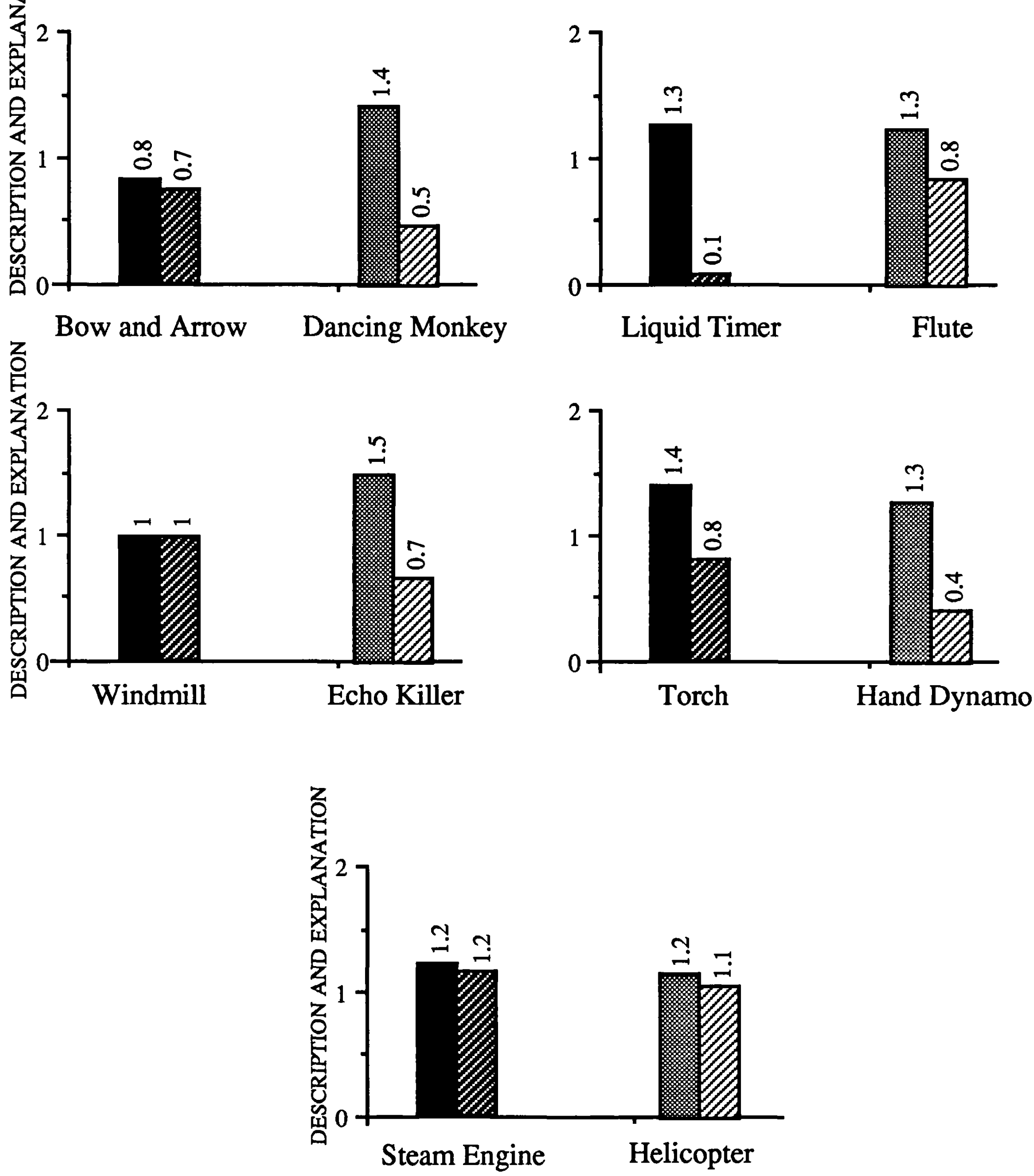
P5= 50



▨ Average length of chain of explanation ▨ Average length of chain of explanation
■ Average length of chain of description ▩ Average length of chain of description
All numbers are actual

Average Length of reasoning chain for describing and explaining the activities based upon correct answers

P6= 51

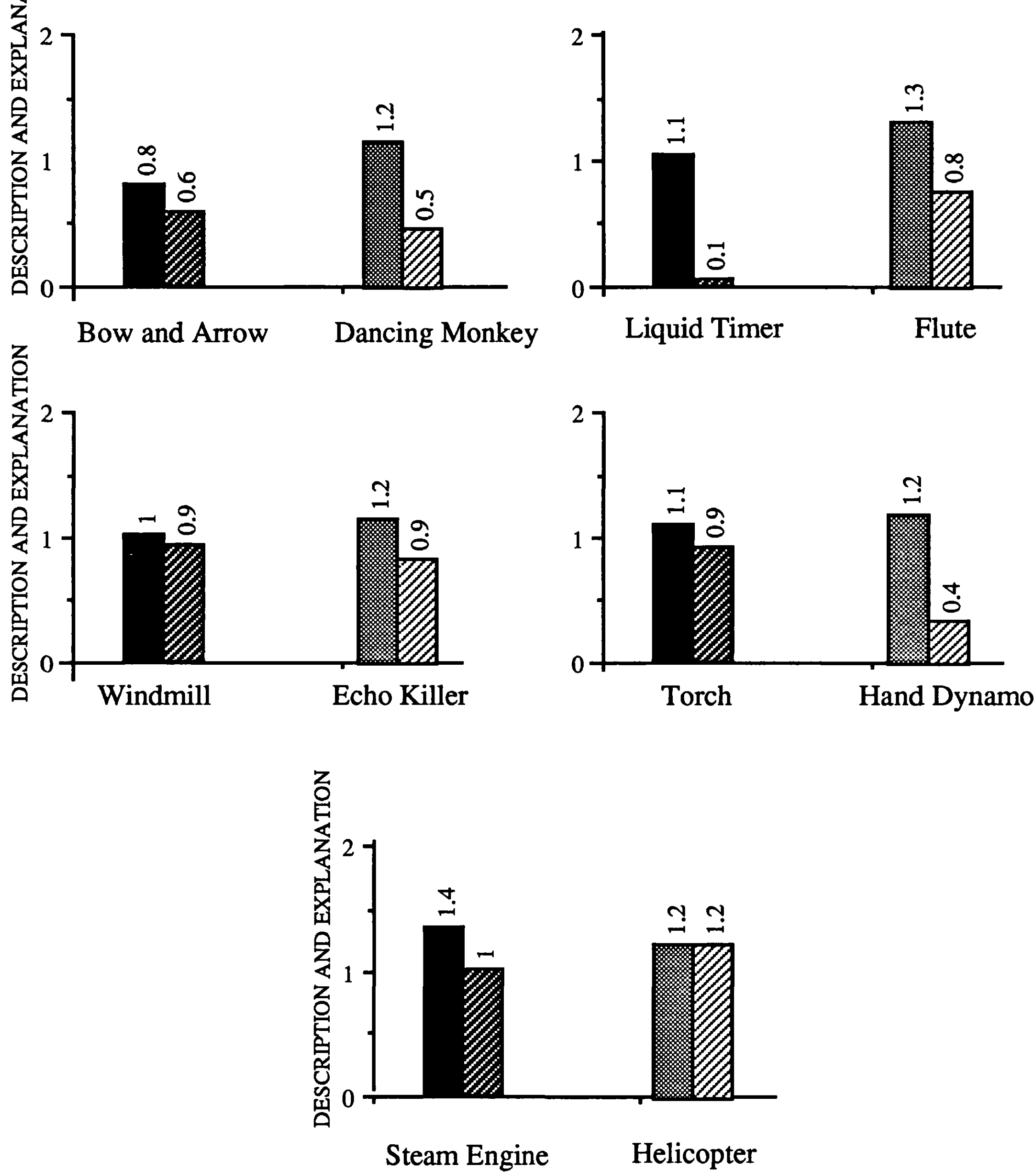


Average length of chain of explanation | Average length of chain of explanation
Average length of chain of description | Average length of chain of description

All numbers are actual

Length of reasoning chain for describing and explaining the activities based upon correct answers

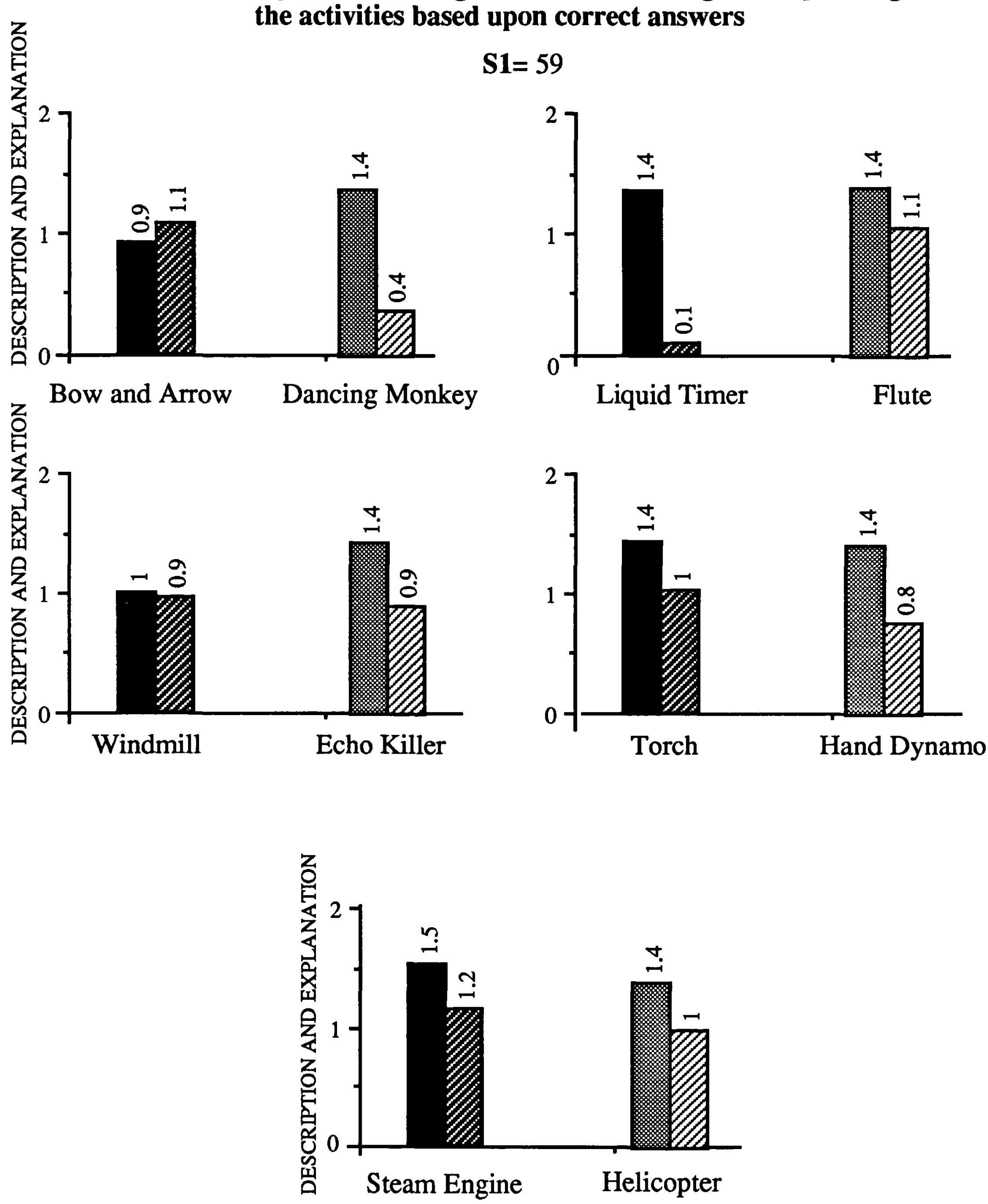
P7= 84



Average length of chain of explanation ▨ Average length of chain of explanation
Average length of chain of description ▩ Average length of chain of description
All numbers are actual

Average Length of reasoning chain for describing and explaining the activities based upon correct answers

S1= 59

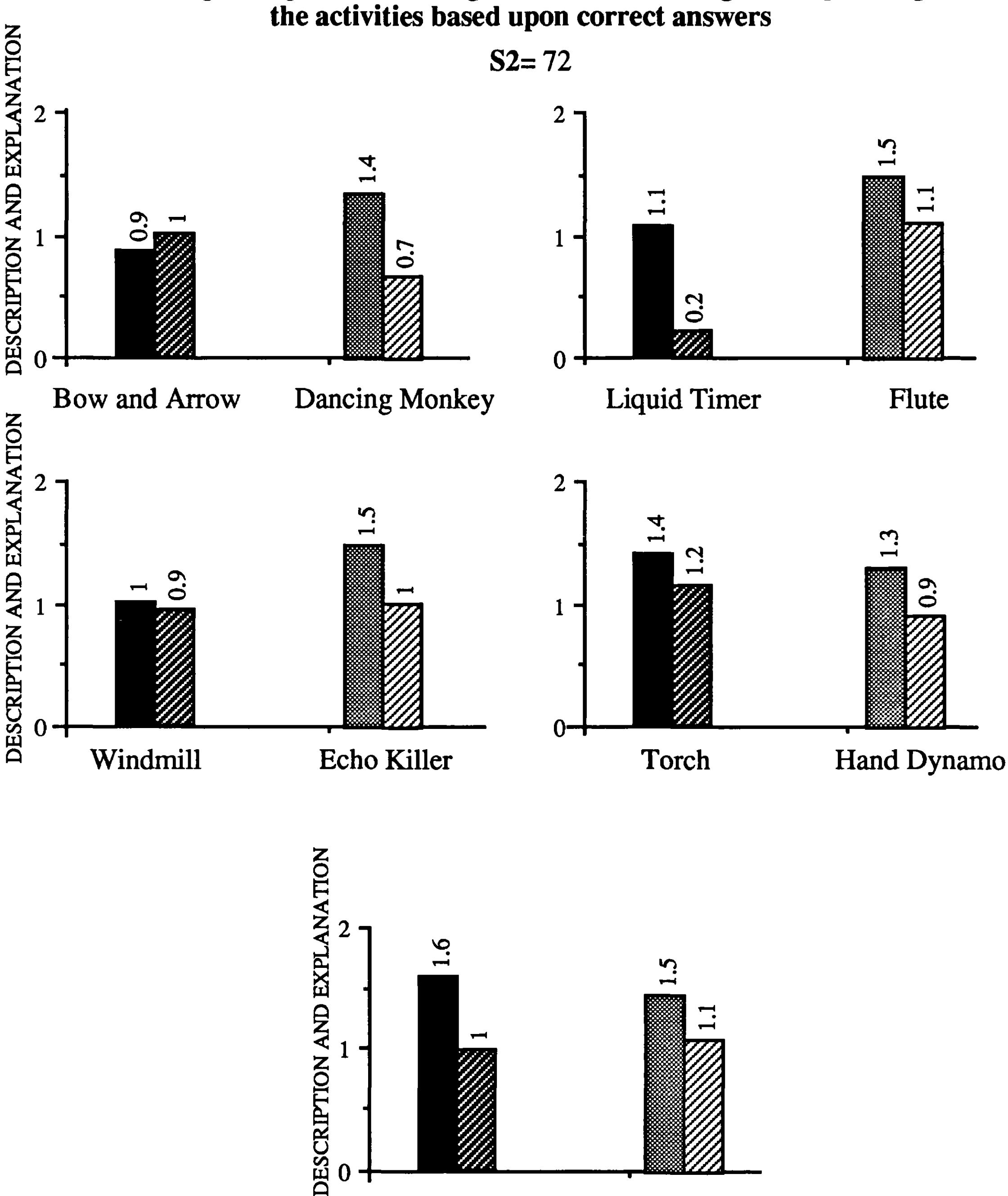


Average length of chain of explanation | Average length of chain of explanation
Average length of chain of description | Average length of chain of description

All numbers are actual

Average Length of reasoning chain for describing and explaining the activities based upon correct answers

S2= 72

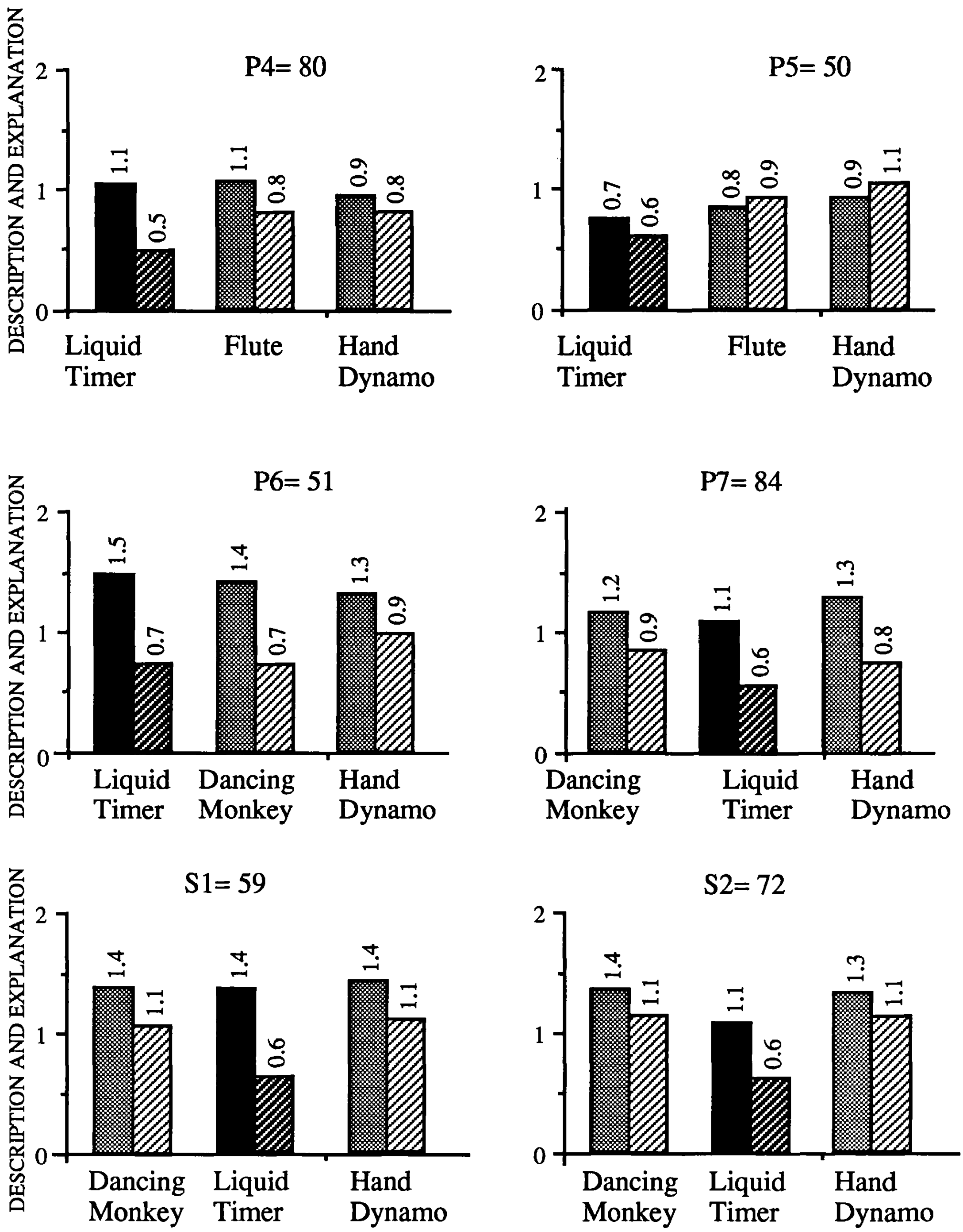


Average length of chain of explanation / Average length of chain of explanation
Average length of chain of description / Average length of chain of description
All numbers are actual

4.10. AVERAGE LENGTH OF REASONING CHAIN BASED UPON CORRECT AND ALTERNATIVE ANSWERS:

It was felt that some children might be able to hold a longer chain of reasoning even if though it was not entirely correct. Therefore data were arranged on the basis of length of any kind (right or wrong) of reasoning chain held by children (Fig.58). This showed a small increase in the performance of the children in some activities as compared to the performance excluding the reasoning chain for alternative answers. For example; there is a small increase in describing and explaining the Dancing Monkey, the Liquid Timer , the Hand Dynamo and the Flute when the length of reasoning chain of incorrect responses is also considered.

Length of reasoning chain for describing and explaining the activities based upon correct and incorrect answers

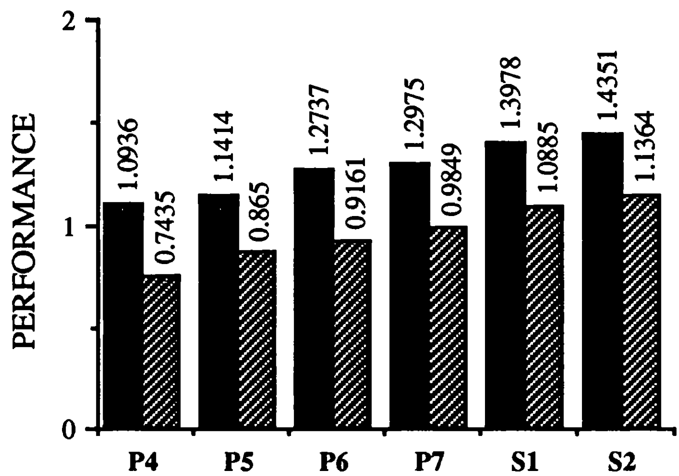


▩ Average length of chain of explanation ▨ Average length of chain of explanation
■ Average length of chain of description ▩ Average length of chain of description
All numbers are actual and first column of each activity represents "description" and the second columnre presents "explanation" of each activity.

4.11. CUMULATIVE RESULTS *. When the average chain of reasoning (cumulative scores for all ten activities) for description and explanation held by children were plotted against the age level of the children, it showed a very slow but steady increase in performance with increase in age (as shown below in figure-59).

CUMULATIVE SCORES FOR WHOLE SAMPLE

Figure-59



▨ Length of chain of reasoning for explanation
■ Length of chain of reasoning for description
Performance means length of chain of reasoning (includingg right and wrong responses).

* **Cumulative scores:** Cumulative scores were calculated as follows:

i. For each child the average length of reasoning chain was calculated for all ten activities.

ii. Then the average length of reasoning chain was found for each level (e.g. P4).

4.12. DISCUSSION.

Although the technique had been changed in this part of the work, the same patterns emerged as in the previous two phases. These patterns are now based on much more information.

1. **The children mix up description and explanation and do not differentiate between describing and explaining a process.** This is illustrated in the following examples:

LIQUID TIMER

When you turned the Liquid Timer upside down:

Q.i. What makes the lower wheel turn round?

RESPONSES.

a. The hole makes the wheel turn round.

b. The liquid.

c. Turning the timer upside down.

Q.ii. What makes the blue liquid fall down?

RESPONSES.

a. Colourless liquid.

b. Pressure from the colourless liquid.

c. Holes.

Q.iii. What makes colourless liquid rise up?

RESPONSES.

a. Blue liquid.

b. The lower wheel.

c. The bubbles (of colourless liquid).

STEAM ENGINE

When you put the burner under the tank:

Q.i. What happened?

RESPONSES.

a. It started to burn up and water came out.

b. The spirit burnt and water came out.

c. The wheels started to move.

d. It started and made a noise like a train.

Q.ii. What made it happen?

RESPONSES

a. The wheel (piston) made it happen.

b. The engine started.

c. The heat made it happen.

d. The burning spirit made it happen.

2. **Children have ill-formed explanations for many things based upon partially digested input from formal or informal sources. A few may be self-generated.** For example,

LIQUID TIMER

When you turned the Liquid Timer upside down:

Q.i. what makes the blue liquid fall down?

Many children had the concept as, " The pressure from the wheel" (The wheel pulled it down). One child said, "Because the air favours it".

Q.ii. What makes the colourless liquid rise up?

Some children considered as, "Air pressure makes the colourless liquid rise up".

