LANGUAGE AND CONCEPTUAL CHANGE STRATEGIES IN PHYSICS TEACHING

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ABSTRACT

This study considers pupils understanding of the topic of pressure together with some of the language problems they experience. Some language strategies which may be used by teachers to remedy these problems are identified.

The sample is mainly standard 7 black children (aged about 13, N = 431) in a second language situation in South Africa. The black children spoke mainly Sepedi (also known as Northern Sotho) at home. However two classes of English first language pupils and teachers were involved in the initial stages of the research. During this initial investigations ten lessons and interviews were tape recorded and language and conceptual difficulties identified. Then interviews were conducted with 4 teachers and 10 pupils. Anecdotes in the interviews showed language difficulties and conceptual difficulties which could be attributed to language. These were then used in the development of worksheets for pupils and a teachers' guide.

During the initial investigations of the misconceptions, an open test was administered to graduate student teachers as a convenience sample because of the unrest situation caused by the political climate of the day at the schools. This open test was then converted into a multiple choice form and administered to a large sample of school pupils. Respondents to the tests were also required to give reasons for their answers. The test was first piloted with student teachers and physics bridging course students at a university, before the main pilot with school pupils. Further misconceptions unfolded during the piloting process.

The final test was administered both as a pre-test and as a post-test to an experimental and a control group, a total of 571 pupils. The reasons given for the correct answers were coded so that quantitative analysis could be used.

In general, performance was poor both in the experimental and the control groups despite intervention. In an effort to understand effects of language competence on performance in the conceptual test, four language tests which were previously used in an English 1st language situation in the UK were modified and each administered to 25% of the sample. These language tests however proved very difficult for the pupils. Scores were low and no correlation could be found between the language tests and the conceptual tests. Language difficulties were however identified in single incidences from teachers as well as pupils. Some of the language difficulties led to conceptual difficulties.

In conclusion many pupils have difficulty in understanding the concepts in the topic hydrostatic pressure. Some of these difficulties may be compounded by language problems.

Key words: Language, conceptual change

DECLARATION

I declare that this thesis is my own work. It is submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

N Nkopodi

30th day of January 1998

This thesis is dedicated to my family, friends and everybody who encouraged and/or supported me directly or indirectly to complete this research.

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1.0 CHAPTER ONE - Background to the study

1.1 Introduction

In South Africa, with its history of racial segregation, the standard and quality of life has been divided along racial lines in almost all aspects including education. This policy has, for a long time ensured a vicious circle whereby each racial group would produce and reemploy a labour force of a quality which corresponded to the privileges enjoyed by that group, resulting in the perpetuation of standards associated with the group.

While the importance of redressing these issues systematically to bring about equality in education is recognised, this research study looks at problems that can be addressed while the country is still in a stage of transition with many of the problems still existing. The focus of this research is therefore on a disadvantaged second language situation with limited or no facilities for science teaching. For the purpose of this research a second language is a language that is not a speaker's mother tongue but which is used at school and often outside school (for example, in business) but not in normal social discourse. A foreign language is a language that will only be encountered at school and seldom if ever used outside school. In this way English is a second language for black South Africans and Portuguese a foreign language. The reverse is true for black Mozambicans.

This study looks at both language problems and conceptual problems on the topic of 'hydrostatic pressure' in second language science classes in South Africa.

It is a follow-up of a research project in which recognition of some science concept definitions in English and Sepedi were investigated (Nkopodi, 1989). In that study, it was shown that the children most disadvantaged by language are those in the lower standards (ages about 13) - although South African levels of education have very little to do with age because of the examination system which determines a pass or a fail. In this system children write examinations at the end of every year. A pass in the examination (an aggregate of about 33,3%) allows promotion to the following year of study. This means that some children repeat the year of study. Furthermore the absence of compulsory education for blacks at the time of this research (compulsory education only started in 1995 for children aged 6) resulted in a situation where pupils could leave and come back to school several years later resulting in different age groups in a single standard. Thus typically a class of nominal age 13 years will range in age from 12 to a staggering 27 years!

In the present study, language and conceptual problems have been investigated among both pupils and teachers. Conceptual problems may arise from different sources including language and everyday experience. Conceptual difficulties (misconceptions) due to language arise when someone misinterprets the meaning of a word or has difficulties in understanding the logical links. When a word is misinterpreted, the concept may be misunderstood. The problem is worsened by the fact that often the second language users are not aware that they have a problem.