STEAM ENGINE

Q. What makes it happen (what causes the movement of the Steam Engine)?

One child said, "Heat energy flowed inside the tank, flowed through; goes to the one wheel (piston) which had wires (belts) attached to it and that moved another wheel which moved another wheel and so on until everything was moving". Another child said, "The power got heated". One girl from Secondary 1 said, "This happened because the fire got in contact with the water and made the steam. All the wheels (pulleys) made the experiment happen. They turned the water to the fire which made the steam and the little tapper at the front slowed down and stopped the contact with fire and the water and steam stopped.

HELICOPTER

Q. What made the helicopter move about?

A girl at Secondary 2 explained, "The fan and string made the helicopter fly. The fan caught the wind and made the helicopter rise up". Two girls from Secondary 2 explained, "It was the weight of the helicopter that made it move about". Another girl from secondary 2 added, "Air is caught when helicopter moves. The air moves the fans. If there is no air , the fans could not move". One boy from Secondary 2 said, "The batteries operated a small cog that turned the fan of the helicopter". Another boy at Secondary 2 explained as, "The helicopter moved because there was nothing supporting it underneath".

Q. What made the fan go?

Four children from Secondary 2 said, "The air in the form of convectional currents made the fan go".

TORCH

Q. What makes it happen (what causes to produce the light)?

One child from P7 said, "The battery activated the light on the torch". A girl from P7 explained as, "Wires inside made electricity which turned on the light when the button is pushed up". Another child stated, "The light went on because it heated the Torch". A girl from Secondary 2 said, "When you switch the torch on, it gives the battery a signal to produce a light". One girl explained, "When the button is pushed, it triggers off the battery to eventually produce a light".

FLUTE

Q. What makes it happen (what causes it to produce the music)?

One child from P5 said, "There are kind of whistles inside the Flute that give different sounds". Another child said, "The sound travelled down the tube and came out of the holes but if you block the holes, it makes a different sound".

DANCING MONKEY

Q. What makes it happen (what makes the monkey move)?

A boy from P7 explained it as, "The button activates an air gun which pushes the monkey over the bar".

HAND DYNAMO

Q. What made it happened (what causes the bulb to light)?

A girl from P7 said, "The (connecting) wire, metal (dynamo) and handle made it happen because when I turned the handle, it seemed to slowly light up because the metal, wire and handle give signals to each other". Another girl said, "When you turn the handle, it puts electricity through the thing (Dynamo) and it puts through wires and the light comes on". A boy from P7 said, "The wheel turns the other wheel which heats up. Then it evaporates through the red wire, the black wire helps the bulb light up". One child from Secondary 1 explained as, "You make the power with your hand. So you make electricity and it comes on". Another boy said, "We gave it energy from muscles and the bulb went on". A girl explained it like this, "The wheel turned and the heat makes the bulb light". A boy from Secondary 2 said, "By turning the handle, an electric current was created and then amplified by Dynamo". Another girl said, "The heat from the wheel turning goes through the wires alongwith electricity and turned the light on".

ECHO KILLER

Q. What made it happen (what caused the different sounds when different buttons were pressed)?

A boy from P7 said, "I think there was a spring which went down and touched a battery which was programmed to make noises". A girl from Secondary 1 explained it as, "The noises are planted in the toy and with the help of the batteries we could hear *them". A girl from Secondary 2 explained as, "when you press the button, the holes at the top must have air going in , then batteries made it go".*

WINDMILL

Some of the children explained the turning of the windmill over a lit candle as, "The heat's pressure is pushing upwards. It is powerful and makes the windmill move". A girl from Secondary 1 said, "The steam from the candle made the windmill turn". Another Secondary 1 boy said, "The rising heat was trapped and pushed the blades round". A Secondary 2 girl stated, "The windmill moved because if you lit the candle, it gives hot air and the air beside the windmill is cold and then when hot air and cold air goes together, it gives movement to the windmill and makes it move and that's how the planes work".

3. Personal experience plays a very important role in the development of concepts. Children develop concepts from one activity and use them to explain another. For example:

A girl performed the windmill activity and got the idea of moving the windmill with hot air. When she performed the Steam Engine activity, she explained its movement as, "The hot air from the fire and the steam from the water move the wheel (piston) which moves the others". Another P6 girl developed the idea, "The reason it happened , is because the pressure of the fire pushed upwards and because of the pressure of the fire provided, the wheels turned round".

At the start, the piston of the Steam Engine needs a push to move it because of the low pressure of the steam. One girl at P7 picked up this idea and stated her concept about the movement of the Steam Engine as, "When the person gave the wheel next to the burner a push, everything started to move". Similarly, one child from P7 constructed his concept from the windmill turning over a lit candle and the helicopter moving with batteries and explained the movement of the steam engine as, "Heat, wire and electricity made it happen". One child from P7 stated as, "I think there was a fan underneath which when touched by the flame, made it turn and started up the engine".

A girl from Secondary 1 explained the movement of the fans in the helicopter activity as, "Wind blowing on to the fans makes them turn". While answering to the question "what made the helicopter move about?, she wrote, "The fans and the propellers were turning two separate ways and this helped the helicopter to turn". Similarly, two girls at Secondary 1 developed their concept about the movement of the steam engine from the helicopter and stated as, "There is a wheel turning inside (the steam engine) which made it go". A girl explained the movement of the helicopter as, "The wind makes it move. It moves in the direction the wind moves. When the wind changes direction, it changes direction too". A child mixed the concept about the music coming from the echo killer with the explanation for the Flute and explained it as, "It were the batteries inside the Flute that made the noise". Another girl developed a concept of movement with batteries (in helicopter) and used it while explaining the dancing Monkey as, "The battery makes it (the monkey) move". A boy from P4 developed the idea of lighting a bulb in the torch and explained Hand Dynamo as, "It is the battery which makes the light". Two boys from P7 explained, "When you turn the handle, the battery inside the Dynamo makes electricity which is conducted by the copper wire down to the light bulb. The faster you turn it the better".

4. **Many phenomena go by either unobserved or pupils are content to accept them without explanation**, e. g.

Many children were content to write that it is the button only which makes the dancing monkey, torch, and echo killer to work. They just observed the process and did not think an explanation was necessary. The vast majority of the children thought of themselves as the source for the process of the activity, e. g . "The helicopter went about because I pressed the button; The monkey moved because I pressed the button; The flute made a noise beacause I blew it, etc".

5. **In most of the cases, while explaining an activity, pupils settle for a statement about the beginning and one about the end. For example;**

1. "when you turn the liquid timer upside down, the blue liquid falls down".
2. "When you put the burner under the tank, the steam engine moves".

3. "When you press the button, the helicopter moves".

4. "When you press the button, the torch lights".

5. "When you press the button, the dancing monkey moves".

6. "Turning the handle makes (of the hand dynamo) the bulb light up".

7. "The heat makes the windmill move".

4.13. **ADDITIONAL INFORMATION.** In addition to these previous patterns, the following information was also gathered:

1. Even when the children performed the activities themselves, they were very poor at explaining different activities .

2. The children could describe activities/ experiments better than explain them.

3. They could describe the activites / experiments better if a few steps were involved such as, the bow and arrow; i.e. simple one step cause and effect. If the activity had easily observable steps, e. g; Liquid Timer has two immiscible liquids and two wheels inside, or Torch had batteries which cause light, better descriptions are given, whereas the flute had more deductive or hidden steps causing poor description for the activity.

4. If an activity had many steps, such as, the helicopter in which batteries cause movement of the fans or propellers, and fans move the helicopter in turn, the children could not describe the full process of the activity.

5. Almost none of the 130 children at P4 and P5 (age 8,9) could describe more than two steps in any activity. Only a few children from P7 onward could describe up to three steps. (There was a maximum of three steps used to describe the activities).

6. There was only one child at Secondary 2 level (one out of 396 children overall) who could give an explanation of an activity which involved four steps. There was a very small percentage (maximum 4 %) of the children who could explain the full process of an activity. Therefore it was considered not valuable to compare the performance on the basis of the ethnic background of the children or on male and female basis.

7. The graphs prepared on the basis of vocabulary used for describing or explaining these activities showed that even if the children are not taught science/ scientific words at Primary level, their vocabulary increases in diversity from P4 to P7. The children

describe/ explain with the help of words which they use in their daily life and relate the science experiments with their personal experiences, such as, "Toxic in the Liquid" for "anything solved in the liquid", "Power" for electricity; "Lever" in the sense of piston; "triggers" in the meaning of starting to move; "activates the battery" in the sense of putting the battery on; "juice inside the battery" instead of chemicals; "signals" in the sense of electric current; "sensory unit and microchip" for producing music; "tug of string" giving the meaning of tension etc. With the start of the formal science teaching at Secondary level, this diversity decreases and the children are focusing on more scientific words.

8. The graphs prepared on the basis of the average performance (ability to describe/ explain different steps in the chain of reasoning in an activity) of the children at each level, showed that they can hold a longer chain of reasoning while describing/ explaining the Bow and Arrow, the Windmill, the Torch, the Steam Engine and the Helicopter. All these activities had some steps which are quite observable, e. g; pulling the string in the Bow and Arrow; burning candle, flame, in the Windmill; spirit, flame, heat, steam and piston in the case of Steam Engine; battery, fans and wind blown backward by the fans in the case of helicopter, etc. The children do not hold a long reasoning chain where the activities involve unobservable steps, such as, explaining the Flute and the Echo killer. They cannot deduce the unobservable steps, such as, while blowing a Flute the children could not deduce what happened to the air inside; how the pitch changes inside the Flute; how the vibrations reach the ear. Similarly, in the Echo Killer activity, the children were unable to deduce that the chemical energy in the battery produces electricity; electricity travels through the circuit and then electricity is changed into sound. A similar situation occurs while explaining the Liquid Timer and the Hand Dynamo. However, the ability to hold a longer chain of reasoning increases with the increase in age.

9. When the graphs were prepared on the basis of the length of reasoning chain (including alternative answers/ concepts) it showed a small increase in the performance

as compared to the performance excluding the chain of reasoning from alternative concepts.

10. When the cumulative scores (chain of reasoning including alternative concepts/ answers) were plotted against the level/ age, it showed a very small but steady increase in performance (ability to hold different steps in the reasoning chain) with an increase in age.

4.14. **OUTCOME**. From the above results it is quite evident that;

1. The children develop and construct their own concepts if they are given a chance to perform an experiment or activity without guidance.
2. They have very limited capacity for holding up to 3, 4 steps in a chain while describing or explaining an activity.
3. The performance increases very slowly, but steadily as the age increases.
4. In most of the cases while describing or explaining an activity, pupils settle for a statement about the beginning and one about the end, for example, I press the button (start) and the helicopter moves (end).
5. Normally description is better than explanation.
6. Only those steps are reported which can be detected by senses. Deductive steps are generally missing.
7. Explanations may be given "to please" but may not be seen as necessary by the pupil.

4.15. The verification of the above results needed further development of suitable activities and techniques. It was considered that the holding of a limited number of reasoning steps while describing and explaining the situation might have a correlation with Working Memory capacity. This also needed further verification. The development of activities and the description of the psychological test is dealt with in the next chapter.

CHAPTER FIVE
5- DEVELOPMENT OF ACTIVITIES

5.1. INTRODUCTION. To verify and extend the results of the previous phase, new activities were devised and tried before using them in schools. For this purpose, literature had to be consulted [67-90]. Science is a major area of human mental and practical activity which generates knowledge; knowledge that can be the basis of important technological applications as well as of intellectual satisfaction. It is an important part of the education of all, not just of scientists, to be aware of the status and nature of scientific knowledge, how it is created and how dependable it is [1]. Every science activity/ experiment happens due to certain causes and for every cause, there is an effect. Similarly, for every effect there is a cause. In other words, every scientific activity is a combination or chain of causes and effects. Moreover, in each scientific activity there are certain causes and effects which are easily observable but others are hidden and an observer has to deduce those steps. As far as the observable steps or observations are concerned, one needs only training in the use of the senses but, children can't deduce the hidden steps (explanations) until they are trained. If the children are going to understand the scientific knowledge and to be encouraged to investigate and to draw sensible conclusions from observations, chains of reasoning need to be established. Keeping in view the importance of the "explanation factor", it was decided in this phase not to consider the "description factor" of the activities. In order to make science learning more effective and enable the children to develop a scientific attitude, there is a need for emphasising the explanation factor of the activities to generate chains of reasoning with varying lengths. Moreover, increase in diversity of the vocabulary along with the increase in age was also reported in the last phase. This is an obvious effect of everyday experiences because this diversity decreases as formal science teaching takes place. So, this will not be considered for further testing. The comparison of the *interview, questionnaire and stations techniques* showed that the *stations technique* was the most successful for exploring the children's concepts. It gathered a treasure store of children's alternative concepts. It also provided the basic information about the relation between the age and the length of reasoning chain of the children. At the same time, it showed some weaknesses. There were some children who did not participate in some of the activities at all and gave no response. There were some children who copied each other's responses because they were working in groups. Therefore it was decided to use both the techniques (questionnaire and 1:1 interview) simultaneously. To make sure that every child should participate in all the activities, the idea of an expert at each station was considered the best.

5.2. **LITERATURE SURVEY.** As a result of the literature survey a variety of activities with varying lengths of reasoning chain was chosen. These were tested and improved later on. It was also kept in view that the maximum length of reasoning chain should be within the bounds of the length of reasoning chain held by the children discovered during the previous phase. All the initially selected activities were first tried by the researcher. Out of a variety of activities, some of them were chosen for further testing.

5.2.1. *Activities having a one-step reasoning chain; simple one step of cause and effect.*

a. PUFF SIGNALS (Mixing of hot coloured water and cold plain water):

Hot blue coloured water in a beaker with aluminium foil cover on it is put inside a larger beaker half filled with cold water.

Making a hole in the foil allows the hot blue coloured water to rise up in the form of puffs.

REASONING STEPS: i. Hot water being "lighter" rises up.

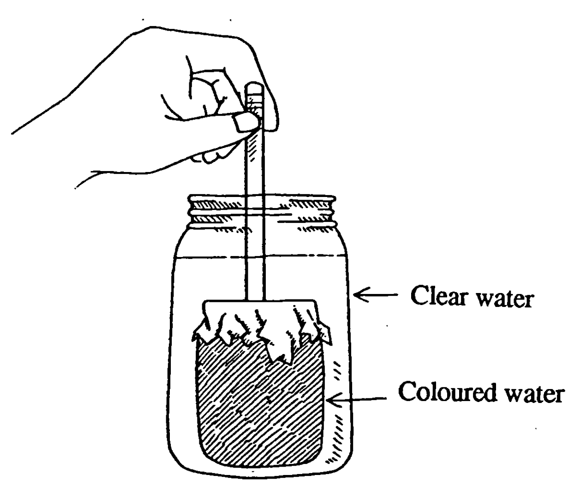


Figure-60

b. FLOATING EGGS. Two beakers of the same volume are put in front of the child. Tap water is put in one of the beakers and salty water in the other. Two boiled eggs

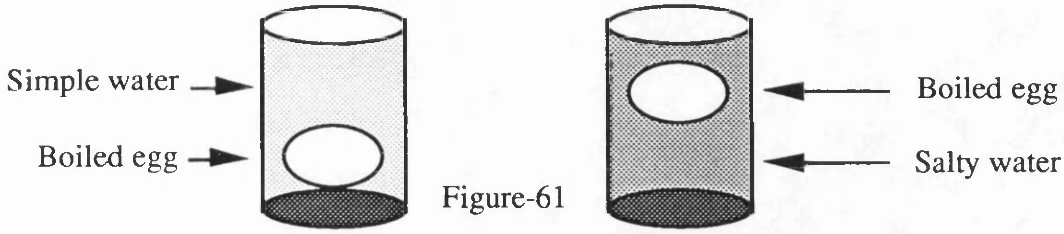


Figure-61

of the same size are immersed in the beakers. The egg immersed in tap water sinks whereas the egg in the salty water floats.

REASONING STEPS: i. The egg floats in the salty water because the egg is less dense than salt water.

c. SKY HOOK.

A piece of wood or plastic is cut in the form of a Hook.

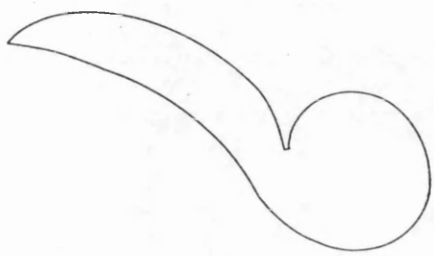


Figure-62

When one tries to balance it on its tail, it can not be balanced. When a leather belt is placed on the hook, it can be balanced on its tail.

REASONING STEPS: i. The belt is balanced because the "the line of action of the weight" is shifted under the finger.

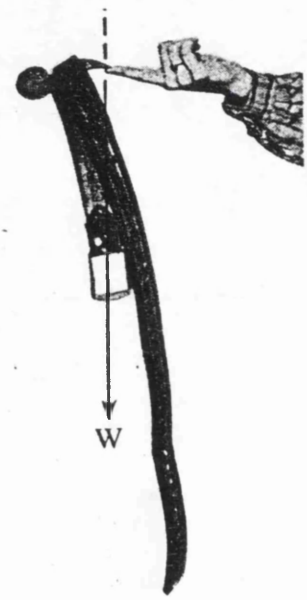


Figure-63

5.2.2. *Activities having two steps of reasoning chain.*

a. STRANGE DIVER. A plastic bottle is filled with water and a dropper, semi-filled with water, is placed inside the bottle. When the bottle is pressed, the dropper (strange diver) falls to the bottom and rises up again when the pressure is released.

REASONING STEPS:i. Squeezing the bottle the pressure is transferred to the water inside the dropper (causes rise of water inside the dropper).

ii. The dropper sinks being now denser than water.

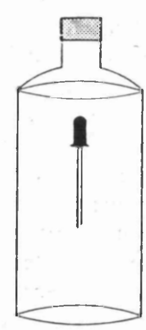


Figure-64

b. FLOATING ICE IN SUNFLOWER OIL. Chilled sunflower oil is put in a long wide cylinder and clamped on a stand. Dried ice cubes dropped in the oil which float.

When the ice cubes melt, the melt water falls to the bottom whereas the ice cubes remain floating in the oil.

REASONING STEPS: i. Ice cubes are "lighter" than sunflower oil and float.

ii. Water is "heavier" than sunflower oil and sinks.

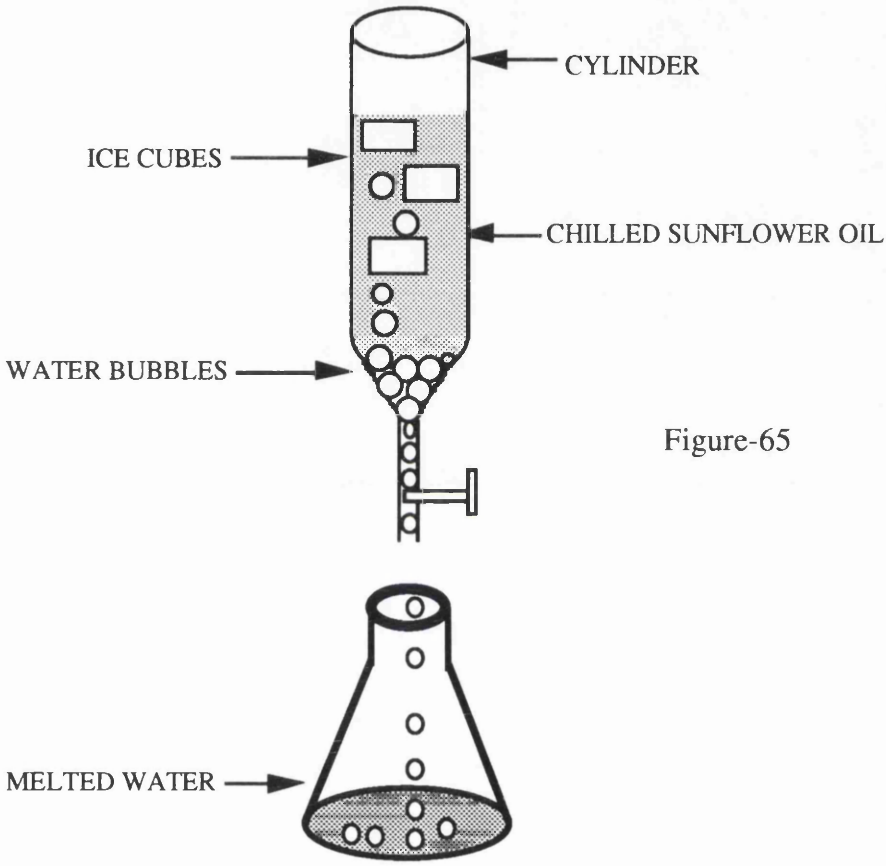


Figure-65

c. POURING WATER OUT OF CAN. A Coca Cola can is emptied. Three holes are made of equal diameter on one end of the can. Water is put in the can. Water does not come out of the inverted can if two holes are blocked; water also does not come out if one hole is blocked and two are open and the can is balanced horizontally.

REASONING STEPS: i. Taking water out decreases the pressure inside the can.

ii. Air from outside the can presses the water in it to equalise the pressure, and so the water does not come out.

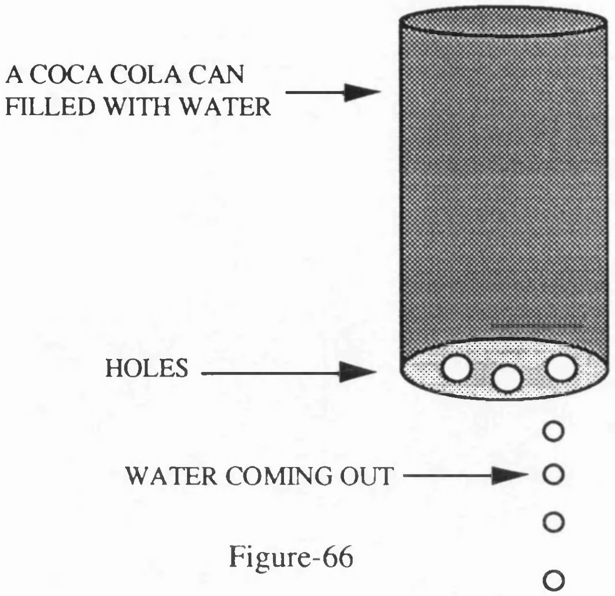


Figure-66

5.2.3. *Activities having three steps of reasoning chain.*

a. INFLATING A BALLOON INSIDE A BOTTLE. A balloon is put inside an empty plastic bottle. The bottle has a hole in it. When the hole is blocked, the balloon cannot be inflated. The balloon can be inflated easily when the hole is open. If the hole is blocked after the balloon has been inflated, the balloon does not deflate automatically.

Figure-67

REASONING STEPS: i. Inflating the balloon inside the bottle needs extra space.
ii. The excess air escapes out of the hole.
iii. The blocking of the hole keeps the air pressure inside equal to the outside pressure. Therefore the balloon does not deflate.

b. INFLATING A SOAP BUBBLE. The mouth of a round bottom flask is dipped in a washing liquid. A thin layer of the liquid covers the mouth of the bottle. When the bottom of the bottle is covered with the hands, the bubble grows.

REASONING STEPS: i. The bottom of the flask absorbs heat from the hands.

ii. The air inside the bottle absorbs heat from the bottom.

iii. The air inside the flask expands and the bubble grows.

5.2.4. *Activities having four steps of reasoning chain.*

a. RISING WATER PUZZLE. Water is put in a large size watch glass. A small birthday candle is lit and put in the middle of the watch glass. The candle is covered with an empty bottle. The candle goes out and water rises up in the bottle.

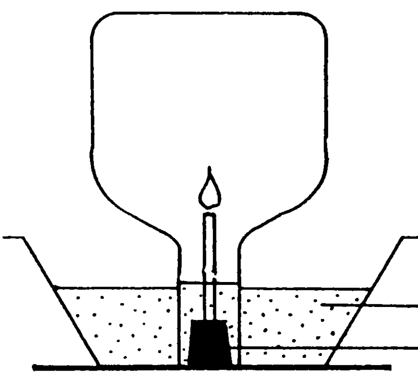


Figure-68

REASONING STEPS: i. Oxygen inside the bottle is used up (to produce carbon dioxide).

ii. Carbon dioxide dissolves in the water.

iii. Pressure is decreased inside the bottle.

iv. Air from outside forces the water in to the bottle.

b. HAND DYNAMO. This is the same activity used in the previous phase. A handle is moved to produce electricity in the dynamo which causes a bulb to light.

REASONING STEPS: i. Movement within the dynamo.

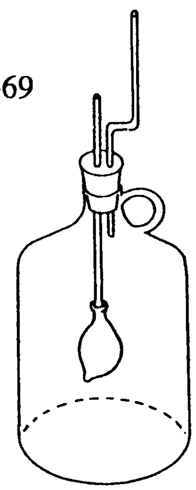
ii. Electricity is generated.

iii. Electricity travels through the circuit.

iv. Electricity is changed into light.

5.2.5. *Activities having five steps of reasoning chain.*

Figure-69



a. BALLOON FOUNTAIN. A glass tube is bent as shown in figure-69. A jet is formed at one end of the bent tube. A balloon is attached to another straight glass tube. Both the tubes are passed through a rubber stopper fitted to the mouth of an empty plastic bottle. When the tube with jet inside the bottle is blocked, the balloon cannot be inflated. When that tube is opened, the balloon can be inflated easily. If the balloon is inflated first and then the other tube is blocked, the balloon does not deflate. Now, if the bottle is turned over and the tube, now unblocked, is dipped in water, water rushes inside the bottle through the jet in the form of a fountain.

REASONING STEPS: i. Inflating the balloon inside the bottle needs extra space pushing air out.

ii. Blocking the other tube keeps the air pressure inside the bottle equal to the outside pressure.

iii. Opening the other tube, allows the balloon to deflate.

iv. Air pressure decreases inside the bottle.

v. Air from outside forces water in to the bottle to keep the pressure equal to that of outside.

b. SPIRAL MOVING OVER A LIT CANDLE. A spiral of aluminium foil is hung over a lit candle and it turns.

REASONING STEPS: i. Wax burning (chemical change).

ii. Heat energy produced.

iii. Hot air or air gets heated.

iv. Hot air rises up.

v. The rush of hot rising air makes the spiral move.

c. WINDMILL MOVING OVER A LIT CANDLE. This is the same activity which was used during the previous phase. A windmill is hung over a lit candle and it moves.

REASONING STEPS: i. Wax burning (chemical change).

ii. Heat energy produced.

iii. Hot air/ air gets heated.

iv. Hot air rises up.

v. Hot rising (lighter) air makes the blades of the windmill move.

5.3. **FURTHER TESTING THE ACTIVITIES**. To test the activities further, one group of a Primary school play scheme was invited. The group comprised of P4, P5, P6, and P7 children. No one from the group could explain any activity beyond three reasoning steps. On another occasion, two pupils, one from P7 and the other from Higher Grade chemistry, were invited to explain the activities. The P7 child could explain the Hand Dynamo up to four reasoning steps because he had been using the Hand Dynamo on his bicycle and had full knowledge about it. He could also explain the Balloon fountain with five reasoning steps because he had seen this on T. V. The other pupil from Higher Grade (age 17) was able to explain the activities with five reasoning steps because he had studied science throughout his Secondary education. Afterwards, two female secretaries (age about 40) in the department were invited and were asked to explain the activities. One of the secretaries could not explain more than three reasoning steps but the other was able to pick up four reasoning steps in the case of Hand Dynamo. This testing proved that all these activities had the length of reasoning chain not far beyond the capacities of the Primary and Secondary school children.

In order to help the expert and enable him to understand the children's answers, an information leaflet was prepared regarding each activity. To eliminate any writing and spelling problem , the children were not required to write anything. The child would only perform the activity or the expert present would demonstrate. The child was required to explain the activity. If the child was unable to explain the activity, the expert would give him some indirect clues to encourage the child. The expert would then write the child's explanation when he had left the station.

5.4. **DIGIT SPAN TEST**. For the measurement of the working memory of the children, Jacob's [91,92] digit span test, which has been used recently in the Centre for Science Education [93], was considered suitable. The digits were to be read by an expert and the child was required to repeat the digits in the reverse order. The sample digit span test and the proforma for assessing the performance of the child on the digit span test are given below.

5.5. All the activities and the questionnaires which were to be used for the verification of the results obtained in the previous phase, were ready for the final phase. The procedure used during this final phase, administration of the test and the results will be discussed in the next chapter. The sample digit span test and the sample proforma for recording pupils' answers to the digit span test are given in tables-12, 13. The sample information leaflets for all the activities, are given in appendix-3.

DIGIT BACKWARD TEST

DIRECTIONS: Start by saying-

I am going to give you a set of numbers. When I have finished saying each set of numbers, you have to repeat them in reverse order. For example, if I say " 638" You would say" 836". You listen carefully, turn the number over in your mind and repeat from left to right. Are you ready? Then let's begin :"

SERIES	NUMBERS								
2	3	7							
	6	9							
3	4	3	8						
	5	1	4						
4	7	3	2	9					
	6	8	4	9					
5	5	2	8	1	6				
	6	1	4	8	3				
6	5	3	9	4	1	8			
	7	2	4	8	5	6			
7	8	1	2	9	3	6	4		
	7	4	3	9	2	8	1		
8	3	7	9	4	6	2	5	8	
	7	2	8	2	9	6	3	5	
9	2	7	5	8	6	2	4	8	5
	8	1	4	9	3	7	5	6	8

IMPORTANT:

Say the digits at the rate of one per second, not grouped. Let the pitch of the voice drop with the last digit of each series. The series denotes the number of digits.

(Table-12)

DIGIT BACKWARD TEST

DATE: 29.01.1992

SCHOOL: HYNDLAND SECONDARY ***CLASS: S.......***

PUPIL SYMBOLS:

* *ELEPHANT (M)*	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE(F)*
WOLF (M)	*FOX (F)*	*BEAR(M)*

SERIES	Y	N
2		
3		
4		
5		
6		
7		
8		
9		

Signatures....................................

* : The animal names were identifiers which kept the children's actual names confidential.

Table-13

CHAPTER SIX

6- RESEARCH METHOD -IV

6.1. **INTRODUCTION.** Keeping in view the experience obtained from the previous three phases, a stations technique was employed. All the activities were set out on different tables. Every child was required to perform the activities individually and, at each station, there was an expert to record the children's explanations and to encourage the children, if needed. An attempt was made to encourage every child to perform the maximum number of the activities within the time available. The children were required to visit all the stations in turn and at the end to go to a separate room for the digit span test. An arrangement was made to keep the examined children separate from those still to be examined.

6.2. **SCHOOL PUPIL SAMPLE.** To make the samples similar, it was decided to include two children of lowest abilities, two of medium abilities and two with the highest abilities at each age level as judged by their teacher. It was also decided to include equal number of girls and boys with different abilities at each age level in all the schools. So, almost 24 children were examined at each of the Primary school from P4 to P7. The selection of the sample was left to the teachers concerned. At Secondary level, it was decided to include 9 children at each age level because there were only three local Secondary schools conveniently available. The selection was again done by the teachers concerned having three children in each ability group. At the request of the teachers, children and the parents, a specific arrangement was made to allow the children to participate anonymously. The abilities of the children were not known in advance to the researcher. To keep a record of the performance of the same child for five activities, different animal names, such as, elephant, eagle, tiger, horse, wolf, fox, deer, giraffe and bear were proposed by the researcher as identification labels on each child. Teachers controlled the allocation of the names to preserve anonymity and bias in the interviewing. The distribution of the sample at each level and school is given in the table below (table-14).

S. No.	NAME OF THE SCHOOL	NO. OF CHILDREN					
		P4	P5	P6	P7	S1	S2
1	Hillhead Primary school	6	6	6	4	x	x
2	St.Charles' Primary school	6	6	6	6	x	x
3	Willowbank Primary school	6	6	3	9	x	x
4	Lorne Street Primary school	6	6	6	6	x	x
5	Hyndland Secondary school	x	x	x	x	9	9
6	Hillhead Secondary school	x	x	x	x	9	8
7	Woodside Secondary school	x	x	x	x	9	9
8	Total number of children at each level.	24	24	21	25	27	26

Table-14

6.3. **ADMINISTERING THE TEST.** Different local Primary and Secondary schools in Glasgow city were contacted. A general information letter, as usual, describing the purpose and the duration of the test was sent to the schools and to the parents of the children. After the approval of the parents had been given, the schools were contacted to arrange the required visits. One visit was arranged for each of the Primary and Secondary schools. During the same visit all the P4, P5, P6,and P7 classes were examined in one Primary school. Similarly, during one visit for a Secondary school all the children from secondary 1 and secondary 2 were examined. Experts were made available at each station with record sheets for the activity. Each child was first asked to perform the activity, otherwise the expert would demonstrate it. The child was then asked to explain the whole process. The expert would write the explanation possibly in the child's words after the pupil had left for the next station. The interviewers tried to encourage the children in many ways. Firstly, if any child could not perform an activity, the expert present would demonstrate the activity. Secondly, if a child could not explain the activity, the expert would give him some kind of indirect help and encouragement, such as giving an example. Thirdly, at any one station, there were several activities with the same number of steps. Whichever activity the child was able to explain was included in the data for analysis. Fourthly, if the child was able to explain all the activities present at any station, the highest performance on any activity was included in the analysis. Lastly, even if the child gave an incorrect or unscientific explanation, the reasoning chain offered by the child would be included in the analysis of the results. During the first two visits in the Primary schools, it was noticed that no child from P4 to P7 could explain all the steps in the five step activities. So, for the next two Primary school visits, the five step activities were not used. Similarly, all the activities with one-step were excluded while examining the Secondary school children.

6.4. DESCRIPTION OF THE RESULTS:

6.4.1. When the data were arranged on the basis of the full explanation of all the steps, they showed (Figure-70) that:

i. There were some children (although the maximum number of children taking part in an acitivity was 27) who could hold a reasoning chain up to 4 steps.

ii. There is a very small number; i.e. three children at S1 and one at S2 who could hold a five step reasoning chain.

6.4.2. When the data were arranged with increasing complexity for the same group, it showed that the number of children attempting the activities with a maximum of four steps is almost constant. The number of children attempting different steps within 5-step activities decreases as they try to sense more steps. (Figure-71).

6.4.3. When the data were arranged to compare ages with the activities of the same complexity, it showed that the length of the chain of reasoning increases with the increase in age (Figure-72.A, 72.B).

6.4.4. When the cumulative scores for length of reasoning chain held and average Working Memory span were plotted against age, it showed (Figure-73) that:

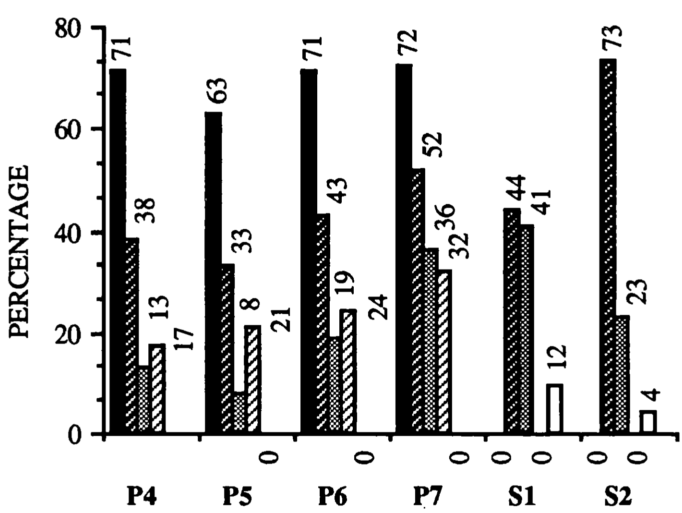
i. There is a very slow but steady increase in the length of reasoning chain held at each level as well as an increase in the working memory of the children with the increase in age.

ii. The length of reasoning chain held by any child at each level is lower than the individual's Working Memory span.

6.4.5. When the average length of reasoning chain held by the children was plotted against the average Working Memory span at each level, it showed a correlation of 0.20 significant at 0.01 level, i.e. a significant correlation between working memory and the length of reasoning chain held by the children, for the size of the sample in question.

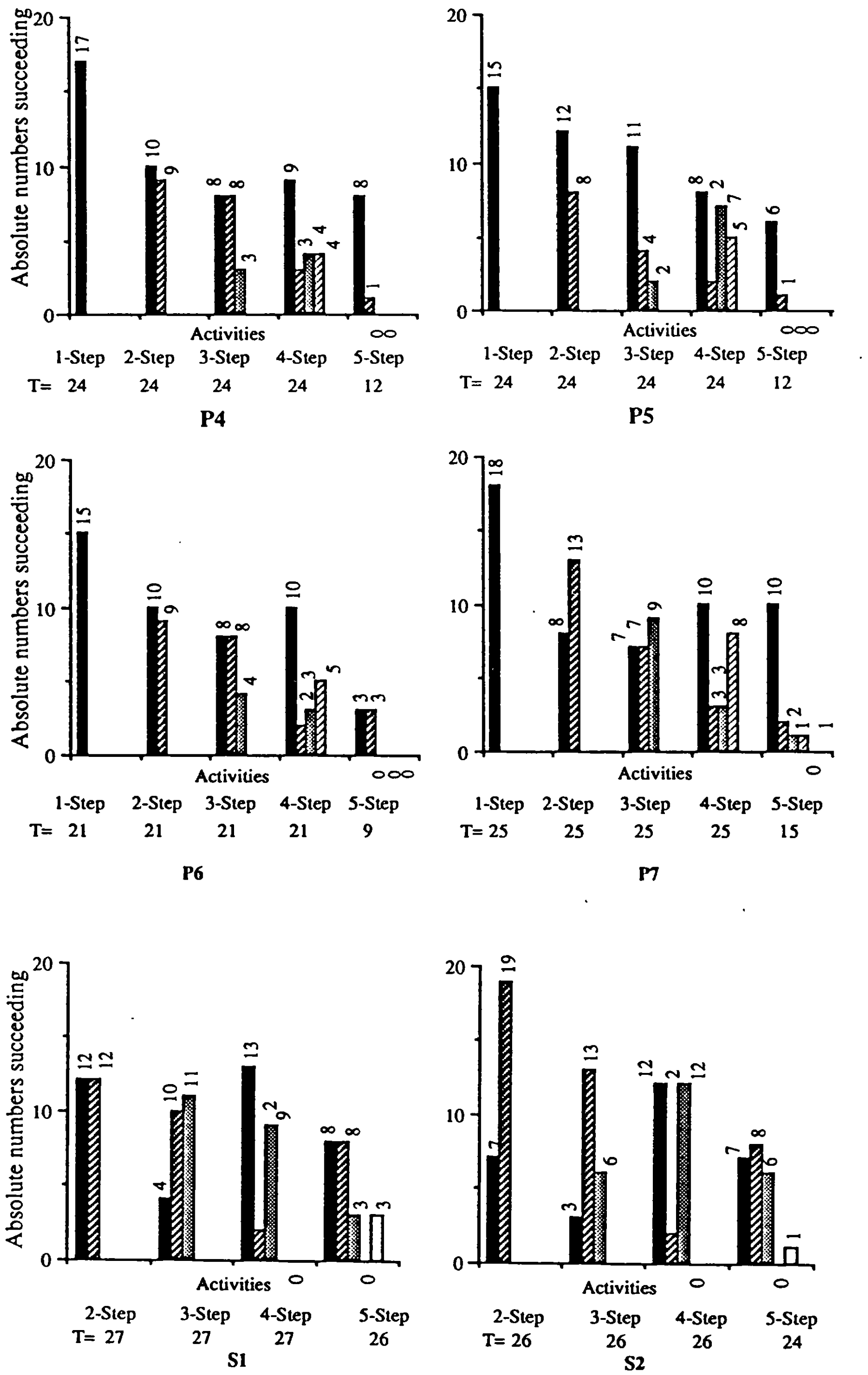
Figure-70

FULL EXPLANATION FOR THE ACTIVITIES



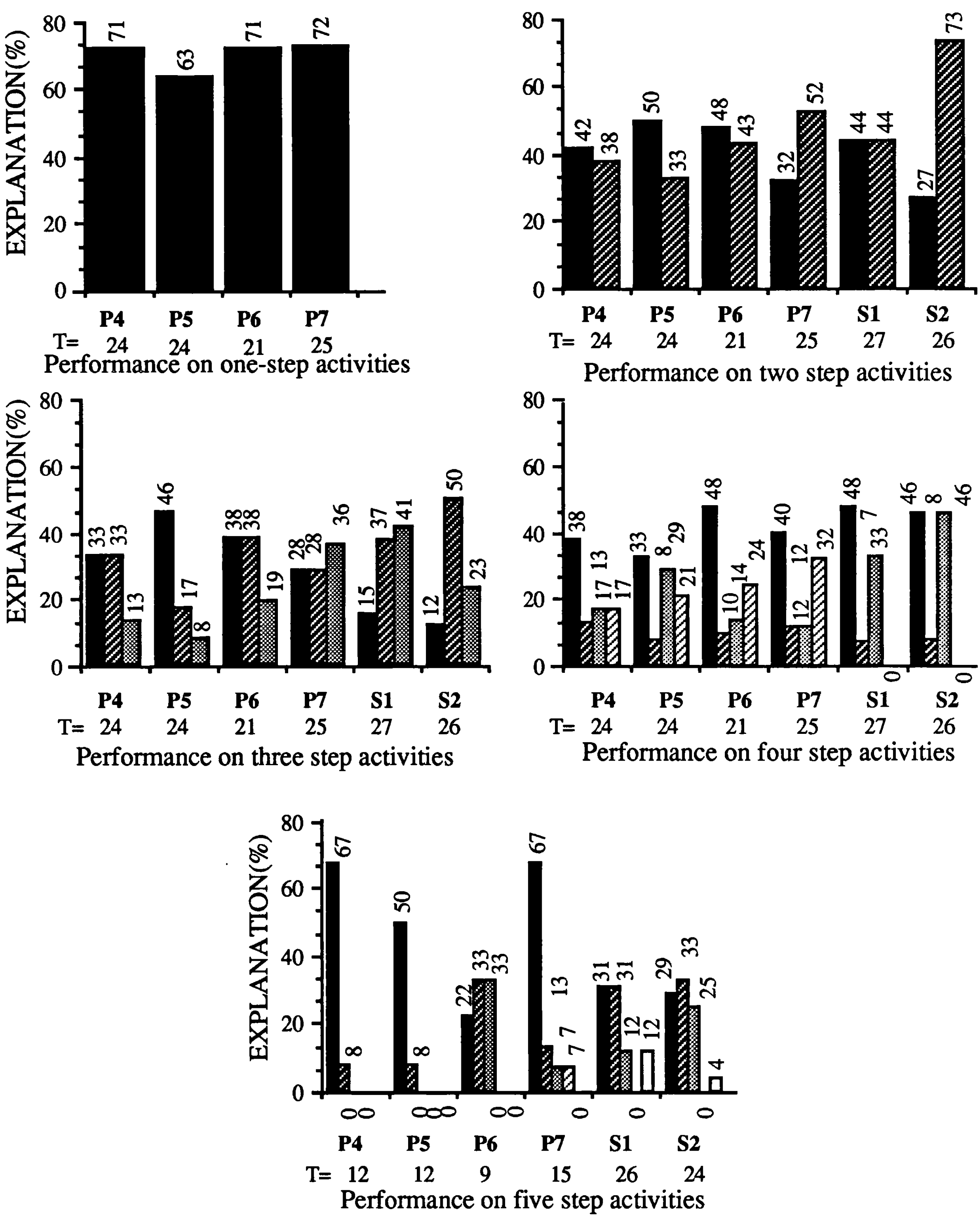
□ Children explaining the full process of five-step activities
▨ Children explaining the full process of four-step activities
▩ Children explaining the full process of three-step activities
▨ Children explaining the full process of two-step activities
■ Children explaining the full process of one-step activities
All the numbers used are percentages

(Figure-71)
LENGTH OF REASONING CHAIN OFFERED BY CHILDREN AT DIFFERENT LEVELS FOR FIVE ACTIVITIES



Pupils attempting 3- steps
Pupils attempting 5- steps
Pupils attempting 2-steps
Pupils attempting 1-step
Pupils attempting 4-steps
T= Total number of pupils taking part in each activity
Pupils attempting no step at all are not included.

Figure-72.A
LENGTH OF REASONING CHAIN COMPARED WITH AGES FOR ALL ACTIVITIES

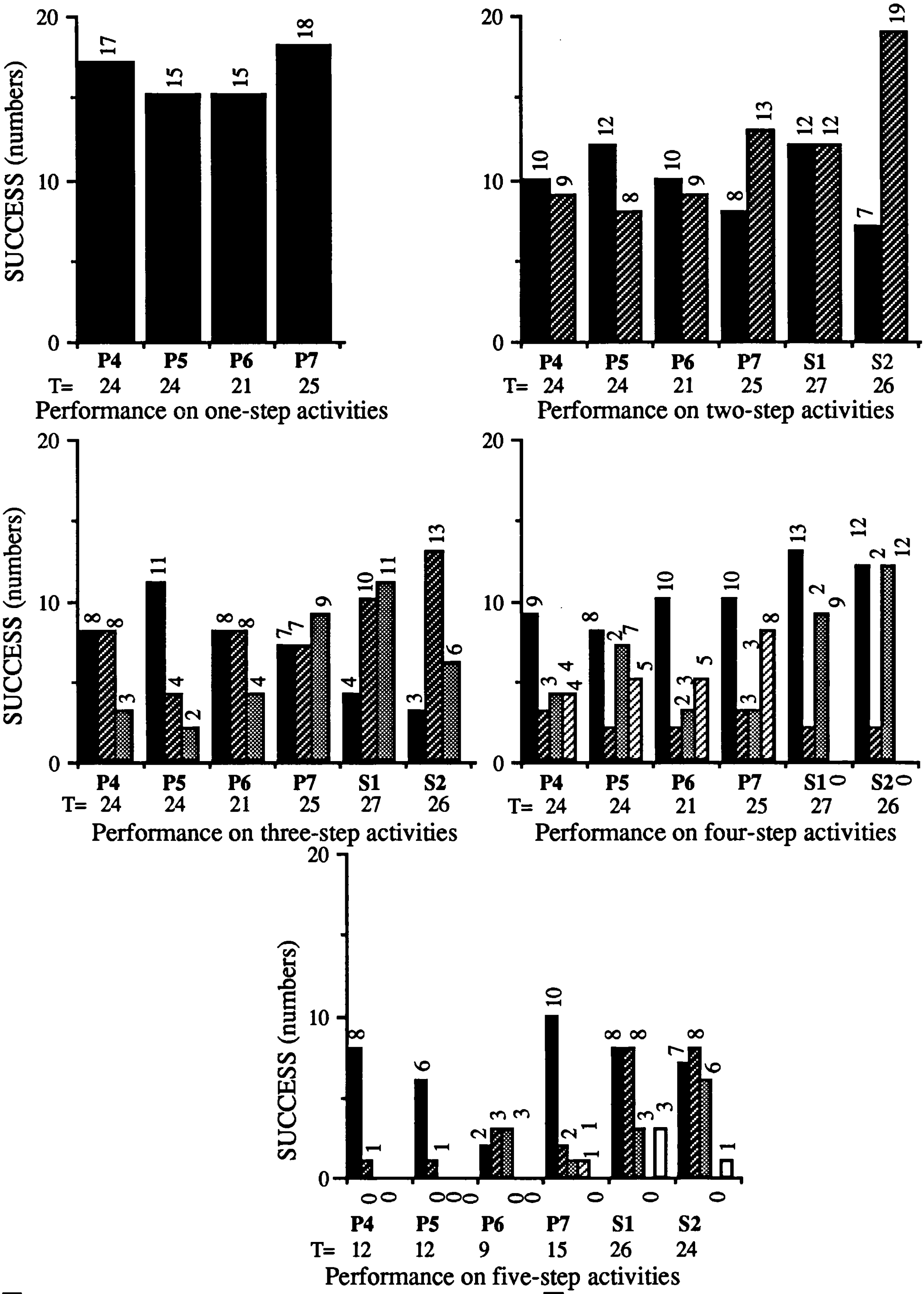


- Children attempting three steps
- Children attempting two steps
- Children attempting one step
- Children attempting five steps
- Children attempting four steps

T= Total number of children attempting an activity.