Language strategies used by different teachers in standard 7 classes when the topic 'hydrostatic pressure' was taught were identified and areas of conceptual confusion and misunderstanding were addressed in materials written for teachers and pupils.

The reasons cited in support of the maintenance of English as a medium of instruction have been mentioned elsewhere (eg. Rutherford and Nkopodi, 1990). The focus of this research from the language point of view is therefore how best to address language problems while maintaining English as a medium of instruction for English second language learners.

This research was also partly aimed at achieving conceptual change, using conflict strategies, as well as low cost equipment. It was felt to be essential to support teachers to achieve this.

1.2 Overview of the chapters

This work is divided into 9 chapters as the flowchart shows.

The nature of this research (as it will become clear after reading through the relevant chapters) was such that results were obtained at intervals during the project. The flowchart below illustrates the sequence of the chapters and the chapters in which results are reported.

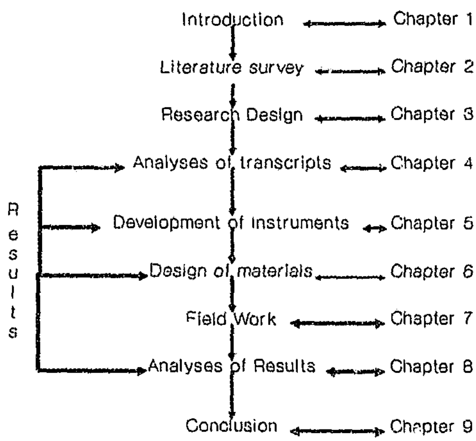


Figure 1: Chapter overview

The results, which are both qualitative and quantitative, have both a language and a conceptual component. The rationale behind this research project can best be understood in context.

1.3 Context of the research

The context of this research should be seen in terms of the medium of instruction, facilities, teacher education, teacher-pupil ratio, funding and school type.

The inadequacies of both teachers and facilities in South Africa as a whole fits the description of the Indonesian situation documented by Beeby (1979) in that there is a range from the well equipped to the poorly equipped. In particular, the schools which participated in this project can be categorised as formalist (Beeby, 1966), i.e. they are *highly organised with tight discipline, and only one text book is used.* However inspection of the pupils' work was not stressed because of the large pupil-teacher ratio.

This research was conducted in a rural area under the former D.E.T. (Department of Education and Training). This was the department of education for the education of a black person in South Africa. In broad terms these schools represent some of the educationally most disadvantaged in South Africa (Hofmeyr and Spence, 1989). Indeed while Hofmeyr and Buckland (1992), quoting D.E.T. sources, report a pupil-teacher ratio of 38:1, this research was conducted in situations where the ratio was at best 60:1 and at worst 160:1.

Inadequacies in the number of qualified teachers and school facilities in South Africa have been documented elsewhere (University of Natal, 1982). D.E.T sources reported 52 percent underqualified teachers in that department compared to zero in white education, 2 per cent in Indian education and 45 percent in Coloured education (Hofmeyr and Buckland, 1992). 'Underqualified' here means less than standard 10 (school leaving) with a 3 year teacher's diploma.

The low pass rates in standard 10 matric results in DET schools have also been well documented eg. Hofmeyr and Spence (1989), Straus, Plekker and Straus (1991) as well as Blankley (1994). Blankley (op. cit.) attributes the sharp contrast between this and the corresponding pass rate for white schools to the learning conditions at the schools. Since reasons leading to this pass rate are complex, and include such factors as political and socio-economic status, some of these were outside the scope of this research. This research c. .y addresses classroom issues such as language, teaching strategies and equipment.

1.3.1 Adequacy and quality of facilities and teachers

The previous government policy of 'separate development' which separated different racial groups in virtually all spheres of life, together with the fact that South Africa has many more English second language speakers than first language speakers resulted in a situation where the majority of pupils and their teachers had a poor knowledge of English. When English is a medium of instruction, this poor level of English competence becomes an additional obstacle to learning.

Academically most teachers have not studied science at a level higher than standard 10 (school leaving certificate). Even those who did science until standard 10 do not necessarily have a pass in the subject. In general there are many teachers who teach physical science because they do not have a choice since there is nobody else to teach the subject.

Although attempts are made to support these teachers with the help of science subject advisors, often these subject advisors themselves have not had adequate academic training to enable them to handle such tasks with competence. Some areas do not even have subject advisors because of the shortage of suitable people and of funding.