All the numbers are percentages

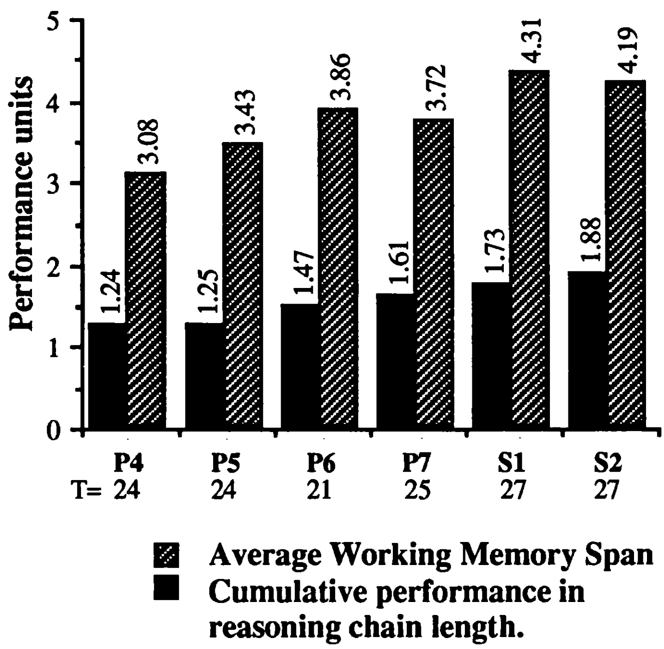
Figure-72.B
LENGTH OF REASONING CHAIN COMPARED WITH AGES FOR ALL ACTIVITIES



Children attempting three steps
Children attempting two steps
Children attempting one step
Children attempting five steps
Children attempting four steps

T= Total number of children attempting an activity. All the numbers are actual numbers

(Figure-73)
CUMULATIVE PERFORMANCE IN CHAIN LENGTH VS WORKING MEMORY



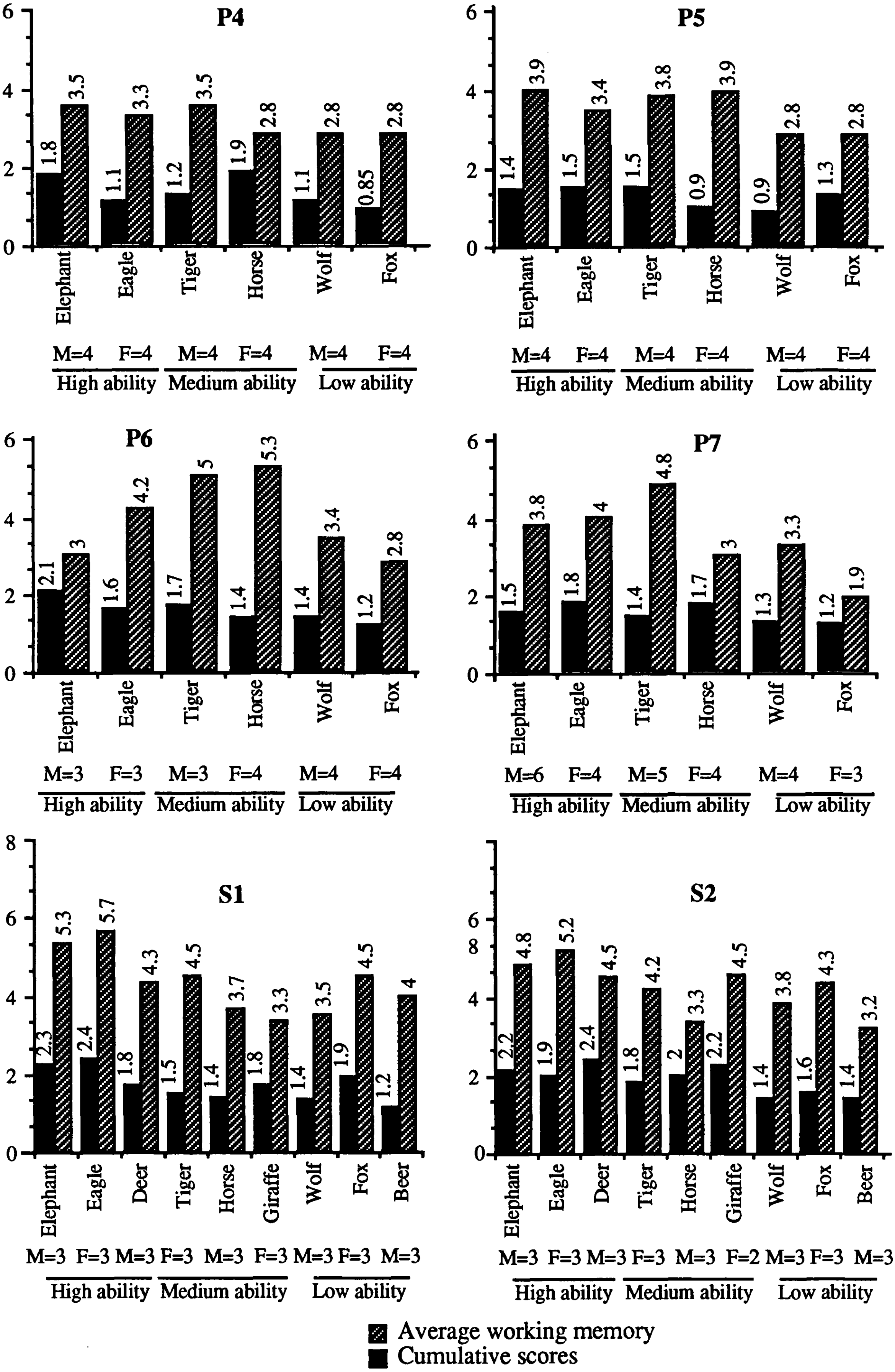
CUMULATIVE SCORES: Cumulative scores were calculated as follows:

1.For each child the average length of reasoning chain was found for all the activities.

2. Then the average length of reasoning chain was found for each level (e. g. P4).

6.4.6. At the start of the final phase of this research work, the abilities of the children were not known to the researcher. When the cumulative scores and the average working memory of the children were arranged against the abilities of the children, no significant pattern emerged. The average length of reasoning chain held by the children and their average Working Memory span were almost the same irrespective of their abilities as judged by the teachers (Figure-74). This analysis also suggests (Figure-74) that there is no significant difference in the length of reasoning chain held and the working memory of of the male and female pupils at any specific age level.

(Figure-74)
ABILITIES COMPARED WITH LENGTH OF REASONING CHAIN AND WORKING MEMORY, FOR MALE AND FEMALE



6.5. RESPONSES OF THE CHILDREN:

6.5.1. When the responses of the children were categorised on the basis of the characteristics and the styles of the responses, it provided similar patterns to those obtained from the results of the previous phase. Results are set out in the tables below.

1. The children mix up description with explanation and do not differentiate while describing or explaining a process, e. g;

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	PUFF SIGNALS:
P5	Hot water rose up because you made a hole in it.
	SKY HOOK
P4	Simple hook is balanced on the finger due to the cut.
	ICE FLOATING IN SUNFLOWER OIL
P4	Oil is heavier because more/ lot of it; Ice at top because it is floating.
P5	Water soft, ice hard, therefore water falls; ice at top and water at bottom because there is cooking oil in between; water is heavier because it falls down.
P7	Ice stays up because it is hard and big and bubbles go down because they are small.
S1	Ice at top water at bottom because more pressure (lot of oil); ice stays at top because it is frozen.
	POURING WATER OUT OF A CAN
P4	Water does not come out because hole is too small.
P5	Hole is too small to let water out.
S2	Hole at the bottom too small.
	INFLATING A BALLOON INSIDE A BOTTLE
P7	The hole in the bottle makes the balloon blow up.
S1	Air can go through the hole to put balloon down; Blocking air supply around balloon, so cannot blow up with hole covered, allowing air to go out of container the balloon is blown up; air goes into the bottle to allow inflation; blocking the hole keeps air from going into the bottle to allow inflation; air was going from outside to inside of bottle; air inside the balloon came out of a hole in the balloon and escaped through the hole in the bottle; air can go through hole to put balloon down.
S2	When the hole is closed, air is trapped inside bottle, no inflation; If the balloon is inflated inside the bottle with hole open and then hole is closed, the balloon does not go down because no air left in to make balloon go down; When plasticine put on the bottle, balloon cannot go down, cannot blow up because air cannot get out of plasticine.
	INFLATING A SOAP BUBBLE
P5	Squeezing the bottle makes bubbles.

Level	ACTIVITIES AND CHILDREN'S RESPONSES
P6	Fairy liquid in flask makes bubbles; Hands pushing (holding) the bottle make bubble grow; Air went up and up (the bubble grew); Hands pressure causes bubble to grow.
	RISING WATER PUZZLE
P4	Water rises up because air has blown out the candle.
P5	Smoke from candle puts candle out; Air gets trapped in jar, jar is holding the water up; Jug (beaker) made the water go in; Water goes in because there is so much water outside; candle keeps water in jar; Water is pushed up by smoke; smoke disappeared in water; candle goes out because water goes up.
P6	Water is pushed up by smoke; Smoke disappeared into water.
P7	Water causes candle to go out; Smoke comes down into water and keeps it up; Steam (smoke) from candle goes into water and water enters jar; water makes it work ; Shape of watchglass causes water rise up; Jar keeps water from getting out; Light goes off and water sucked in.
S1	Candle goes out and water rises up but if beaker is removed , water falls out and candle relights; When put glass (beaker) over the candle, the air trapped in glass put candle out; water comes in because of lip on rim of beaker; Light went out, there was steam inside and water rises; Water goes up because candle goes out; Water rises up when the cup (beaker) is put over the candle; Water rises up because when you put cup (beaker) into water and lift it up, water comes up;Water trapped inside jar; Water goes up because candle goes out; Oxygen got trapped by jar.
	HAND DYNAMO
P6	The bulb lights up because of electricity in wires, it goes to the wooden base up to metal support (dynamo) and hence to wires and to bulb.
P7	Dynamo goes round and electricity goes through wires to bulb to make it light. When it stops turning, power stops; Handle goes round, wires go round; To do with handle going round; handle goes round, dynamo goes round, something touches wires, wires touch bulb and light comes on.
	SPIRAL MOVING OVER A LIT CANDLE
P4	The fire goes up and moves it.

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	BALLOON FOUNTAIN
P4	As balloon gets smaller, water jet get less; Water going up makes the balloon smaller.
P5	Water is going inside the bottle because you have put the tube inside the water.
P6	Deflation in the balloon is according to the water jet; Water hits the balloon and balloon goes smaller.
P7	If both the glass tubes are dipped in water, water comes out of one and goes inside the bottle through the other.
S1	Air is stuck inside, water is being pushed up, balloon is sucking up, air is coming out of the balloon and water is pushed up; Something to do with the rubber cork and the air, tubes are attached to each other.

2. Children have ill-formed explanations for many things based upon partially digested ideas from formal or informal sources. A few may be self-generated. For example,

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	PUFF SIGNALS:
P7	Cold water is bringing hot water up.
	FLOATING EGGS
P6	Air trapped in water makes the egg float; Air inside egg makes egg float.
P7	Gravity pulls it down, pressure keeps the egg up, pressure pulls egg down.
	SKY HOOK
P4	The hook along with the belt is balanced because air pushed the belt.
	ICE FLOATING IN SUNFLOWER OIL
P4	Oil is pushing ice up there.
P6	Oil made the drop of water come down.
	POURING WATER OUT OF A CAN
P4	Water does not come out of the can (with one hole open) because water stuck at top of the can.
P7	Something in the air has to do with it (when one hole on the top and one hole at the bottom is open), air does not go that way (from down), it goes that way (from above).
S1	Air goes in top hole and pushes water out; Air pushes water out when hole at top is uncovered; Oxygen (air) went in the top hole and pushed water through.

	INFLATING A BALLOON INSIDE A BOTTLE
S1	When balloon is inflated first and then the hole is closed, the balloon does not deflate because there is enough air in the bottle to keep the balloon up; Inflation in the balloon because air inside the bottle helps the balloon to blow up.
S2	Air can not get in to let the balloon go down if the hole is closed after inflating the balloon..
	INFLATING A SOAP BUBBLE
P4	Heat rises; Static electricity; Air was trying to get away from heat.
P6	Hot air rises and the bubble grows; Air is pushing up because of hotness; Steam from the fairy liquid makes the bubble grow.
	RISING WATER PUZZLE
P4	Fire was pushing water up; Candle went off because all air steamed off; Water had gone up through the candle to put out the flame; Candle flame pulled up the water; Water rises up because air has escaped.
P5	Glass is so hot inside, it put the candle out, steam makes the water go up; Water rises because it is being pulled up by the fire; Candle goes out because of water; The beaker made the water to go in; Candle has gone out because it cannot breathe; Candle cannot breathe because jar is over it.
P6	Water is pushed up by the smoke; Smoke disappeared in water, oxygen gathered inside cannot come out; Oxygen pushes blue water up; More air inside than at the start; Candle goes out and air pulls water up; Candle makes water go up; You are going to suffocate the candle and it goes out; All heat goes into glass; Glass keeps water in.
P7	Candle has no air and steam from candle makes water go up; water comes up because of steam; Water evaporates and rises up; Something to do with the heat of the candle, cooling water rises; Air burnt out, no gravity, so water rises; Jar keeps water from getting out; Flame makes the water go up; Watchglass holds water up; Candle could not breathe; Air has gone away into water.
S1	Water was being pushed up because of weight of the container (beaker). If beaker removed, the candle would relight; Fire needs air to breathe and when it did not get enough air it sucked in water; Candle went out when the oxygen in container runs out, water gets sucked in to give more

Level	ACTIVITIES AND CHILDREN'S RESPONSES
S1	oxygen; Water rises up because flame is sucking oxygen and sucks water up; Water is sucked in to container, carbon dioxide attracted it, may be something is attracting into jar; Candle went out because when you put jar over it, air blows the candle out; Water rises up because something to do with heat of candle and air mixed together; Something to do with the cork or the tubes, tubes are attached (both the tubes pass through the same cork); When jar is removed, the candle will relight; Water is connected with candle going out so if water goes down, there is nothing stopping candle from relighting; Candle has shrunk, there was no air getting into the jar, so it went out; Jar pushed over water, makes the water go up; Water goes up because water is trapped inside, if jar is removed, all water will go out and the candle will relight.
S2	Coloured water has come up and made the space less for it, there is no breathing space for candle and went out; If jar is removed the water will flow down and the candle will relight.
	HAND DYNAMO
P4	Light was going down the wires; Air is forming electricity; Dynamo is full of electricity, it goes through wires to light the bulb.
P5	Liquid goes through the wires.
P7	Handle goes round, heats up the dynamo, makes electricity, energy go through wires and makes the light go; This dynamo has got electricity in it, goes through wires to bulb and bulb lights.
	SPIRAL MOVING OVER A LIT CANDLE
P4	Air and heat mix and rise and move it. Heat and fire and air beside the candle make the spiral move.
P7	Heat and fire and air beside the candle make the spiral move.
	BALLOON FOUNTAIN
S1	Water goes up because of the air; Water is going up there to deflate the balloon; Water goes up and touches it to make it smaller; Oxygen inside the balloon is pulling water up; water goes up, compresses the balloon and it goes down; Air is coming down to the water and making it go up.

3. Personal experience plays an important role in the development of concepts. For example,

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	PUFF SIGNALS
P4	Hot water rises; Hot water just like steam; Steam vapourising.
P7	Hot water just like steam, steam rises so hot water rises; Steam is pushing; Pushing up because it is light..
	SKY HOOK
P7	Belt keeps the sky hook balanced like the wings of a plane.
	TAKING WATER OUT OF A CAN
P6	Air was coming out as water comes out just like taking lemonade out of a can.
S2	When the hole is uncovered, the air goes in and pushes water out.
	INFLATING A SOAP BUBBLE
P5	May be the wind that causes the bubble to grow; Air pushes the bubble up;
	RISING WATER PUZZLE
P4	Air went up just like a straw, it is sucked up and water went up; Water made the candle cold, so that the candle went out.
P5	Water puts candle out.
P6	Water is sucked up by the jar; Candle put out by dampness.
P7	Glass pulls water up like a sucker on the skin.
S1	Water gets sucked up and the candle went out; Liquid is sucked up. Water has gone up into the beaker because of suction; Water gets sucked up into it and candle went out; Candle uses oxygen and no oxygen left so it went out, it sucked water up; Air pressure inside jar blew candle out.
S2	When you put the beaker over, air gets sucked up from underneath and there is no air left for candle; Putting jar over candle, air was trapped putting the candle out; Coloured water has come up and made less space for oxygen. There is no breathing space for candle; Candle will relight again if jar is removed because he has seen like this candle relighting before; Flame died out when put jar over it, something to do with pressure inside jar.
	SPIRAL MOVING OVER A LIT CANDLE
P5	Similarly as coal burns inside an engine, it makes steam which makes it (the spiral) move;

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	BALLOON FOUNTAIN
P5	Balloon is sucking up water.
S1	Air pressure is sucking up water; Air inside the bottle is sucking up the water.
S2	Tube is sucking up the water; air come down in water and pushes water up; it is suction; Tube is sucking water; Air inside the tube is sucking water; air is sucking the water up.

4. Many phenomena go by either unobserved or pupils are content to accept them without explanation, e. g;

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	PUFF SIGNALS:
P4	Blue hot water comes up because there is a hole in it; coloured water rises up because you made a hole.
	FLOATING EGGS
P4	Some sugar/ salt pushes the egg up.
P7	Something in water makes the egg float.
	SKY HOOK
P4	Weight of the belt and the finger made the hook balanced; It is standing because it is much heavier.
P5	You have put more weight on the belt that's why it is standing; it is the weight that makes it balanced.
P6	The weight will do the balance; Belt evens the balance.
P7	The belt will balance the hook.
	STRANGE DIVER
S1	Water does not have anywhere to go, so it goes into the dropper.
	ICE FLOATING IN SUNFLOWER OIL
P4	Ice floating because water floats in oil.
	TAKING WATER OUT OF A CAN
S1	Water is at top of the can, that's why it does not come out.
S2	Pressure stops water coming out, finger off, presses water out, air in.
	INFLATING A BALLOON INSIDE A BOTTLE
S1	Air trapped inside bottle so plasticine stopping air from getting into bottle. Air gets trapped in the bottle when hole covered. Air trapped would not move; Air around balloon loose.

	INFLATING A SOAP BUBBLE
P4	The air grows.
P7	Air make the bubble go higher.
	RISING WATER PUZZLE
P4	Water rises up because it is a kind of magic water; Water in jar puts candle out, jar on top made the candle out; Water goes up because it could not go out at the bottom; water and jar put the candle out; water has a small space (lip on the rim of the beaker) and goes up, climbs up inside jar.
S1	Beaker has stopped air getting in; Candle went out, steam inside jar; Air is trapped when put jar over it; Water is trapped inside the jar; jar is holding water up.
S2	Jar is holding water up; As jar pushed on slowly, all the air went out.
	HAND DYNAMO
P4	Something goes along wires and lights up the bulb.
	BALLOON FOUNTAIN
S1	Air has something to do with the balloon; Air is trapped inside the bottle; Air inside the bottle is bringing water up; One tube is slanting, it is sucking water .
S2	Balloon is taking water inside; Balloon is spiral one and holds air inside it, the tube is dipped in water, balloon will be filled with water.

5. In most of the cases, while explaining an activity, pupils settle for a statement about the beginning and one about the end.

Level	ACTIVITIES AND CHILDREN'S RESPONSES
	FLOATING EGGS
P5	Sugar/ salt make it float.
	INFLATING A SOAP BUBBLE
P6	The heat makes the bubble grow.
P7	Warmth (heat) makes the bubbles; Heat/ smoke make it grow.
	RISING WATER PUZZLE
S2	Heat makes the water rise.
	HAND DYNAMO
P6	Turning the handle lights the bulb; Pushing (turning handle) hard makes bulb light.
	Torch
P6	Torch stays (lights) because of switch; Torch works because you press the button.
P7	Torch goes on because you press the switch.
	BALLOON FOUNTAIN
P4	As balloon gets smaller water sucks in; Smaller balloon causes smaller water jet.
P5	Air going out of balloon causes water jet.
P7	Larger balloon causes a bigger water jet.
	SPIRAL MOVING OVER A LIT CANDLE
P5	Light rises and causes to turn; heat makes it move.
P7	Heat makes it move; Heat and flame go up and make it move.

6.6. SCIENTIFIC AND UNSCIENTIFIC (ALTERNATIVE) RESPONSES:

6.6.1. When the children's responses were arranged so as to look for the effects of formal science teaching at Secondary level, it provided the information that:

a. There are two kinds of responses at Primary level, e. g.,

i. Children's own or unscientific concepts for the explanation of different activities and processes- categorised as alternative explanations.

ii. Scientific and unscientific mixed explanations for the same process.

b. There are three kinds of responses at Secondary level, e. g.,

i. Children's own concepts or unscientific explanations- alternative explanations.

ii. Scientific explanations.

iii. Scientific and unscientific mixed explanations given for the same process.

Examples (From Table-16 and onward) are set out according to the symbols in the Table-15

ACTIVITIES	SYMBOLS
PUFF SIGNALS:	1-A
FLOATING EGGS	1-B
SKY HOOK	1-C
TWO-STEP ACTIVITIES	
STRANGE DIVER	2-A
ICE FLOATING IN SUNFLOWER OIL	2-B
POURING WATER OUT OF A CAN	2-C
THREE-STEP ACTIVITIES	
INFLATING A BALLOON INSIDE A BOTTLE	3-A
INFLATING A SOAP BUBBLE	3-B
FOUR-STEP ACTIVITIES	
RISING WATER PUZZLE	4-A
HAND DYNAMO	4-B
FIVE-STEP ACTIVITIES	
SPIRAL MOVING OVER A LIT CANDLE AND/ OR WINDMILL MOVING OVER A LIT CANDLE	5-A
BALLOON FOUNTAIN	5-B

Table-15

PRIMARY SCHOOLS

ALTERNATIVE EXPLANATIONS

Level	Symbol	Activities	ALTERNATIVE EXPLANATIONS
P4	Elephant	3-B	Hands squeezing glass and make air make bubble.
	Elephant	4-A	Fire was pushing water.
	Eagle	4-A	Water rises up because the air has blown out the candle; water rises up because air has escaped.
	Eagle	1-C	Weight and finger make the hook balanced.
	Tiger	3-B	Fire inside the flask makes the bubble grow.
	Tiger	2-C	Water does not come out of can (with one hole open) because water stuck at the top of the can.
	Horse	4-A	Water had gone up through the candle to put out the flame.
	Horse	4-A	Water made the candle cold so that the flame went out.
	Wolf	4-A	Water rises up because it is a kind of magic water.
	Wolf	2-B	Ice is floating because oil is pushing the ice up there.
	Fox	2-B	Oil is heavier than water because there is a lot of oil.
	Fox	4-A	Candle flame pulled the water up.
P5	Elephant	4-A	Smoke from candle puts the candle out.
	Elephant	5-B	Water going up makes the balloon smaller.
	Eagle	3-B	Squeezing hands makes bubble grow.
	Eagle	4-A	Glass is so hot inside, it made candle out ; Steam makes water go up.
	Tiger	5-B	Air going out of balloon causes water jet rise in the bottle.
	Tiger	4-A	Water rises because it is being pulled up by the fire.
	Horse	4-A	Jar is holding the water up.
	Horse	3-B	Holding the flask makes the bubble.
	Wolf	4-B	Liquid goes through wires.
	Wolf	5-A	Similarly as coal burns inside an engine, it makes steam which makes it move.
	Fox	4-A	Candle has gone out because it cannot breathe.
	Fox	2-B	Ice at the top and water at the bottom because there is cooking oil in.
P6	Elephant	1-B	Air trapped in water/ air inside egg makes the egg float.
	Elephant	4-A	Oxygen pushes blue liquid up/ gas sucks the blue water up.
	Eagle	1-B	Sugar/ salt make the egg float.
	Tiger	3-B	Fairy liquid in flask makes bubble.
	Horse	1-C	The weight of the belt balances the hook.
	Horse	4-A	Candle goes out because water goes up.