The teacher's diplomas previously mentioned, until recently offered no more academic content than the standards at which these teachers were supposed to teach. Although the teacher education syllabus has now changed, by the time this research was implemented, no teachers had graduated with the diplomas containing an enriched subject content.

Because of poor training, often the teachers can not make full use of even the limited equipment at their disposal. As a result some equipment is simply locked away in cupboards. Many of these teachers do not like teaching physical science because of their poor content knowledge of the subject.

1.3.2 The schools

Different schools even within the D.E.T. have different physical and financial situations, some of which are described below.

Funding in rural schools

Most schools in rural villages were built with financial contributions from the villagers themselves, the state only paying the teachers' salaries. As a result there were usually no funds available for a laboratory or library. Very few or no experiments were done, while at the same time the teacher's resource material was limited to the prescribed student text book. Low cost, self-constructed apparatus was not usually considered since the teachers either had no knowledge of the piece of apparatus or lacked the skills to construct it.

Alternative schools

A recent phenomena in South Africa is the growth of 'alternative schools' in the cities, one of which has been used in this research. These schools offer black children an alternative when the political climate in the country does not allow normal tuition to take place in townships. These schools offer the same curriculum as that offered by government schools. Admission to the schools range from a situation when any child whose parent can pay is admitted to a situation where strict selection tests are administered.

Some of the schools were established as business ventures by people who have little educational background. The schools are often plagued by financial problems and it is not unusual for them to have poor facilities and a short life span. They are therefore sometimes referred to as 'fly by night schools' and their teaching staff as 'pavement academics'.

Other alternative schools however, like the one visited, offered some hope in that they are stable and have a high pass rate.

1.3.3 The pupils

The pupils in this study had different home backgrounds as well as different learning conditions at school although the majority came from very similar situations.

All the children who participated in the main study were English second language (E2L) speakers who did not speak English at home. A smaller number of children and teachers from an English first language situation were involved only in the initial stages of this research (when initial language strategies being used in science classes were observed).

The E2L speaking children studied in their vernacular until standard 2 (age 9) after which they switched to English as a medium of instruction. Because these children spoke English only at school and are often taught by people who are themselves not fully competent in English, it is doubtful whether these children had acquired the necessary vocabulary to study in a second language.

For science in particular, language competence is crucial as it is felt that improper use thereof may possibly result in or reinforce misconceptions, alternative conceptions and naïve conceptions. Since different researchers use these terms in different ways, they need to be defined.

1.4 Definition of terms

The discussion which follows reflects only the personal views of the researcher regarding the definition of terms. A further discussion regarding other views from the published literature is in section 2.7.4.

Children's incorrect ideas were originally known as misconceptions and are now frequently called alternative conceptions. The words misconception and alternative conception can both be used -- each one being more appropriate under certain circumstances.

The word 'misconception' might mean an incorrect view when compared with a scientist's view of reality, eg. if a person standing on the ground believes an object dropped from moving aeroplane will fall vertically below the point where it was dropped, he has a misconception. However one who associates a concept word with its everyday meaning, eg. police 'force' or a person being 'forced' to do something has an alternative conception -- a correct but different meaning of the same word.

In addition we can define a naive conception as an undeveloped conception eg. if one only views a force as a physical push or pull.

The word misconception is thus considered appropriate where some researchers prefer the words 'alternative conception'.

The literature encountered does not make any distinction between 'language in science' and 'the language of science'. The researcher however feels that there is a difference which needs to be made clear. Language in science refers to problems due to everyday language when used in science context. However, the language of science refers to language specifically for science such as the use of precise technical words and constructions specific to the scientific discipline.

These terms when used should thus be seen in the light of these definitions.

1.5 The purpose of this study

In the light of the forgoing discussions about teachers, schools and pupils, it was decided that a research project that would be most beneficial should

(a) address subject content to support teachers.

(b) address language issues since both the teachers and pupils are learning science in a second language.

(c) cater for the dearth of laboratory equipment by using improvised equipment and

(d) attempt to identify the most efficient language strategy used.

These issues were addressed in a teaching package written for the teachers (appendix A).

This research project addresses misconceptions on the topic of hydrostatic pressure together with the above issues.

2.0 CHAPTER TWO - Literature survey

2.1 Introduction

This research looks at difficulties in science learning from the two perspectives of language and concepts. The literature review therefore contains discussions related to language, conceptual difficulties and research methodology.

In South Africa the issue of language is somewhat sensitive because the previous South African government was perceived to use it not only as a medium of communication but also as a political tool to control blacks both politically and economically (Lemmer, 1993). It was also noted that the previous South African government was reluctant (despite negative attitudes towards Afrikaans as a medium of instruction) to use English as a sole medium of instruction in black education (Walker, 1986). In general English has achieved this privileged status since the 1976 student uprisings against the use of Afrikaans as a medium of instruction.

When South Africa's first democratically elected government took over, all eleven major languages in South Africa were given official status. However despite this, the international usage of English as well as the poor state of development of the indigenous languages in South Africa indicate that English will remain the medium of instruction for a long time in the country.

It is thus important in the first instance to review the different points of view regarding

(a) language acquisition

(b) how language difficulties are addressed where English is used as a medium of instruction especially in an English second language situation

(c) the language of science.

Secondly, it is important to investigate typical misconceptions which may emerge as a result of teaching methods which fail to address language issues.

2.2 Language and thought

The relationship between thought and language remains confused with different researchers expressing different points of view.

Chomsky (1965) has investigated first language acquisition and suggested the existence of a language acquisition device (LAD). This is like a ' black box' within an individual which is triggered by hearing language spoken. Processes will then take place in the device to help the child to interpret rules of a language as it is spoken and so subconsciously acquire language despite its complexity. Common language errors among children which could not be a result of imitating other speakers are then attributed to an undeveloped LAD. Chomsky thus largely attributes first language acquisition to biological factors.

It would seem Chomsky is not in conflict with Krashen (1981) regarding language acquisition in children. Regarding second language, the latter draws a distinction between conscious learning (monitoring) associated with adults and the subconscious language acquisition associated with children. This view however drew some criticism, because of the difficulties in drawing such a sharp distinction (McLaughlin, 1990).

Piaget suggests that the acquired language does not affect thought but merely serves to express it (Piaget, 1954). He further suggests that this is explained by the fact that thought can take place even when language has not been acquired, eg. the early stages of a child's life.

In a more practical situation which seem to support Piaget's view, two extreme cases, namely the deaf and the hearing were investigated. Oleron (1953) suggests that the deaf have difficulty in conceptual thinking and generalisation because of their reliance on observed data. Furth (1961) on the other hand, gave 180 hearing and 180 deaf children three non verbal tasks on

(a) sameness
(b) symmetry
(c) opposition

While hearing children were found to be superior on the third task only, the deaf children occasionally outperformed the hearing children until age eleven in the first two tasks. Since the deaf children reportedly came from a lower socio economic status in general, this finding therefore was not in agreement with previous studies which had shown positive correlation between socio economic status and intelligence. On the other hand this study showed that the deaf children could outperform the hearing children on some tasks despite their poor language development.

In what seems to be an improvement on Piaget's findings, Vykotsky (1962) indicated that there is no relationship between speech and thought until an age of about two when a symbiotic relationship between the two starts. Language and thought then start leaning on each other - each helping to shape the other.

A more extreme emphasis on the importance of the relationships between language and thought was taken by Whorf. Whorf (1941) reported the existence of a connection between the language spoken by an individual and the level at which the individual analyses reality, citing Standard Average European and Hopi (a North American Indian language) respectively as examples of languages where speakers tend to generalise and look at events differently. Whorf (1956) added that language is only useful to the extent that it is used to analyse concepts that belong to that language. It is not known whether Whorf (op. cit.) was comparing the analysis of reality by people with comparable educational background and thus capable of analysing reality at the same level.

It would appear that while several researchers link language to thought they differ on the nature of the link. It appears not easy to resolve the confusion regarding the relationship between language and thought. This is particularly true in situations where the medium of instruction is a second language because often there is a strong connection between one's educational level and one's ability to speak the second language. It thus becomes difficult to find two people with comparable experience but speaking two entirely different languages, say European and African.

2.3 Learning in a second language in general

Following second language acquisition it becomes of interest to shift emphasis from learning a second language to learning in a second language.

In a second language situation, the learners may be involved in either an immersion or a submersion program.

Swain (1978) describes immersion programs as a situation where children

"from the same linguistic and cultural background who have had no prior contact with the school language are put together in a classroom setting in which the 2nd language is used as a medium of instruction" (Page 238).

Immersion programs carried out among English and French speaking children in Canada reportedly showed that the immersed children performed just as well as the native speakers of the language in which they are immersed (Swain, 1978). Swain (op. cit.) found that the results were consistent across programs and geographical areas.