Le-vel	Symbol	Activities	ALTERNATIVE EXPLANATIONS
P6	Wolf	4-A	Candle goes out and air pulls the water up.
	Wolf	2-B	Ice stays up because it is hard and big and bubbles down
	Fox	4-A	Candle put out by dampness.
	Fox	4-B	Turning the handle lights bulb.
P7	Elephant	3-B	Steam from the fairy liquid makes the bubble grow.
	Elephant	1-C	Belt keeps the balance like the wings of a plane.
	Eagle	4-B	Handle goes round, heats up the dynamo, makes electricity, energy goes through wires and lights the bulb.
	Eagle	5-A	Heat move it; heat and flame go up and moves the spiral
	Tiger	5-B	Water hits the balloon and balloon goes smaller. If both the tubes are dipped in water, water comes out of one and goes inside the bottle through the other.
	Tiger	4-A	Air burnt out; no gravity so water rises.
	Horse	4-A	Jar keeps water from getting out.
	Horse	4-B	To do with handle, it goes round. Torch bulb lights due to machinery.
	Wolf	4-A	Flame makes water go up; watchglass holds water up; Candle could not breathe.
	Wolf	1-A	Cold water is bringing hot water up
	Fox	4-A	Air has gone away into water; light goes off then water sucks in.
	Fox	4-B	The dynamo has got electricity in it ; goes through wires to the bulb and the bulb lights up. Bulb remains lit until handle is turned on, by turning the handle light comes on. Torch bulb lights because of batteries, magnet things in it make things on and off.

Table-16

SCIENTIFIC AND UNSCIENTIFIC/ ALTERNATIVE EXPLANATIONS (PRIMARY)

Le-vel	Activities	SCIENTIFIC EXPLANATIONS	ALTERNATIVE EXPLANATIONS
P4	2-B	Water heavier than oil Oil lighter than water.	Ice heavier than oil. Oil lighter than ice.
	4-A	Candle used up air and when no more air, candle goes out. Candle goes out because it needs air.	Water has small lip on the rim of the beaker and goes up. Fire was pushing the water up.
P5	4-A	Candle needs air for burning.	Candle goes out because air got trapped in jar. Water rises up because it has been sucked up, pressure has pulled it up.
		Candle goes out because it needs more air. If bigger jar, candle would stay lit more longer.	Water goes up through the lip on the rim of the beaker. If the water did not go up, it would go off the plate; Jar is holding the water up.
P6	4-A	Candle goes out because no air in jar so water goes up.	Smoke goes up and then makes water go up.
		Candle needs air to keep burning but there was less air.	Water is pushed up by smoke.
P7	4-A	Candle didn't get a lot of wind and it went out. Since the air is burnt out, water is sucked inside from under the beaker.	Jar keeps water from getting out. No gravity; so water just rises.

Table-17

SECONDARY SCHOOLS

ALTERNATIVE EXPLANATIONS

SYMBOL	Activities	ALTERNATIVE EXPLANATIONS S1
Elephant M	5-B	Balloon is sucking up the water.
Elephant	4-A	Water was being pushed up because of weight of the container(beaker). If beaker removed, the candle would relight.
Eagle	4-A	Fire needs air to breathe, and when did not get enough air it sucked the water in.
Eagle	5-B	Air inside the bottle is sucking the water up.
Deer	5-B	Air is stuck inside, water is being pushed up ; balloon is sucking the water up; air is coming out of the balloon and water is pushed up.
Deer	2-B	Ice at top water at bottom because more pressure (lot of oil).
Tiger	2-C	Hole at the bottom too small. When hole at the top is free air goes in and pushes water out.
Tiger	4-A	Candle flame went out and water is sucked into jar; candle went out because when you put jar over the candle, air blows the candle out. Water rises up because something to do with heat of candle and air being mixed together.
Horse	5-B	Balloon is sucking up the water.
Horse	4-A	When put beaker down, the air trapped in the beaker put candle out.
Giraffe	2-C	When one hole at the top was open, water did not come out because all the water was at the top of the can.
Giraffe	3-A	When balloon is inflated and the hole of the bottle is closed the balloon does not deflate because "enough air in the bottle to keep the balloon up. Air cannot get in to push balloon the down.
Wolf	5-B	Water is going upside there to deflate the balloon.
Wolf	4-A	Putting jar over candle blew candle out; water goes up because water is trapped inside; if jar is removed all water go out and the candle will relight.
Fox	2-B	Ice stays at the top because it is frozen.
Fox	4-A	When jar is removed , water would flow out and candle would slowly smoke and might relight.
Bear	4-A	Water rises up becauses when the beaker is put into water and then lifted up, water came back, (thought it was a black magic).
Bear	5-B	One tube is slanting, it is sucking water.

SYMBOL	Activities	ALTERNATIVE EXPLANATIONS S2
Elephant	4-A	If jar is removed, water will flow back and candle will relight.
Elephant	5-B	Water goes up, compresses the balloon and it goes down.
Eagle	4-A	Water has gone up into the beaker because of suction.
Eagle	5-B	Air is coming down to the water and making it go up.
Deer	2-B	Air in the bubble (water from melting ice) from inside the ice is going down.
Deer	4-A	Water gets sucked up into it and candle went out. If jar is removed, water will stay there in for a while and then fall out.
Tiger	4-A	Water is connected with candle going out, so if water goes down, there is nothing stopping candle from relighting.
Tiger	5-B	Air comes down in the water and pushes water up.
Horse	2-C	When can is turned over, the water does not come out because it stays at the top of the can.
Horse	5-B	Tube is sucking the water.
Giraffe	4-A	Candle goes out and water is sucked in because of the air being pulled in blows the candle out.
Giraffe	4-A	Light went out, there was steam inside and water rises. When put beaker over, the air gets sucked in from underneath and there is no air left for the candle.
Wolf	5-B	Air is trapped inside. Air is coming inside the water and the water goes up.
Wolf	5-B	Water goes up, makes the balloon down.
Fox	4-A	Putting jar over candle, air was trapped putting the candle out.
Fox	5-B	Air in the balloon is coming down and making the water come up.
Bear	2-B	Ice up, water down because oil is thick. Oil is lighter than water.
Bear	4-A	Heat brings water up into the jar. If jar is removed, water will go back down and candle might relight.

Table-18

SCIENTIFIC EXPLANATIONS

Activities	Pupil	SCIENTIFIC EXPLANATIONS
S2 2-C	Eagle (F)	When the can is turned over and the top hole is covered, water cannot get out because air cannot get in; hole open, air moves in, pushes water out.
S1 2-A	Horse(M)	When the bottle is pressed, the exttra water makes dropper heavier and it sinks.
	Tiger (F)	When bottle is pressed, water in tube rises up which means tube (dropper) is heavier.
	Deer (M)	When the bottle is pressed, the extra water going into the dropper makes it heavier and it sinks.
	Eagle (M)	When press bottle, water in tube rises. That means it gets heavier and it sinks.
	Elephant (M)	When bottle is pressed, water level rises and it is heavier and it sinks.
S2 2-A	Bear (M)	When the bottle is pressed, water goes into tube, it becomes heavier and it sinks.
	Wolf (M)	When the bottle is pressed, the water is going into the tube and it sinks. It is heavier that's why it sinks.
	Giraffe (F)	When you push the bottle, the pressure puts more water into the tube and the tube sinks being heavier.
S2 2-B	Bear (M)	Ice lighter, water bubble heavier and falls down.
	Wolf (F)	Ice is lighter, water is thick, a little heavier because it is sinking.
	Deer (M)	Ice cube lighter, water is heavier.
	Elephant (M)	Water is heavier and ice lighter than oil.
	Giraffe (F)	Water is heavier and hence falls down.
S1 3-A	Fox (F)	Balloon needs extra space for inflating. When the balloon inflates, extra air escapes.When the hole in the bottle is blocked, the air was not able to escape.
	Giraffe (F)	1. Inflation requires space inside bottle: escaping air allows this. 2. Air can escape through hole if open. 3. When closed, air is trapped inside the bottle; no space for balloon to inflate into.
	Horse (M)	1. For inflation air needs to go out of the bottle. 2. When the hole is open, this can happen; inflation can take place. 3. When hole is closed, the air inside the bottle is pushing against the balloon keeping it down.
	Bear (M)	1. Inflating the balloon needs air to escape. 2. Excess air escapes out of the bottle. 3. The blocking of the hole keeps the air inside so the balloon cannot go up.

Activities	Pupil	SCIENTIFIC EXPLANATIONS
S1 3-A	Tiger (F)	1. For inflating the balloon inside the bottle needs air to get out . 2. The excess air escapes through the hole. 3. If the hole is blocked, air not able to get out.
	Eagle (M)	1. Balloon is taking up space in bottle, so air moves out of the hole. 2. Air cannot move anywhere, so no air cannot go in the balloon. 3 When the hole is open, air goes in and taking up space where balloon was; you cannot blow it up when there is no hole because air cannot get out.
S1 5-B	Elephant (F)	1. Balloon needs extra space for inflation which pushes air out. 2. After inflation, if the second tube is blocked, it keeps the air pressure inside equal to that of outside. 3. Opening the other tube lets air to come inside the bottle to take place of the balloon. 4. When the balloon deflates, it decreases the air pressure inside the bottle. 5. Water enters the bottle to overcome that decrease of pressure.
5-B	Eagle (F)	1. When the balloon is inflated, it pushes the air out of the bottle. 2. Blocking the other tube keeps the air pressure inside equal to that of outside. 3. By opening the other tube, the balloon deflates. 4. When the balloon deflates, it makes space inside the bottle. 5. Water has to fill that space.
5-B	Deer (M)	1. When the balloon expands the extra air will have to move out of the bottle. 2. After inflating the balloon, blocking the other tube keeps the air pressure inside and outside the bottle equal. 3. Opening the other tube allows the air to come into the bottle. 4. When the balloon deflates, it causes an empty space inside the bottle. 5. Water rises in the bottle to fill that empty space.
5-B	Fox (F)	1. Inflating the balloon inside the bottle needs extra space pushing air out. 2. If the other tube is blocked after the balloon is inflated, it keeps the pressure inside the bottle equal to the pressure outside. 3. Deflating the balloon allows air to come in. 4. When the balloon is deflated, it decreases the pressure inside. 5. When the other tube is dipped in water, water rises in the bottle instead of the air.

Table-19

SCIENTIFIC AND UNSCIENTIFIC EXPLANATIONS (SECONDARY)

Activities		SCIENTIFIC EXPLANATIONS	ALTERNATIVE EXPLANATIONS
S1	2-A	Water pressed, water goes up the tube.	Press air, tube pushes it down.
	2-B	Ice is lighter.	Ice at top, water at bottom because more pressure (lot of oil).
	2-C	Air goes in top through the top hole and pushes the water out.	When hole at top is covered water is at the top of the can.
	3-A	To get down need air from outside which cannot get because no hole.	Air can go through hole to let the balloon down.
	4-A	Candle needs oxygen/ air to light, beaker cuts off the air and water makes sure there is no air at all. Water completely trapping the air because water can move about. Water rose up because candle has gone out and pressure of air makes it just come up.	When jar is removed, forecasts that water would flow out and candle would slowly smoke and might relight.
S2	2-C	Pressure stops water coming out.	Finger off, pressure pushes water and air in.
	3-A	When hole open and the balloon is inflated, balloon pushes the air out of hole., when no hole, balloon is staying up because air cannot get in.	If the balloon is inflated inside the bottle with the hole open and then hole is closed, the balloon does not go down because no air left in to make the balloon go down.
	4-A	1. Candle goes out because there is no air inside glass.	Heat brings water up. If beaker is removed, water will go back and candle will relight.
		2. Candle couldn't have any oxygen inside jar. Water went up to take up space of air.	Water is connected with candle going out, so, if jar is removed, water goes down, there is nothing stopping candle from relighting.
		3. Candle burning needs air, putting jar over it keeps air out.	Jar is holding water up. Removing the jar, water will go back and candle must be burning.

Table-20

6.7. SUMMARY AND DISCUSSION. The analysis of the results of this phase supported all the results obtained from the previous phase.

6.7.1. The children as young as 8 years-old construct their own concepts about different phenomena and their concepts have different characteristcs:

The activity "rising water puzzle" had all the characteristics at different levels, e. g.,

a. *Their explanations are a mixture of descriptions and explanations for the activities.*

Many children at Primary level had the concept that "not enough air/ oxygen, that's why the candle went out". At the same time they had the concept that "water goes up through the lip on the rim of the beaker". Similarly at Secondary level, some children had the concept about the activity as "the candle went out because it did not have any air". At the same time they thought that "carbon dioxide is attracting the water inside; something is attracting it".

b. *They have ill-formed explanations based upon partially digested material from formal or informal sources.* A few may be self-generated.

While explaining the activity many Primary children had the concept that "fire was pushing the water up". The Secondary children had the concept about the same activity as "water was being pushed up by the weight of the beaker. If the beaker was removed, the candle would relight".

c. *Children form concepts from their personal experiences*, such as,

Some Primary children explained the candle activity as "the beaker pulls water just like a sucker on the skin". Whereas some of the Secondary children explained it as having similarity with breathing. One child explained it as, "there is no breathing space for the candle, but the candle will relight if the jar is removed because it will have air again.

d. *For many phenomena, the children do not see a need for an explanation.* They do not feel any need to think about them and they just accept them.

Many Primary children explain the activity as "water rises up because it is magic water; water in the jar puts the candle out; water goes up because it could not go out at the bottom". Some of the Secondary children explained it as "the jar is holding the water up; as the jar is pushed on slowly, all the air went out".

e. *In most of the cases, while explaining an activity, pupils settle for a statement about the beginning and one about the end.*

For explaining the activity many Primary children had the concept that heat makes the water rise up. Similarly, for explaining the"Hand Dynamo" turning the handle lights the bulb; pushing hard makes bulb light or for explaining " the spiral moving over a lit candle" they had the thinking "heat rises and causes to turn" etc.

6.7.2. Most of the children from P4 to Secondary 2 (age 8 to14)had a maximum length of reasoning chain up to 4 steps.

6.7.3. As the number of steps in an activity increases, the number of children attempting to explain the activity decreases.

6.7.4. The capability of holding a longer chain of reasoning and the working Memory span increase with increasing age.

6.7.5.The length of the reasoning chain held by the children at any level is within the Working Memory span.

6.7.6. Even after almost two years of formal science teaching , pupils hold alternative concepts; as a separate domain as well as mixed with scientifically correct responses.

6.7.7. The average length of reasoning chain held by the pupils and their average Working Memory are almost the same irrespective of their abilities at any specific age level.

6.7.8. There is no significant difference in the length of reasoning chain held and the Working Memory of male and female pupils within the same age group.

CHAPTER SEVEN

7. SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS.

7.1. BACKGROUND OF THE STUDY. The fact that children tend to develop their own conceptions about the nature of the physical world has been known for a long time. The German educator Diesterweg (1790-1866) [26], pointed out that it is of the utmost importance to start instruction from the student's point of view and that it is necessary for the teacher to investigate student's preconceptions. Formal research on the topic can be traced back to the earlier work of Piaget [94,95] in which he employed the clinical interview technique for the investigation of children's interpretation of natural phenomena. In the present research study, alternative frameworks of the children at Primary and early Secondary school pupils (age 8-14) have been explored.

7.2. SUMMARY. The research was carried out in different phases:

a. During the pilot phase expertise in interviewing pupils with Scottish and Ethnic minority backgrounds was developed. During this phase, eighteen interviews of thirty six pupils from three local secondary schools were carried out.

b. After the pilot phase, the first phase of practical work was started and 57 pupils from three Primary schools were interviewed. For these interviews different pictures illustrating natural phenomena were used. All the interviews were held in groups of two and were audio recorded.

c. For the second phase of the practical work, a structured questionnaire was used and overall 162 pupils at Primary level were tested.

d. For implementing the third phase a stations technique was employed. Ten different activities (mostly based upon the energy concept) were developed mainly using toys. One activity was provided on each station with an accompanying questionnaire. The pupils were asked to take part in the activity in groups of two and then describe and explain the whole sequence. Overall 396 pupils from P4 to Secondary 2 were tested. Analysis of the data collected provided a wide variety of alternative explanations offered by the pupils along with interesting results.

e. Fourth phase. For the confirmation or rejection of the results obtained during the previous phase, 15 new activities/ experiments were designed with varying lengths of reasoning chain from 1 to 5 reasoning steps. Overall 157 pupils at Primary and Secondary levels were tested. The stations technique was again employed with an addition of an expert at each station for 1:1 interview. At each of the stations, three alternate activities with the same length of reasoning chain were provided. The interview was clinical in nature and it was tried, in every respect, to involve the pupil in the activity. At the end of this practical activity, the pupils were tested for a psychological digit span backward test for measuring their Working Memory Span.

7.3. FINDINGS AND CONCLUSIONS. As a result of this research activity, the following patterns and conclusions emerged:

1. The children as young as 8 years-old construct their own concepts about different phenomena. The common features of the children's alternative frameworks which emerged during this study, are:

a. *Their explanations are a mixture of descriptions and explanations of the activities.*

b. *They have ill-formed explanations based upon partially digested material from formal or informal sources.* A few may be self-generated.

c. *Children form concepts from their personal experiences.*

d. *For many phenomena, the children do not feel any need to think about them as they just accept them. This applied particularly to the large phenomena such as changing seasons.*

e. *In most of the cases, while explaining an activity, pupils settle for a statement about the beginning and one about the end with almost no causal chain between them.*

2. When the children are asked to describe and explain an activity or scientific experiment, they can give a better description than an explanation.

3. When the children from P4 to Secondary 2 (age 8 to14) are asked to explain an activity based on different reasoning steps, some children could give an explanation using a reasoning chain of up to a maximum of four steps.

4. There is a very small number of pupils at secondary level who could hold a reasoning chain up to five steps.

5. When the children are exposed to activities with different reasoning chain lengths the number of children attempting to explain the activity decreases as the number of steps in an activity increases.

6. When the children at different age levels were asked to explain the scientific experiments with different lengths of reasoning chains, it was noted that the length of reasoning chain held and the Working Memory span of the children increases with increasing age.

7.The length of a reasoning chain at any level is always within the working memory capacity at each age level.

8. The average length of reasoning chain held by the children of a given age and their average Working Memory span were almost constant irrespective of their general abilities.

9. This study also shows that there is no significant difference in the average length of reasoning chain held and the average Working Memory span of the male and female pupils of the same age.

10. When the children's responses were arranged on the basis of the scientifically correct responses it showed that:

a. The children at Primary level had developed and used alternative concepts with all the characteristics mentioned above as well as some scientific concepts which might be the effect of informal teaching, i. e. T. V., radio etc.

b. The children at Secondary level had developed scientifically correct concepts, but, they also held the alternative concepts developed earlier, as a separate domain and used them as and when "fit" situations arose. Moreover, they still preserved a large reservoir of a mixture of scientific and alternative concepts for different phenomena.

11. This study indicated that formal science teaching at secondary level does not necessarily eliminate the alternative concepts already developed at an earlier age. The

children at secondary level, even after almost two years of formal science teaching, hold similar concepts to those found at Primary level.

7.4. PREDICTIONS FROM THE PRESENT RESEARCH STUDY:

Any practical activity or experiment has two aspects: a) observation and b) inference or reasoning. This study suggests that if an activity has length of reasoning chain within the bounds of the working memory of the pupils, there is high probability that the pupils will learn and understand that activity.

7.5. RECOMMENDATIONS FOR FURTHER RESEARCH

1. This research within the limitations of time gives information about the lengths of reasoning chains held and the Working memory spans of the children from 8 to 14 years of age. According to Pascual-Leone's model, M-Space or M-Operator increases during normal development from e+1 at three years of age to e+7 at 15 years. Where e represents the space taken by the executive schemes, which direct the coordination of the activitated schemes. If the research is extended to the children of three years (even to a lower level) and up to 15/ 16 years of age, (to a higher level) this will give the full information about the length of reasoning chains held and the working memories of the children from the age of three to 15 or 16 years which might be useful for Curriculum Designers, Science Educators and Psychologists.

2. This study shows that at Primary level the pupils have developed only two types of concepts; i. e. a) alternative and b) scientific and unscientific (mixed) but at Secondary level they have developed three types of concepts, i. e. a) alternative, b) scientific and unscientific (mixed) and c) scientific. It means that purely scientific concepts are developing under formal science teaching but prior alternative concepts have not been eliminated. If a research is carried out to see the effects of formal science teaching up to the end of Secondary level, it will be helpful to know how far formal science teaching has been successful in eliminating the alternative concepts.

3. This study indicates that while performing a scientific activity, the length of reasoning chain held by the children is always within their Working Memory span. Research could be carried out throughout Secondary level keeping the reasoning chain of the scientific activities within the Working Memories of the children. This will provide a guide line to the educators about the complexity of appropriate scientific activities.

7.6. IMPLICATIONS OF THIS STUDY FOR EDUCATION

1. Science Education is an area of research that is concerned with science teachers and science educators and their pupils. This present research provides evidence concerning the imperfection and weakness of human inference and the obstacles to progress. It would be advisable for teachers to obtain information about the length of the reasoning chains they should expect of their pupils and operate within that. Inference item-sets could be prepared with varying length of reasoning chain so that pupils could be trained in inference skills if they are going to draw sensible conclusions from the everyday experiences and observations. Moreover, teachers should probably obtain information about the concepts the pupils bring with them to school about different phenomena and design suitable techniques, well within their Working Memory space, for challenging those concepts.

2. The information about the Working Memory span of the pupils at a given stage could prove a basic criterion for assessment purposes.

3. This piece of research indicates that the length of reasoning chains held by children is always within the their Working Memory span and the pupils can sustain a length of reasoning chain of between 2 and 4 within the age range of 8-14 years. This information might be most useful for the Curriculum Designers and specially for the Science Educators and teachers.

4. In Scotland, it is obligatory for all children from P1 to S4 to study some science. The choice of content for this may be less important than the complexity of the content in terms of reasoning chain demands. Since so much of science is built on

causal chains, many of the steps being those of inference rather than observation, great care will have to be taken in designing these curricula if children are not to be put off by science because of frustration.

Also it will be essential to find methods of helping pupils to unpack their alternative ideas and expose them to gentle dissonance so that they can reconstruct scientific ideas without carrying scientific and alternative explanations on two separate mental planes thus causing later confusion.