In another study, Samuels et. al. (1969) compared children taught in a Foreign language (English or French while their native language was the other) with two monolingual English and French control groups taught in their vernacular languages in a novel situation. The immersed groups were taught in their foreign language during their first two years of instruction. The children's conversation was tape-recorded and rated by bilingual judges for the children's ability as decoders of novel information and proficiency as encoders. No significant difference was found between the two groups. However we must remember that these two languages have effectively the same grammar rules.

In an immersion program that involved languages from two entirely different grammar rules (namely English and Chinese), Ho (1982) could only confirm the above results in higher standards. One hundred and seventy six grade ten students (Chinese native speakers) were involved. Eighty six of them were attending an English immersion school while the other ninety were attending a Chinese medium school. By contrasting this with studies made with grades 6 & 7 in the past, it was deduced that by grade 10 students had mastered English well enough to use it efficiently as a medium of instruction. Ho therefore suggests that immersion programs might be beneficial only in higher grades.

The second situation, namely a submersion program is a situation where some children with little or no knowledge of the school language are taught in the same class with children already fluent in the school language.

The results of submersion programs were found to be opposite to the results of immersion programs, i.e the submerged children had an inferior performance compared to their peers learning in their vernacular. However the children who were involved in the immersion program shared a language with their teachers and had a higher socio economic status than their peers in the submersion programs, thus leaving the latter in an unfavourable learning situation (Swain, 1978).

In the South African context it is children from upper to middle class families who are involved in submersion programs (private schools) while most children from working class families are involved in modified immersion programs (state schools). Swain's findings may therefore not be applicable. These South African children often have an inadequate command of the English language for use in academically demanding situations but they often come from societies which have negative attitudes towards the use of their vernacular as media of instruction (Lemmer, 1993). The main reason for the attitudes to the vernacular being the fact that this is interpreted as another face of the previous South African policy of apartheid (Rutherford and Nkopodi, 1990 and Lemmer, 1993).

The possible variation in effects of immersion programs in different countries may also depend on the extent to which such programs are supported by the authorities. In Canada, for example, teachers receive intensive training in these programs and are proficient in both languages (English and French). In contrast, teachers in South Africa do not receive such training and are not necessarily proficient in both languages (the medium of instruction and the child's vernacular language).

From the language point of view, this research is particularly concerned with 'language in science' as well as the 'language of science' and their effect on the acquisition of science concepts.

2.4 The problems of everyday language in science

There are numerous problems caused by everyday language used in a science context.

Language in science is a problem both for those learning science in their first language and those learning science in their second language.

Case (1968) as a teacher in Malawi found difficulties with language in science peculiar to English second language speakers, notably direct translation from their vernacular while Taber (1979) reports difficulties identified from British pupils not necessarily peculiar to English first language speakers such as using different terms to explain the same concept, eg. kinetic energy was also referred to as 'motion energy'. The converse of this finding, i.e. the attachment of different meanings to one term is also possible (Carrol, 1964).

In order to remedy the problem of language in science, Taber (op. cit.) suggests the use of a standard nomenclature. However, Howard (1989) points out that metaphors are useful to clarify science concepts and should be used as long as teachers are aware of their limitations. An example of likening electrons around the nucleus to a solar system is mentioned. In this case it should be pointed out to the pupils that electrons do not move in fixed orbits like planets. Sutton (1980) while not discouraging the use of metaphors warns that these may also cause future problems, eg. metaphors may be taken literally by those who found them of use. It is pointed out that in the olden days, ships literally "sailed" away because they had sails, however the word is still being used today despite the fact that most ships are not using sails any more. Sutton (op. cit.) suggests that problems such as these can be minimised if the importance of language in the growth of ideas can be appreciated, as well as how the language that carries the ideas was acquired.

2.5 The problems of the language of science

These problems appear to be more serious for those learning science in English as a second language, as Rutherford (1993) puts it, this language is a second language for English first language speakers, and a third language for English second language speakers where the scientific material is written in English. However Mackey (1984, p.45) points out that most second language scientists can express themselves in this language better than most native speakers of the language in which the science material is written.

Bulman (1986) has identified the following factors which serve to make the language of science complex to a novice.

(a) It is specific
(b) The vocabulary used is specialised
(c) The passive rather than the active voice is used.
(d) The sentence structure is complicated and is complex, because often there is more than one clause involved, resulting in long sentences.

Sutton (1980) and Merzyn (1987) also note that this language has a preciseness not found in everyday language which makes it difficult for children to appreciate its use. Given these properties of the language of science, it is necessary to look at the languages used to communicate scientific ideas together with the qualities of a language which are demanded by the content knowledge. Such a language would be a useful medium of instruction.

2.6 The medium of instruction

There are different factors which may affect scholastic achievement other than the medium of instruction. Lynch et al. (1979), Lynch and Dick (1980) and Lynch and Paterson (1980) investigated the recognition of simple definition of concept words associated with the concept of matter. They found that the variables: IQ, grade, age, socio economic rating and gender differences all produced significant differences. However, the effect of the medium of instruction on these variables remains to be seen.

There are conflicting reports regarding a suitable medium of instruction of science. There are advantages to learning in one's own vernacular over learning in a second language although in some cases a second language medium of instruction proves not so much of a hindrance as it would appear at first glance.

2.6.1 Learning science in the mother tongue

Despite some advantages of learning in the vernacular such as having access to a strong vocabulary for expressing oneself, there are also difficulties encountered with the use of English as a vernacular in the learning of science. These include the use of logical connectors which are widely used in science. Problems with the use of logical connectors have been reported by Gardner (1980) for grade 7-10 children in 46 Australian schools which represented both school type and area, that is: state schools, technical schools, central schools (containing grades 7 and 8 only), higher elementary schools (attached to rural primary schools), systematic catholic schools (administration by catholic office of education), independent schools (both catholic and non-catholic). It is also noted that these items are very important in science texts (Gardner op. cit.).

Some research studies have looked at comparison of language effects between different language groupings i.e. each administered tests to two groups i.e. English and Hindi (Lynch, et. al.1987) and Scottish and Malaysian (Isa and Maskill, 1982). Lynch (op. cit.) administered his test to English and Hindi speaking children while Isa and Maskil (op. cit.) administered their test to English and Malay speaking children. While each group wrote in their vernacular, the Hindi and Malay groups outperformed their English speaking peers when science words specific to the Hindi or Malay speakers were encountered. Their science specific words were mostly coined while the English speaking groups did not enjoy the same position. In an extensive study with British school children, it was found that many everyday words were more of a problem than the science specific words when used in science contexts (Johnstone and Cassels, 1978).

Very little has been reported about learning science in the mother tongue in the African context, exceptions being in research situations where this is only looked at over a certain period of time, for example Ehinhero (1980) and Bangbose (1984). This was a six year project where concept acquisition was compared between children who learned science in a second language (English) and children learning science in a first language (Yoruba). It emerged that the children learning science in their vernacular outperformed the second language learners despite the fact that both groups of children were tested in English. In addition the children learning in their vernacular were reported to display higher cognitive skills than those learning in their second language.

The writings of Ehinhero (op. cit.) and Bangbose (op. cit.) appear to support an earlier study done with Ga and Twi speaking children in Ghana where Collison (1974) found that children made more complex sentences when using their mother tongue to describe tasks given to them than when they were using English.

Another dimension of difficulties towards solving language difficulties is attitudes towards some languages. Negative attitudes towards black languages as media of instruction were noticed in the African context (Brown, 1988/89). Many devalue their vernacular and regard English as a language of prestige. Some of the arguments against the use of the vernacular however, appear to hold substance, eg. the fact that a lot has already been written in English and the costs of translations would be very high (Rutherford and Nkopodi, 1990).

The above discussion shows different points of view regarding the vernacular as a medium of instruction. These are

(a) the mother tongue can enhance comprehension of science concepts

(b) even when one is learning in one's mother tongue there are still language and attitude difficulties to be considered.

2.6.2 Learning science in a second language

Seddon and Waweru (1987) conducted a study in which the African languages, Swahili and Kikuyu as media of instruction were compared with English. Some students were given tests in their vernaculars and others in English. It was found that transferability of concepts was possible from English and Swahili to Kikuyu and from English and Kikuyu to Swahili without any loss of meaning. However, the sample in this study comprised of only the top 25% in the 15 to 16 year old age group and the sample was very small. Hence no generalisation can be made.

In the South African context, Rutherford et. al. (1989) looked at the recognition of science definitions in English and Sepedi for high school children. Whilst the children were learning science in English (second language), there was no significant difference in performance between children who answered the test in Sepedi and those who answered the test in the language of instruction (English). It was suggested that this meant that the children were not rote learning in English, for if they did, recognition of the Sepedi definitions would have been far worse.