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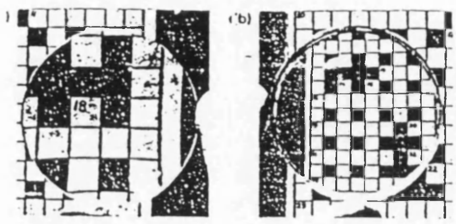
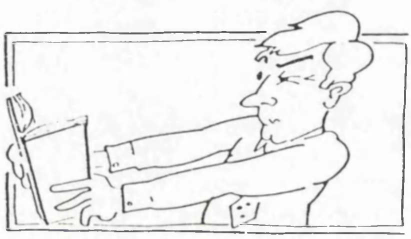
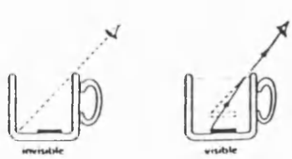
APPENDICES

APPENDIX-1

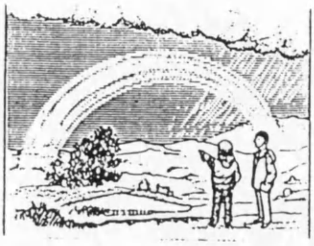
Refraction

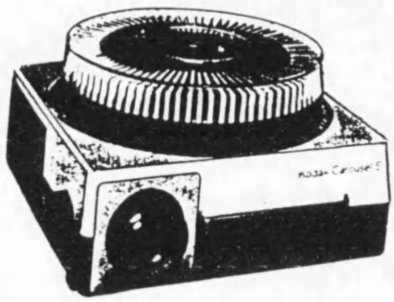


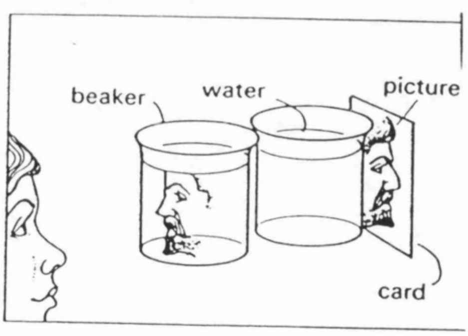




Refraction through water and a glass slab

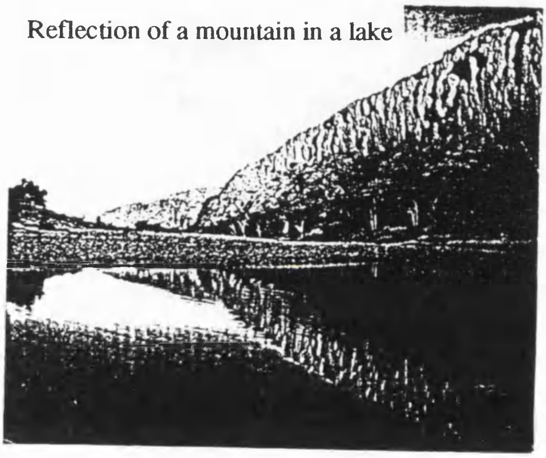


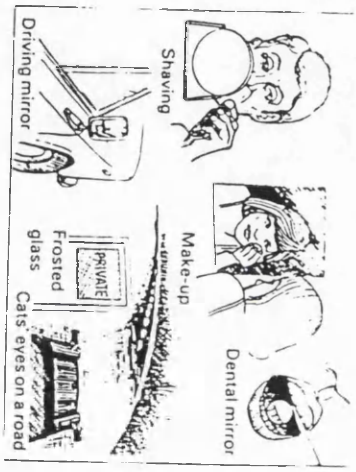


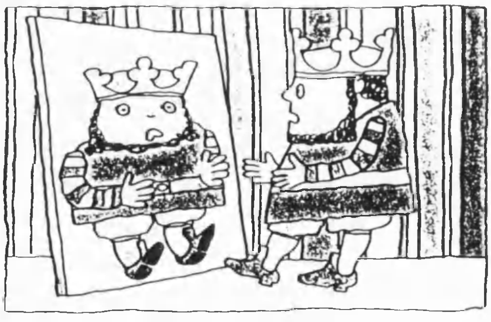

beaker
water
picture
card

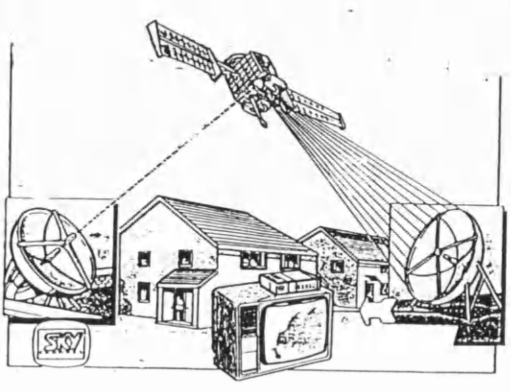
Reflection

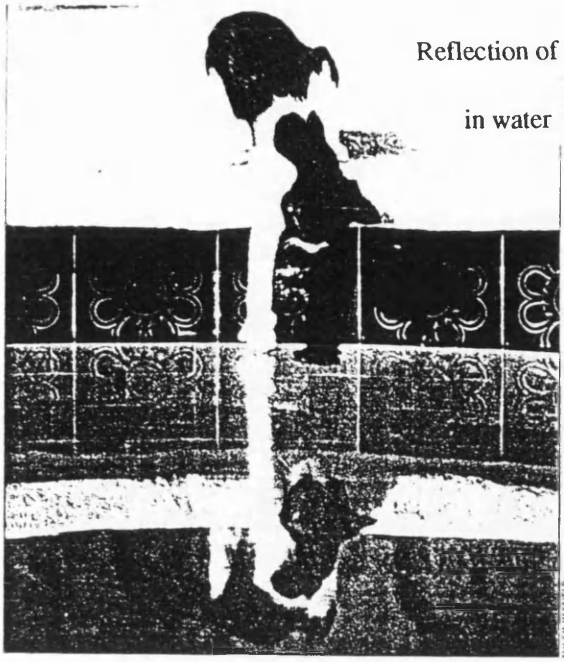
Reflection of a mountain in a lake





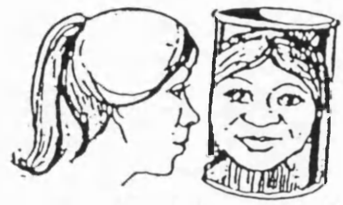


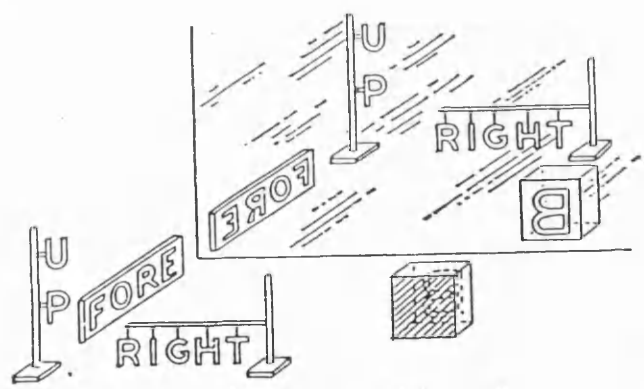


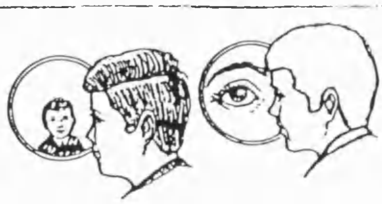


Reflection of a cat

in water

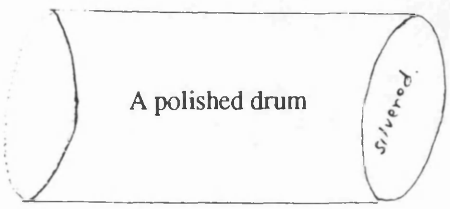


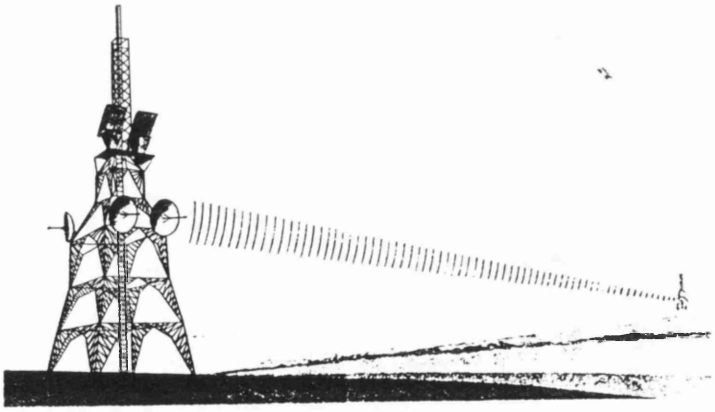




Flowers with different colours

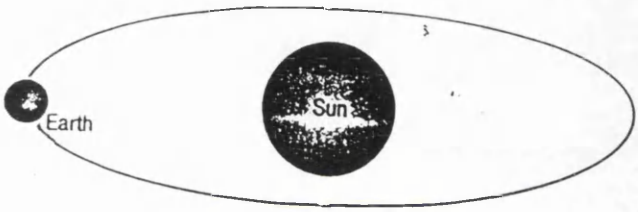
Reflection of sound from a wall

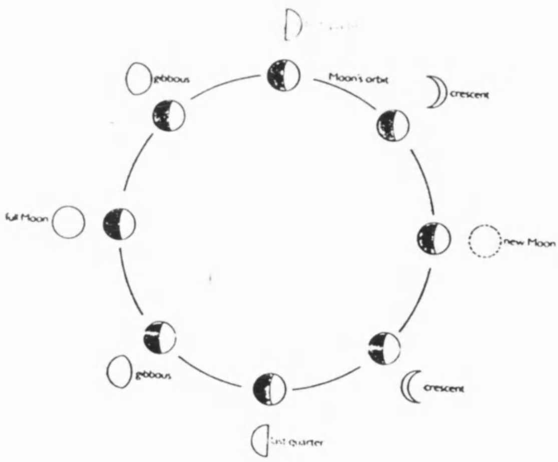


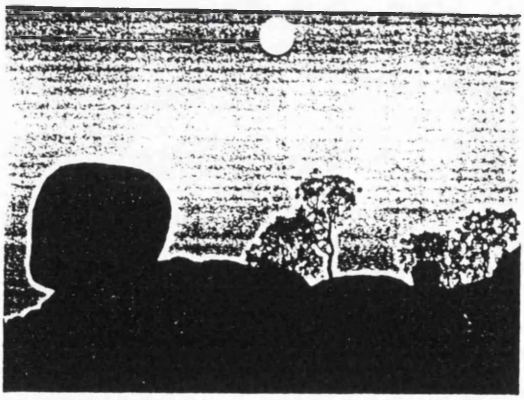


Rotation

A sun-set scene in Autumn

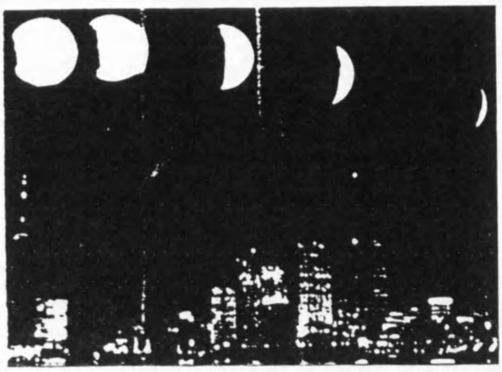




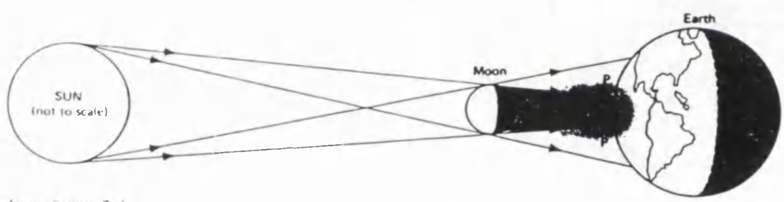


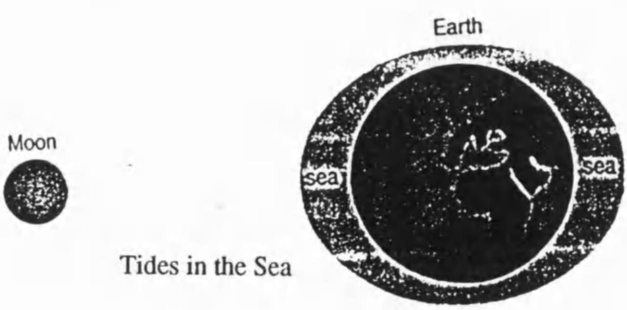
Moon at night on a mountain

Different photographs of an Eclipse



Athletes in the Moon



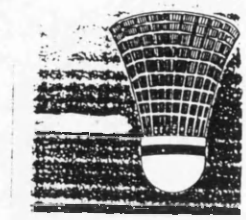


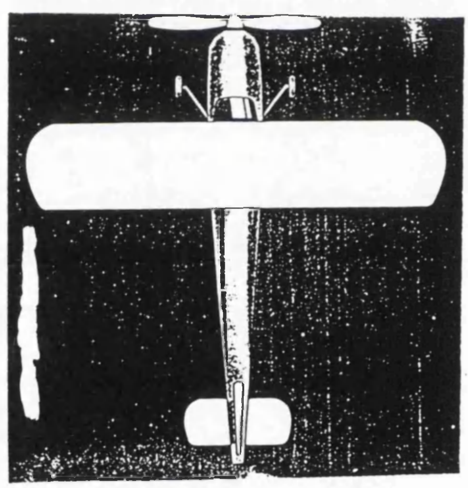
Tides in the Sea

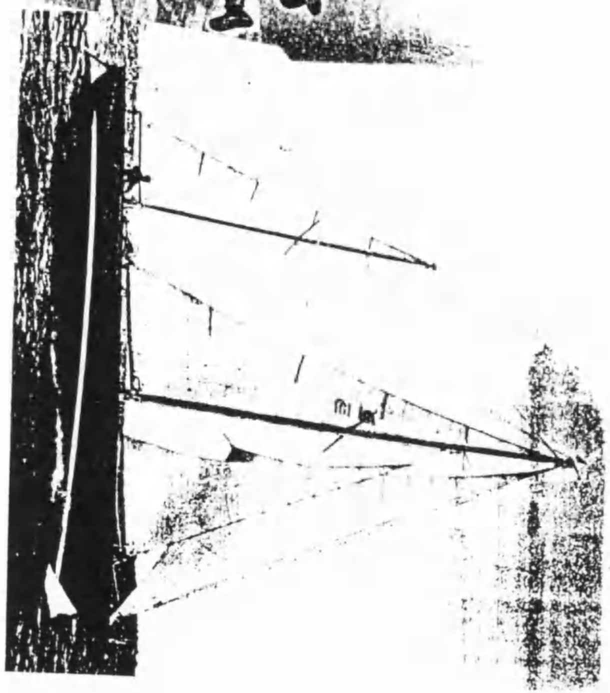
Stones of different colours at the beach

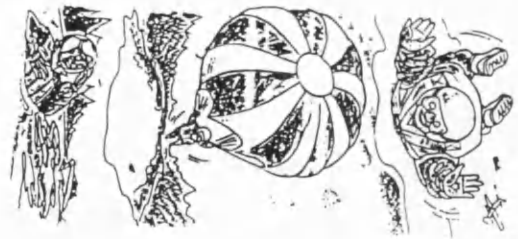
Air resistance

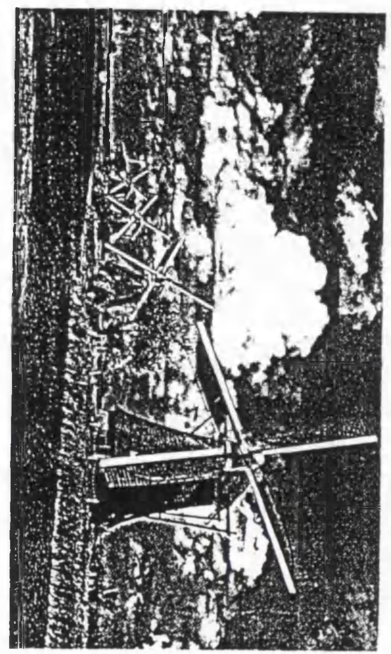
Whirly bird



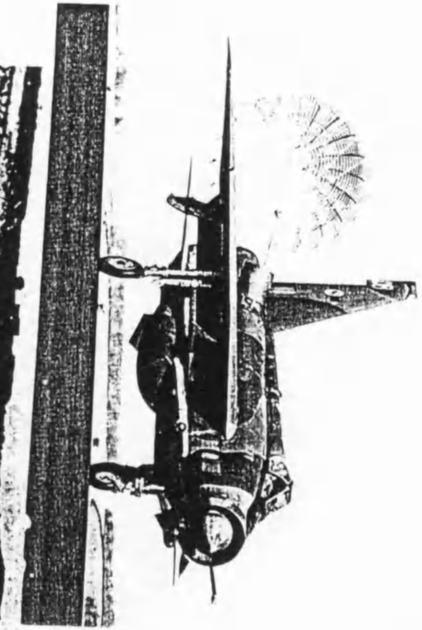


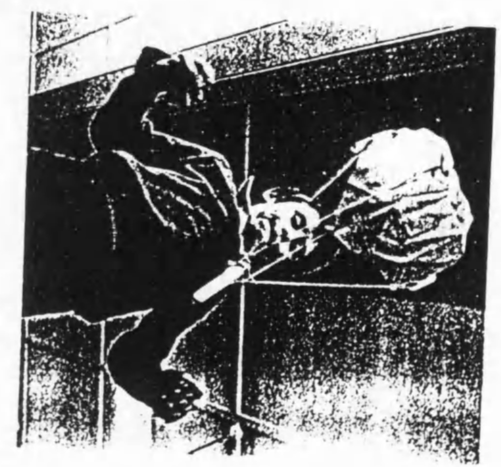




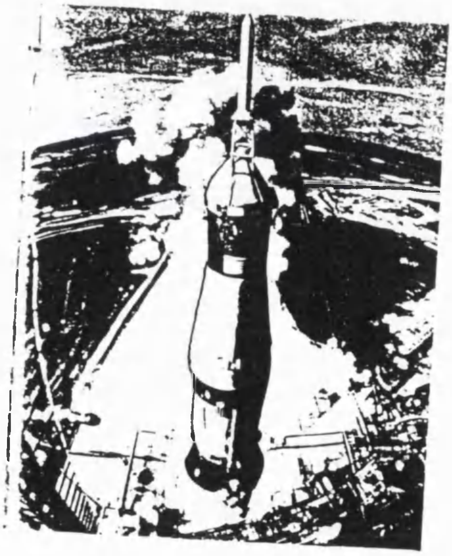


A hovercraft

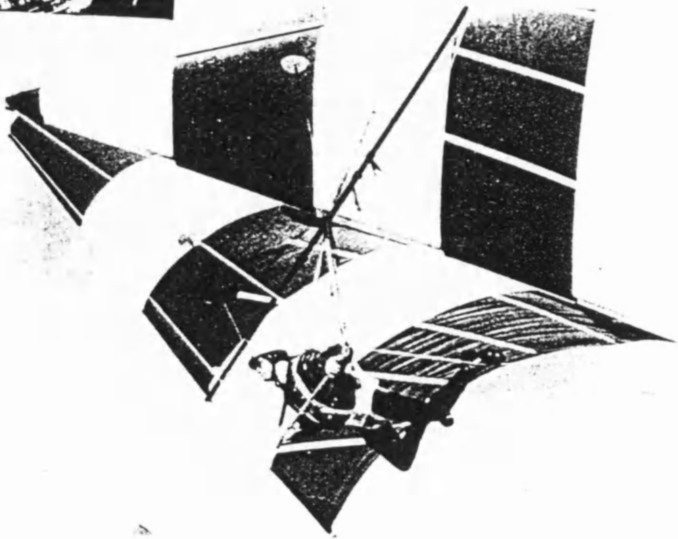




Parachutes of different shapes



Air pressure on a spread paper breaks the wood



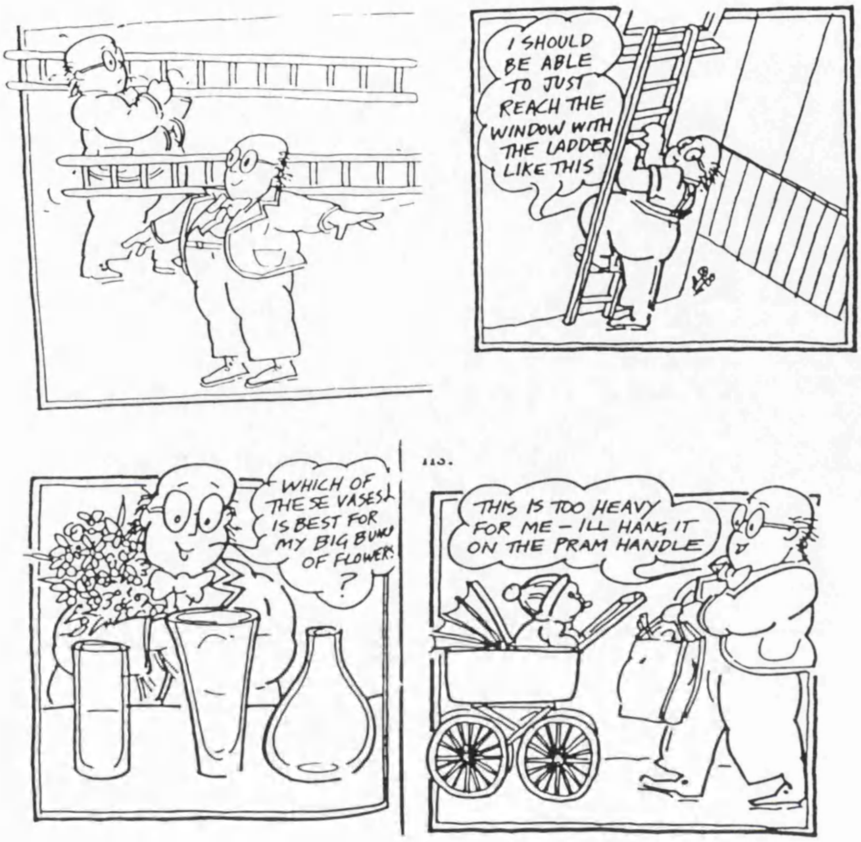
Balance

A person skating on a ramp

Girls doing gymnastics

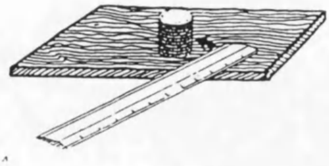
Firemen spraying on the fire

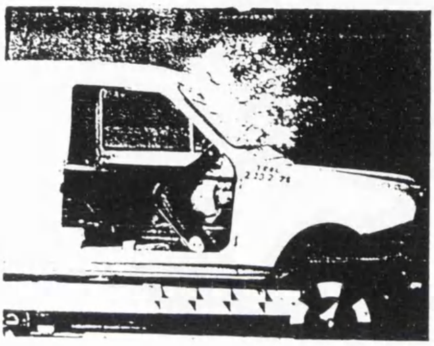
People balancing a boat

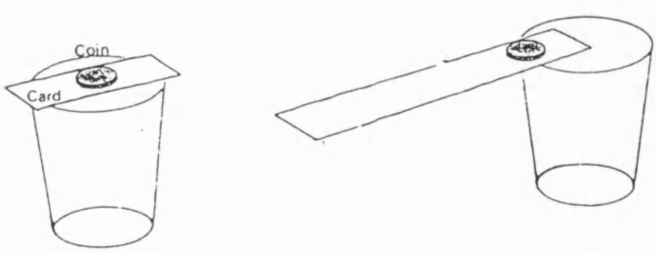


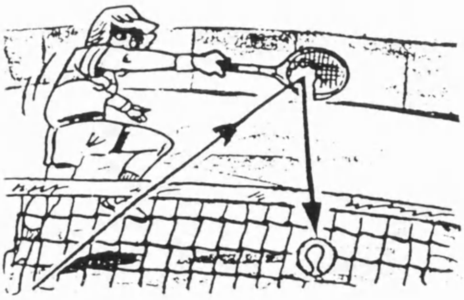
A different kind of leisure time

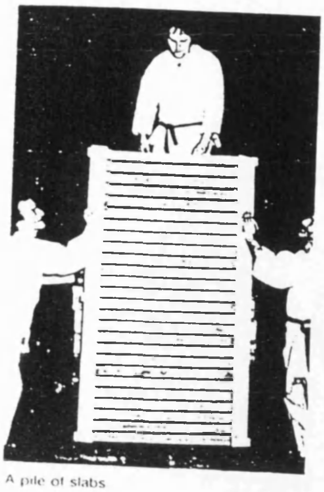
Force/ Inertia







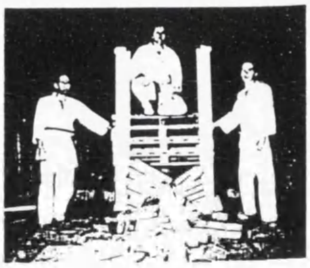


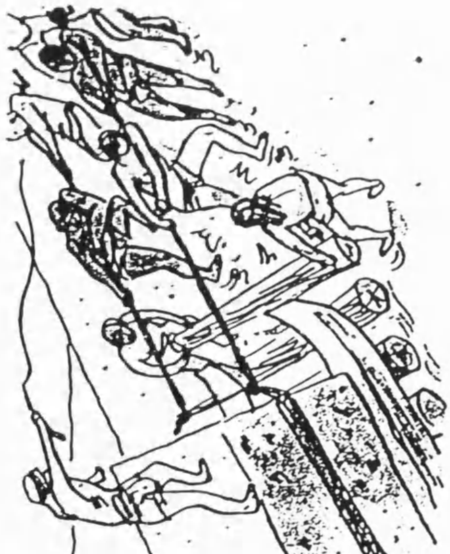


A pile of slabs

a mighty force

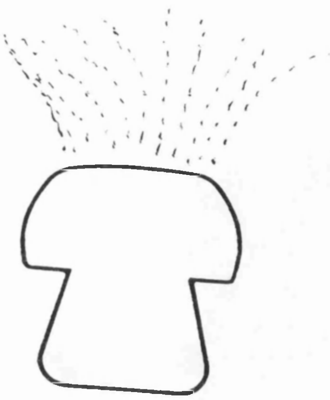
a pile of rubble...