On the other hand, McNaught (1991) found that transferability was not easy and that meaning was lost in translations from English to Zulu (a South African language). In her study, science lessons given by student teachers in Zulu and English were analysed. It was found that Zulu definitions were functional rather than structural as opposed to English definitions. Case (1968) and McNaught (op. cit.) found that the absence of certain words or logical connectors make translations difficult. In fact these may induce conceptual difficulties (Case, op. cit.).

Having noticed problems with both the vernacular and English as a medium of instruction, other researchers, Rollnick, (1988) and Nkopodi, (1989) suggest a language approach that will utilise the strengths of both languages to facilitate understanding, while at the same time discarding weak points inherent to the vernacular. Rollnick, in her study where conversations among student teachers were tape recorded, found that it was easier to pick up misconceptions when the subjects used their vernacular.

The approach advocated by these researchers involves retaining English as a medium of instruction (as is indeed the case in South Africa) but using the vernacular to clarify some concepts where necessary and allowing a mixed language to be used in group discussions.

2.6.3 Culture and the medium of instruction

There is an interrelationship between culture, attitudes and the medium of instruction. Both the extent to which culture is considered in teaching and the medium of instruction may affect attitudes towards the learning of science.

There is however some criticism towards failure of an education system to address cultural issues (Ogunniyi, 1986, Atwater, 1986). In Africa many countries only realised after independence that the European models they had been following were not serving their needs (Ogunniyi, op. cit.).

Culture can be taken into consideration even on a small scale such as lesson presentation (Opalko, 1991). Giving an example of a person wearing snowshoes while teaching about pressure, she realised that while the students who had lived in West Africa all their lives were intrigued by the photograph of the person, they did not get a feel for the example. She therefore started to the excitement of the children, to use local examples such as why camels did not sink in sand and why it is difficult to ride a bicycle in sand.

However, it may not always be easy to consider culture, for example, Maley (1989) points out that culture is a lot more complex than is often reported. It is pointed out in his finding that even in a monolingual society, where one culture is often assumed, there might be different subcultures which induce learning and communication difficulties not dissimilar to those found between people of different cultures.

In other situations difficulties may be caused either by the fact that a concept does not exist in certain cultures or that in that culture the concept is not referred to by name, for example in Papua New Guinea, Jones (1974) found that among the twenty six Papua language groups which were tested, only eight had a term to express the volume of water and only two could express the volume of a block of wood. It was thus difficult to introduce some topics under these conditions. However Nkopodi (1990) pointed out that the absence of a word does not necessarily mean the absence of a concept.

It appears that culture, language used and the attitude towards the language should be considered by teachers. On the other hand, it would seem that, even in the absence of cultural problems language problems exist. This can be inferred from the reported language problems experienced by those learning science in English mother tongue with syllabuses often drawn by people sharing a culture with the students, eg. many parts of Britain.

Even with the language, culture and communication problems addressed, it is believed that greater success can be achieved if the approach to teaching follows a model that makes best sense to the children.

2.7 Selected learning theories

There are different points of view regarding how learning takes place.

2.7.1 Historical background

Views regarding how learning takes place have changed considerably over the years. Traditional thought put emphasis on 'teacher talk' where all the concepts to be learned and their labels are presented explicitly, with the assumption that that was all the children needed to learn. However, it is pointed out that for the child to perform various tasks successfully, corresponding levels of cognitive development are required (Piaget, 1973).

Ausubel (1968) reports that meaningful learning only takes place when the learner's prior knowledge is considered and linked with the new knowledge. The difference between Piaget' theory and Ausubel's is thus an emphasis on the stages of cognitive development by the former and the learner's prior knowledge by the latter (McClelland, 1982).

Ausubel's theory has led to the development and wide acceptance of a constructivist methodology, an approach which takes into consideration the learners' misconceptions, everyday experiences and perceptions.

2.7.2 Constructivist theory of learning and language

According to this theory, learners construct new knowledge using their existing knowledge. It is the interaction of this existing knowledge with the new knowledge confronting them which makes new knowledge meaningful or not.

Watts and Pope (1989, p. 329) wrote that constructivism ' would highlight a less normative, more child centred approach. Within any one topic area students might display a range of understandings which are the consequences of their adroit personal interpretations of phenomena' . This, according to constructivism, they continued, is 'a fundamental feature of the act of human learning, a consequence of individual development within a complex social and linguistic context, and cannot be eradicated'.

Learning using a constructivist approach does not mean the teacher has no role to play. Driver (1989) defines the teacher's role as not that of imparting knowledge, but that of creating learning tasks and situations which would promote learning. This means a greater challenge for the teacher, that of identifying and creating tasks and conditions under which the learning can be most efficient. Some of the conditions under which learning appears to take place are described below.