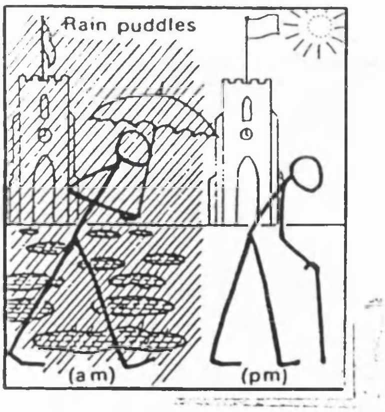


Slaves dragging up the stones

Evaporation



A deoderant Mushroom

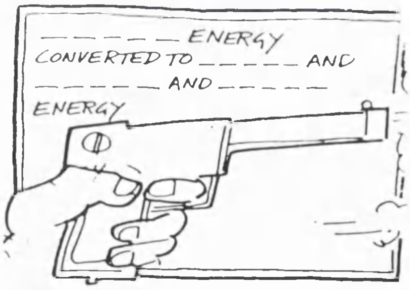


Pressure

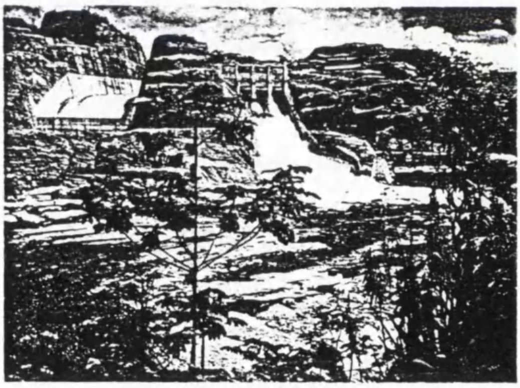
A perfume spray

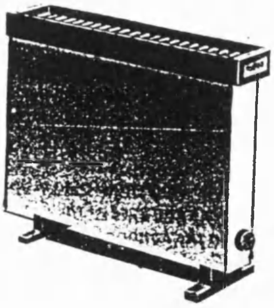
A dancing Monkey

Energy

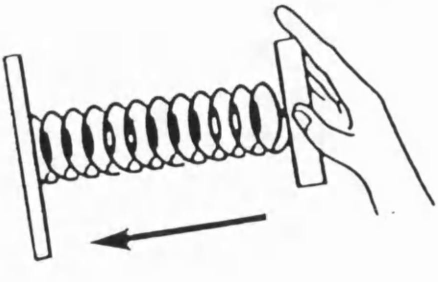


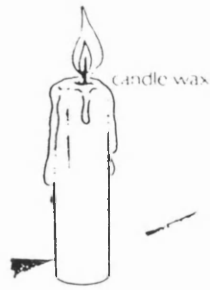
A water Dam

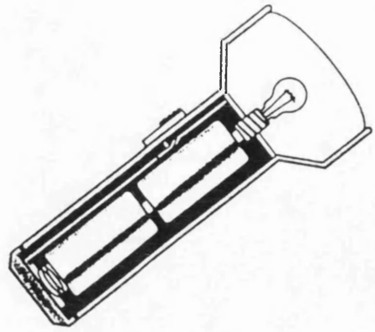


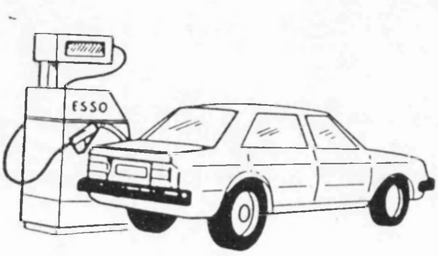


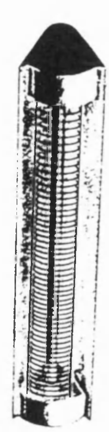
Convector heater (background effect)



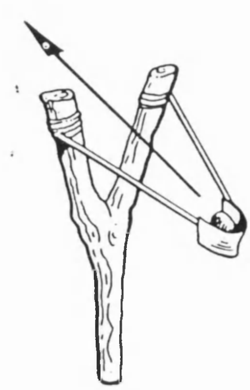






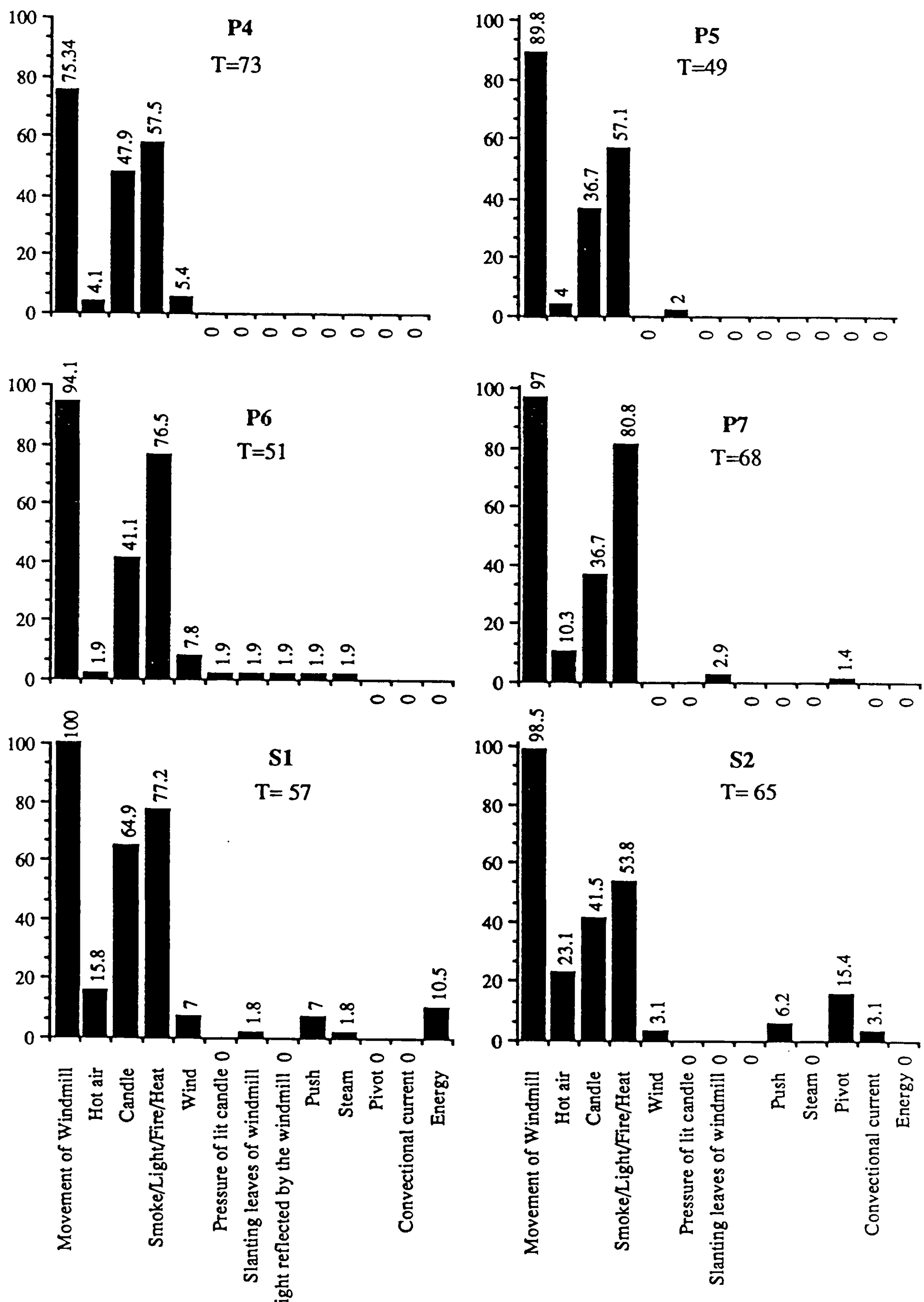


Radiant heater



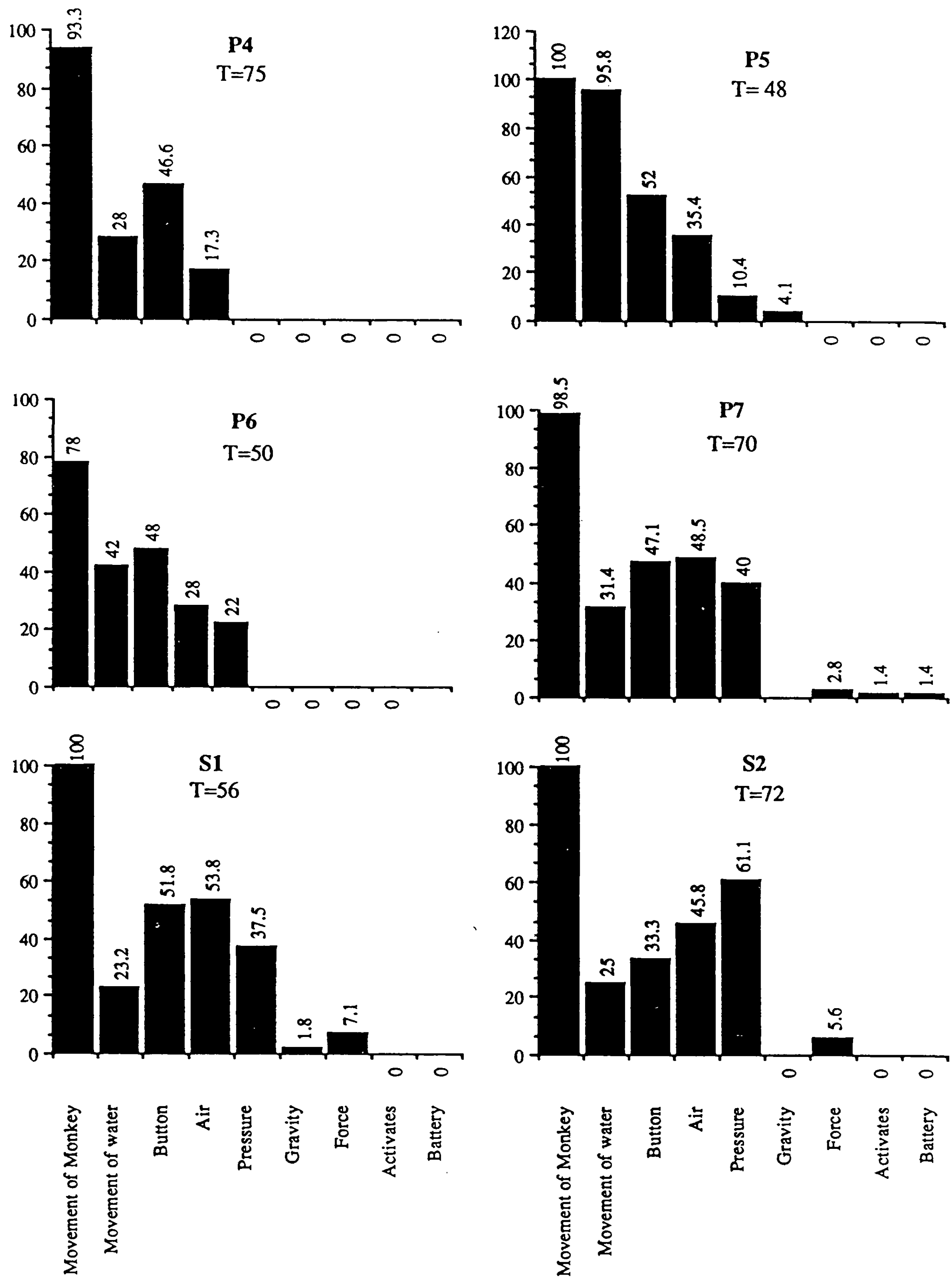
APPENDIX-2

VOCABULARY
(Windmill)



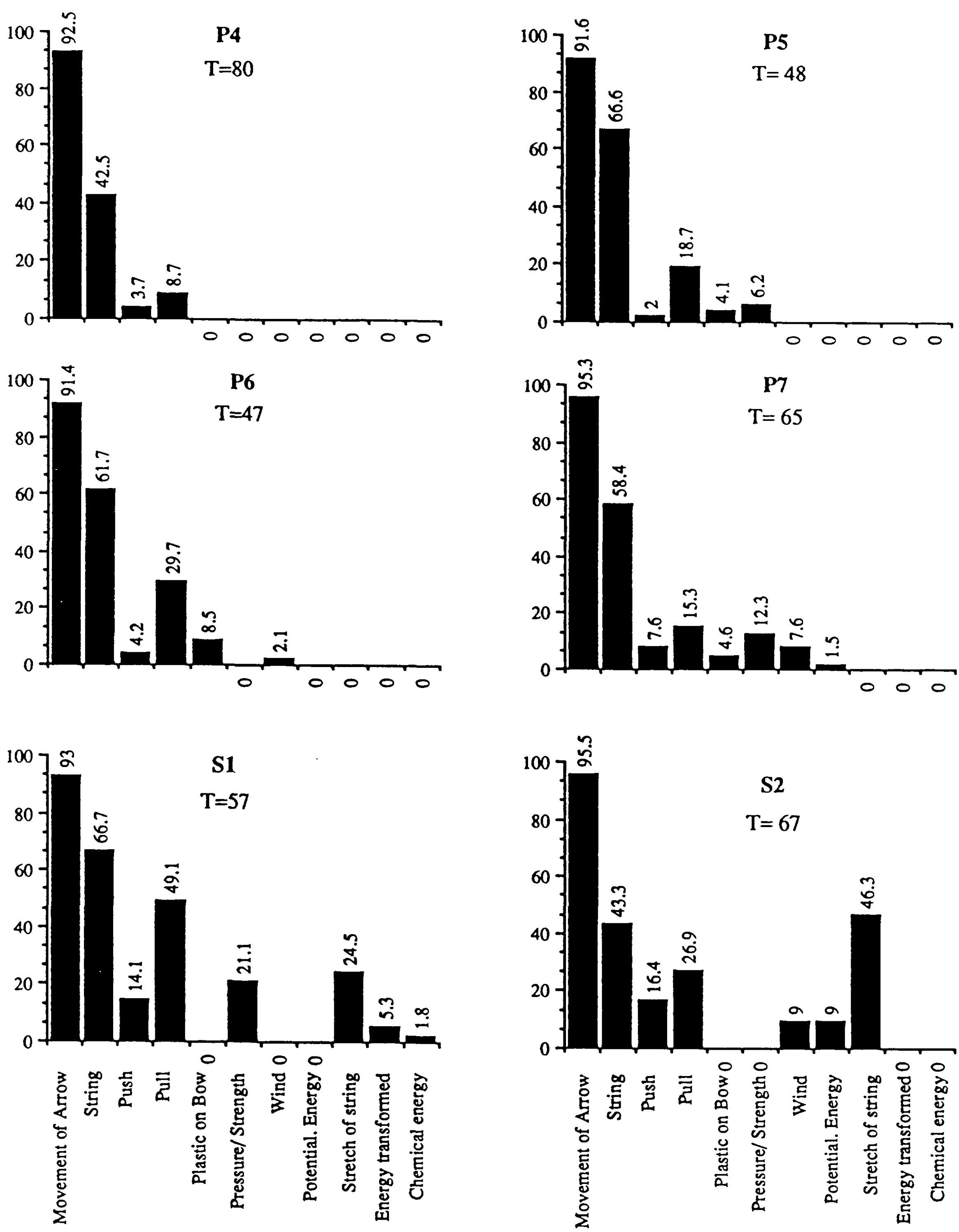
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Dancing Monkey)



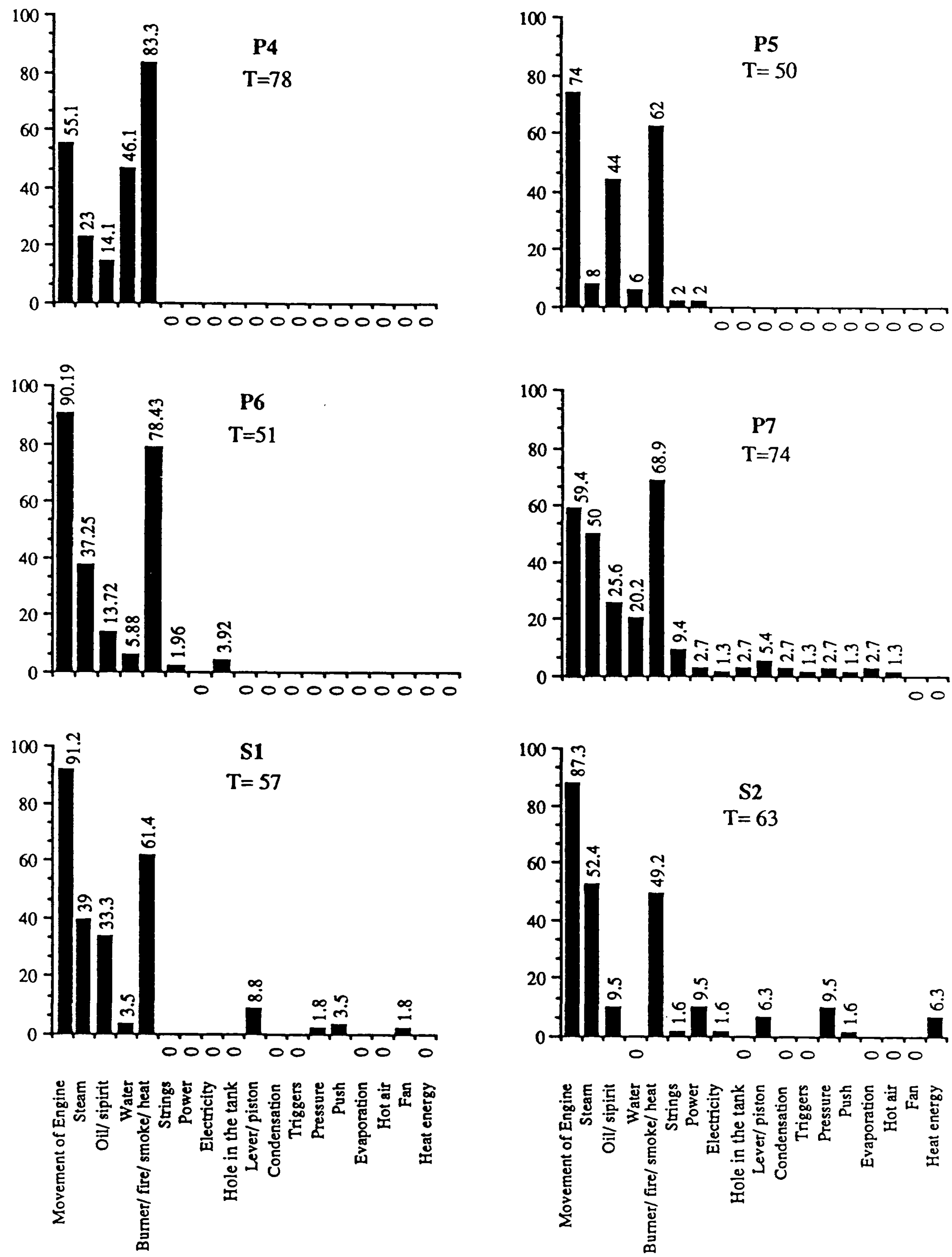
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Bow and Arrow)



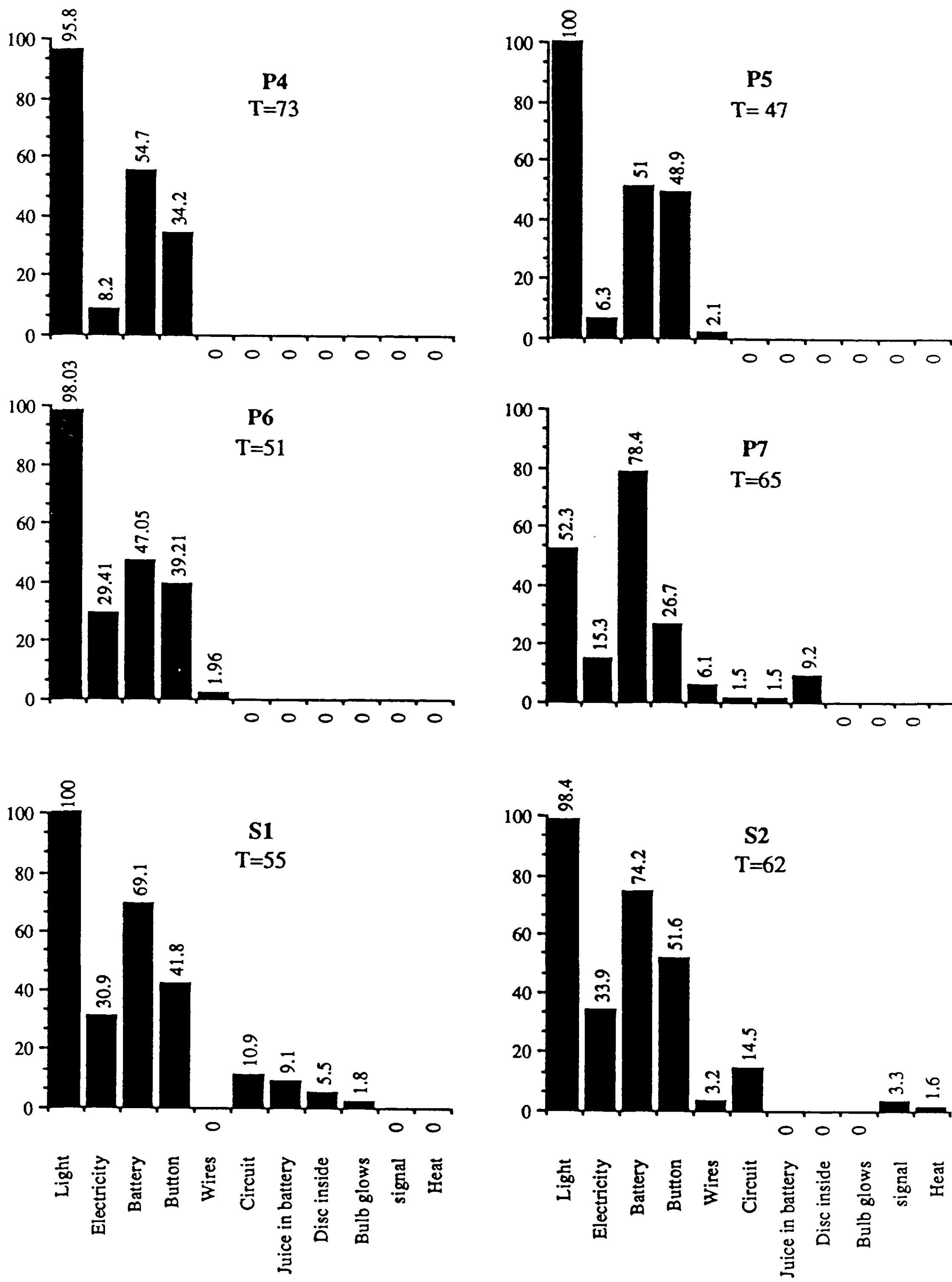
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Steam Engine)



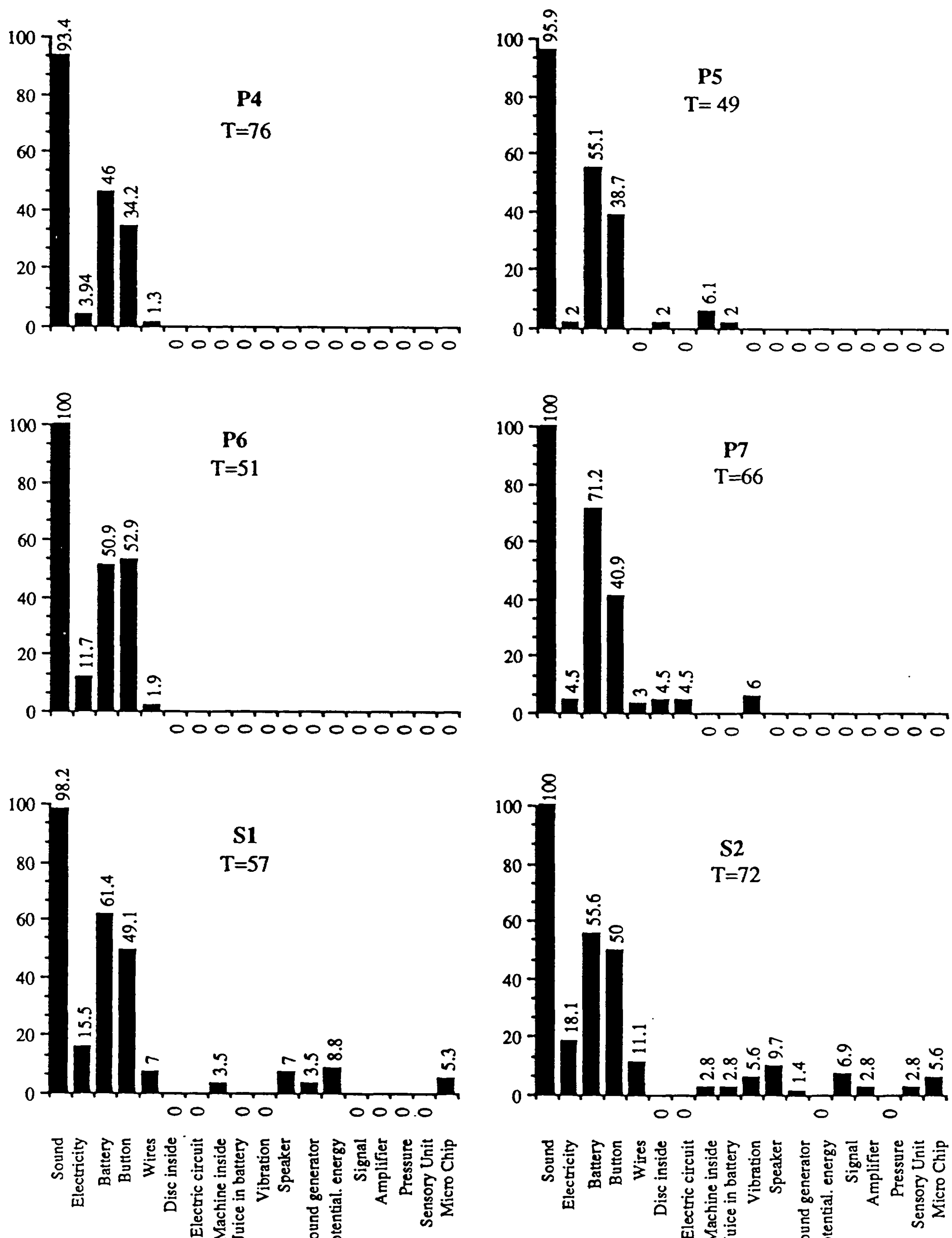
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Torch)



■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of childrentaking part at each level.

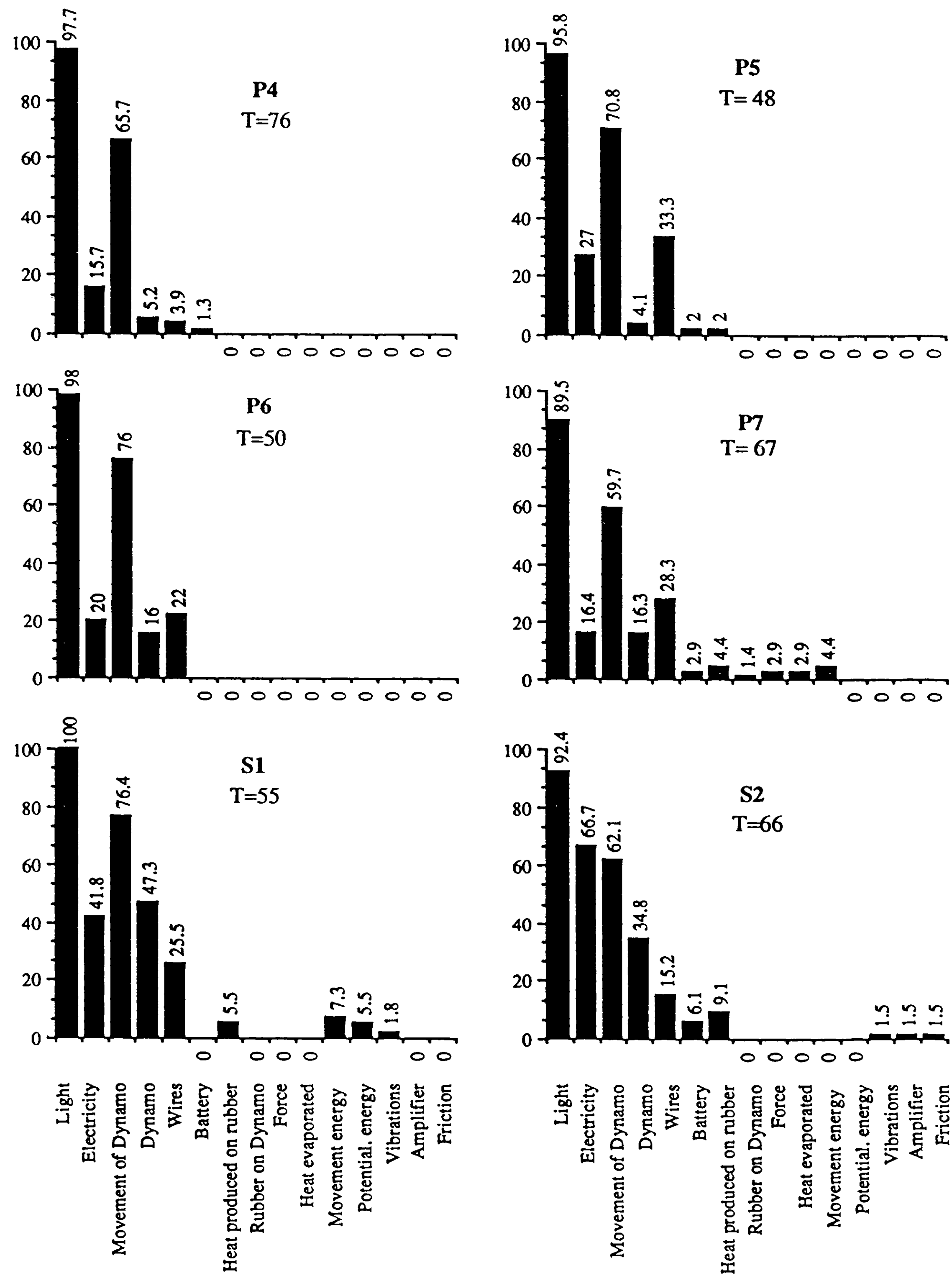
VOCABULARY
(Echo Killer)



■ Percentage of the sample using the specific words while describing/ explaining the activity.

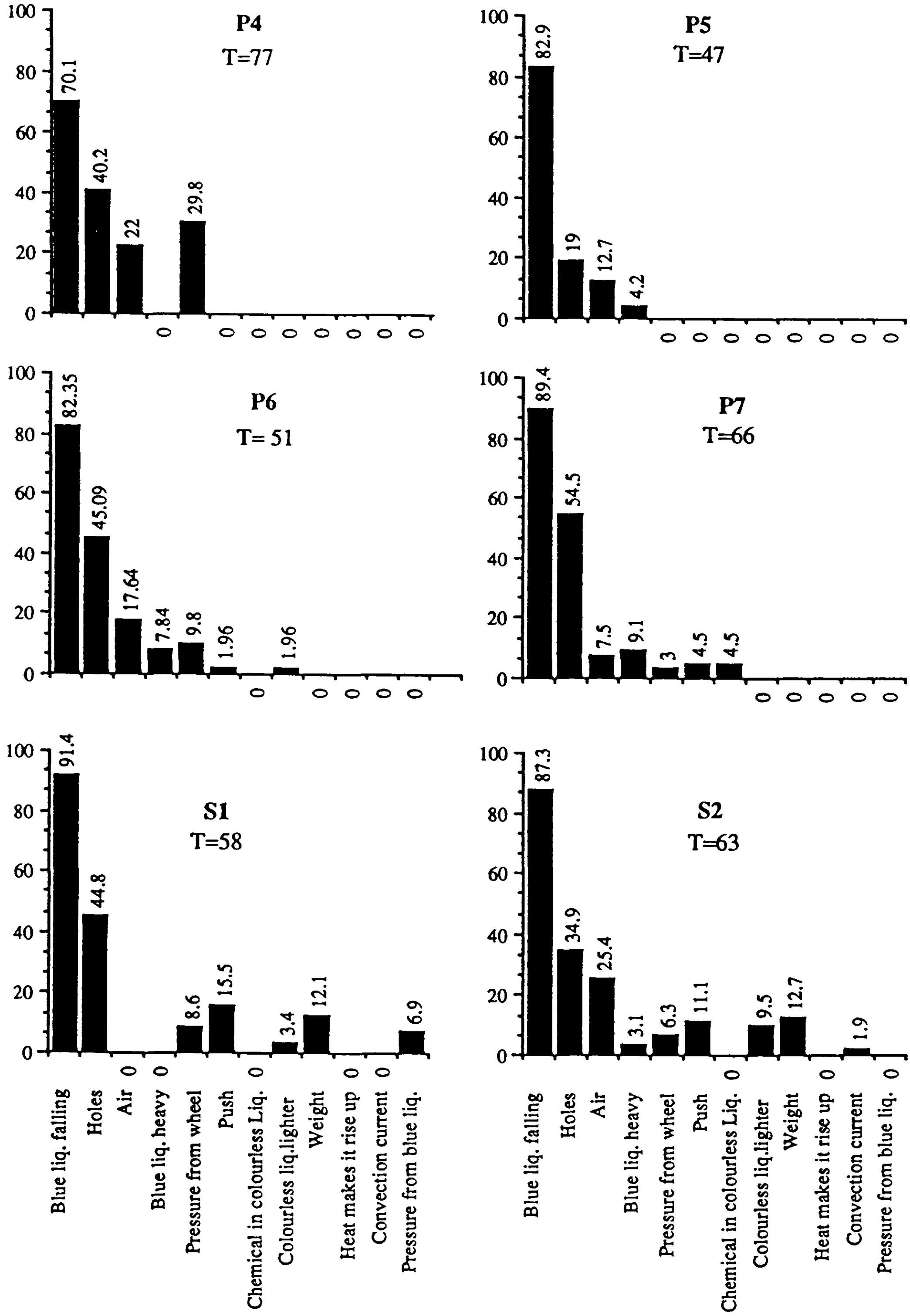
T=Total number of children taking part at each level.

VOCABULARY
(Hand Dynamo)



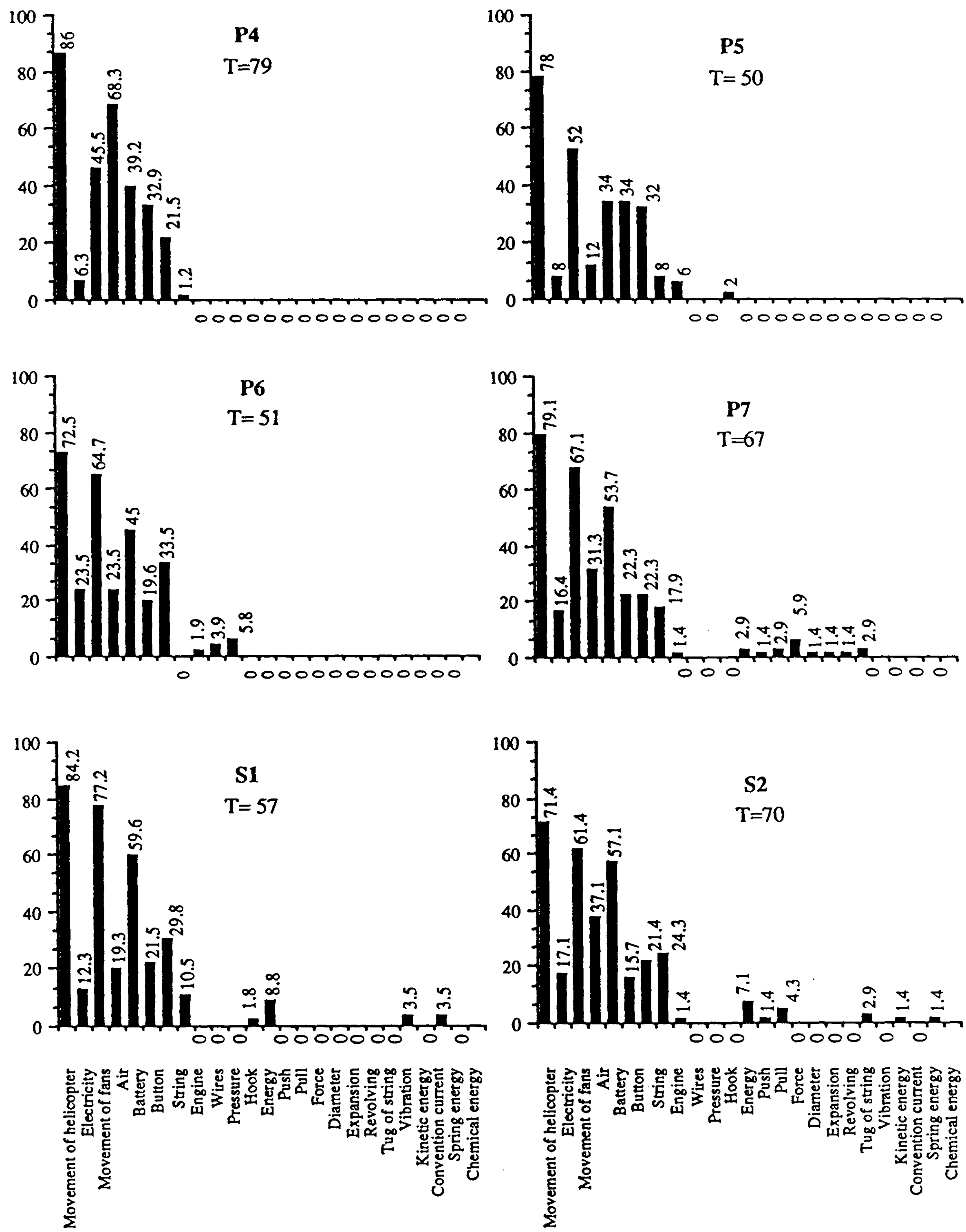
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Liquid Timer)



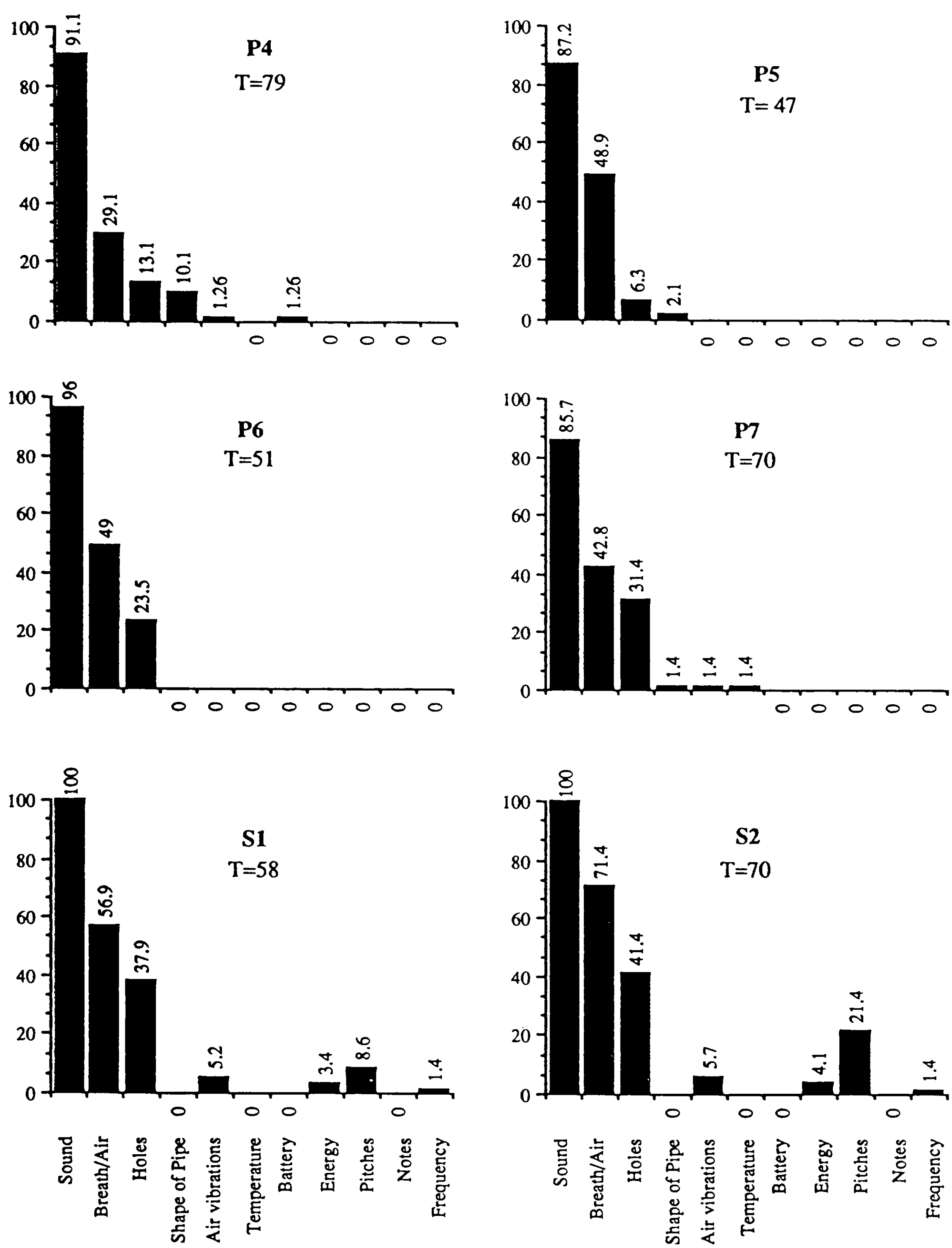
■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Totalnumber of children taking part at each level.

VOCABULARY
(Helicopter)



■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of children taking part at each level.

VOCABULARY
(Flute)



■ Percentage of the sample using the specific words while describing/ explaining the activity.
T=Total number of childrentaking part at each level.

APPENDIX-3

PUFF SIGNALS

SCHOOL : HILLHEAD SECONDARY ***CLASS : S.....***

DATE : 22.01.1992

PUPIL SYMBOLS :

ELEPHANT (M)	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF (M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Hot water less dense (lighter) than cold water	1 : Y/ N Explanation given:	1 : Y/ N	

COMMENTS :

Signature ....

FLOATING EGGS

SCHOOL : HILLHEAD SECONDARY *CLASS :S.....*

DATE : 22.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF (M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1. Water in one beaker is denser than the water in the other.	1 : Y/N Explanation given:	1 : Y/N	

COMMENTS :

Signature ....

SKY HOOK

SCHOOL : WOODSIDE SECONDARY ***CLASS : S .....***

DATE :09.01.1992

PUPIL S YMBOLS :

ELEPHANT(M)	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF(M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Centre of gravity shifted under finger / weight of sky hook and belt balanced against finger	1 : Y/N Explanation given	1 : Y/N	

COMMENTS :

Signature ....

STRANGE DIVER

SCHOOL : HYNDLAND SECONDARY ***CLASS :S.....***

DATE : 29.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE(F)*	*DEER(M)*
TIGER(F)	*HORSE(M)*	*GIRAFFE(F)*
WOLF(M)	*FOX(F)*	*BEAR(M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Squeezing the bottle (pressure) causes rise of water in the dropper . 2 : The dropper sinks being denser (heavier) than water .	1 : Y / N 2 : Y / N Explanation given :	1 : Y / N 2 : Y / N	

COMMENTS :

Signature ....

ICE FLOATING IN SUNFLOWER OIL

SCHOOL : HYNDLAND SECONDARY *CLASS : S .....*

DATE : 29.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE(F)*	*DEER (M)*
TIGER (F)	*HORSE(M)*	*GIRAFFE (F)*
WOLF(M)	*FOX(F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Ice less dense than oil . 2 : Water denser than oil .	1 : Y / N 2 : Y / N Explanation given :	1 : Y / N 2 : Y / N	

COMMENTS :

Signature ....

POURING WATER OUT OF A CAN

SCHOOL : HYNDLAND SECONDARY ***CLASS :S.....***

DATE : 29.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE(F)*	*DEER (M)*
TIGER(F)	*HORSE(M)*	*GIRAFFE (F)*
WOLF(M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Taking water out of the can decreases pressure inside the it . 2 : Air from outside the can presses water in it to equalize the pressure .	1 : Y / N 2 : Y / N Explanation given :	1 : Y/N 2 :Y/N	

COMMENTS :

Signature ....

INFLATING A BALLOON INSIDE A BOTTLE

SCHOOL : HYNDLAND SECONDARY *CLASS : S .....*

DATE : 29.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF (M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Inflating the balloon inside the bottle needs extra space . 2 :The excess air escapes out of the hole . 3 : If the balloon is inflated inside the bottle (hole opened) and then the hole is blocked, the balloon does not deflate because of equal air pressure inside and outside the bottle.	1 : Y/N 2 : Y / N 3 : Y / N Explanation given :	1 : Y / N 2 : Y / N 3 : Y / N	

COMMENTS :

Signature ....

INFLATING A S0AP BUBBLE

SCHOOL : HILLHEAD SECONDARY ***CLASS :S.....***

DATE : 22.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE (F)*	*DEER (M)*
TIGER (F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF (M)	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : The bottom of the flask absorbs heat from the hands 2 : The air inside the bottle absorbs heat from the bottom . 3 : The air inside the flask expands .	1 : Y/N 2 : Y / N 3 : Y / N Explanation given :	1 : Y / N 2 : Y / N 3 : Y / N	

COMMENTS :

Signature ....

RISING WATER PUZZLE

SCHOOL :HYNDLAND SECONDARY *CLASS : S .....*

DATE :29.01.1992

PUPIL SYMBOLS :

ELEPHANT(M) *EAGLE(F)* *DREER(M)*
TIGER(F) *HORSE (M)* *GIRAFFE (F)*
WOLF (M) *FOX(F)* *BEAR(M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 : Oxygen inside the beaker used up / CO2 produced . 2 : CO2 dissolved in water . 3 : Decrease of pressure produced inside the beaker . 4 : Air from outside presses the water in the beaker to rise up . .	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N Explanation given :	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N	

COMMENTS :

Signature ....

HAND DYNAMO

SCHOOL :WOODSIDE SECONDARY ***CLASS : S.....***

DATE :09.01.1992

PUPIL SYMBOLS :

ELEPHANT(M)	*EAGLE(F)*	*DEER (M)*
TIGER(F)	*HORSE (M)*	*GIRAFFE (F)*
WOLF (M)	*FOX(F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 :Movement within dynamo. 2 : Electricity produced . 3 : electricity travells through wires . 4 : Electricity changed into light .	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N Explanation given:	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N	

COMMENTS :

Signature ....

SPIRAL MOVING OVER A LIT CANDLE

SCHOOL : WOODSIDE SECONDARY ***CLASS : S.....***

DATE : 09.01.1992

PUPIL SYMBOLS :

ELEPHANT (M)	*EAGLE (F)*	*DEER (M)*
TIGER(F)	*HORSE (M)*	*GIRAFFE(F)*
WOLF (M)	*FOX(F)*	*BEAR(M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 :Chemical energy .2 : Light / Heat energy . 3 : Hot air / air gets heated . 4 : Hot air rises up . 5 : Rising (hot) air pushes the spiral to move .	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N 5 : Y / N Explanation given:	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N 5 : Y / N	

COMMENTS :

Signature ....

BALLOON FOUNTAIN

SCHOOL : HYNDLAND SECONDARY *CLASS : S.....*

DATE : 29.01.1992

PUPIL SYMBOLS :

(HIGH ABILITY)	*ELEPHANT (M)*	*EAGLE (F)*	*DEER (M)*
(MEDIUM ABILITY)	*TIGER (F)*	*HORSE (M)*	*GIRAFFE (F)*
(LOW ABILITY)	*WOLF(M)*	*FOX (F)*	*BEAR (M)*

EXPLANATION STEPS	STEPS EXPLAINED	HELP GIVEN FOR STEP NUMBER	KIND OF HELP GIVEN
1 Inflating the balloon inside the bottle needs extra space pushing air out . 2 :If the balloon is inflated inside the bottle and the second tube is blocked it keeps the air pressure inside the bottle equal to the outside pressure andballoon does not deflate. 3 : Opening the other tube ,the balloon deflates / pressure inside the balloon is released. . 4 : Air pressure decreases inside the bottle . 5 : Air from outs-ide presses water in the bottle to keep the pressure equal .	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N 5 : Y / N Explanation given:	1 : Y / N 2 : Y / N 3 : Y / N 4 : Y / N 5 : Y / N	

COMMENTS :

Signature ....