Conceptual Ecology.

The Oxford dictionary describes ecology as the study of the relationships between living organisms and their environment. The environment is physical in this context. However Toulmin (1972) uses the term figuratively to include the environment, social and linguistic context in the description 'conceptual ecology'.

Toulmin (1972) reports that knowledge develops as a result of a dynamic interaction between an individual and the environment. The environment can thus be seen as stimulating the thought processes of an individual. The type of knowledge created will thus depend on the environment in which a person finds him/herself and the individual's response to the environment.

Toulmin (op. cit) further describes the individual's response as adaptation to the environment. This view finds support in Hewson, M. G. and Hamlyn, D. (1984) where it was found that people in Southern Africa who live in a hot environment, use the words 'heat' and 'hot' in various ways in their everyday language. As a result, their metaphor for hot which refers to a condition referring to agitated blood fits well with a prekinetic theory of heat. Hewson claims that the language of the people may also be better shaped to understand this area of physics unlike Westerners who are known to hold caloric views.

The idea of conceptual ecology gives birth to the conceptual change strategy developed by Hewson (1981) and Posner et al. (1982).

2.7.3 The conflict strategy of remediating alternative conceptions

Hewson (1981) describes the process of conceptual change as a complex process that involves reorganisation of existing knowledge, displacement of some concepts, and acquisition of additional information. Although Hewson wrote with Posner et. al., the latter report the same view with different terminology.

Hewson, (op. cit.) describes the following possibilities which take place when a person holding a concept C is faced with a new concept C'.

1. C' may be rejected.

2. C' may be incorporated in three possible ways.

- rotely memorised.

- C' may replace C. This is called conceptual exchange (CE). This is referred to as accommodation by Posner et al. (op. cit.)

- C' may be accepted without the total rejection of C. This is called conceptual capture (CC). This is referred to as assimilation by Posner et. al. (op. cit.). In this case each concept will be used when the individual finds one more convenient than the other.

What science teachers usually want is conceptual exchange (CE). However conceptual capture (CC) happens when the learner sees a link between C and C' but no contradiction.

The above possibilities occur depending on the relative status of the old concept and the new concept for the learner (Hewson (1981) and Posner et. al. (1982)). These are described in the following way.

Is the new concept intelligible (I)? i.e Can the learner make sense of it?

Is it plausible (P)? i.e in addition to being intelligible does it seem sensible?

Is it fruitful (F)? i.e in addition to being plausible, is it useful?
Does it give a better understanding of reality? Can it be used to predict what happens in novel situations?

C' can only be exchanged with C, if, to the learner, it is higher in the hierarchy than C. If it has lower status it will be rejected straight away. If the two concepts are given the same status then conceptual capture occurs.

The above discussion suggests that in order to use the conceptual change strategy, it is essential to identify the learner's existing concept. If it is scientifically incorrect, its status must be lowered with respect to the new concept. This can be done by creating dissatisfaction with C (hence lowering its status) or removing some dissatisfaction with C' (hence raising its status).

An alternative way of testing understanding is called 'interviews about instances' which can also be used to achieve conceptual change about instances was developed by Gilbert and Osborne (1980). This entails recognising instances and non instances for concrete concepts. In the case of abstract concepts the interviewee is asked to state a question which he/she thinks that when asked will enable him/her to answer the question. A similar approach to test understanding is described by MacGuire and Johnstone (1987) as entailing the ability to:

(a) define a concept in words

(b) recognize instances of the concept

(c) distinguish between instances and non-instances and

(d) solve problems which involve the concept

It appears that in order to test understanding according to the above researchers, one must be in a position to identify conflicting instances, i.e one where the concept does not hold and another where the concept holds so that the learners can understand through conflict what the correct concept is. Hewson's theory of conceptual change and MacGuire and Johnstone's interview about instances are therefore not in conflict with each other.

2.7.4 Published literature's definition of terms

The terms such as 'framework of ideas', alternative conceptions' and 'misconceptions' are often encountered in the literature and are differently defined by different researchers.

For example, Abimbola (1988) defines a framework of ideas as the category in which children's incorrect ideas about a concept can be classified, although there may be interrelationship between these categories. Such a framework of ideas will then be governed by what Hewson (1985) refers to as their epistemological commitments which may be cultural, linguistic or simply the children's everyday experience.

Many researchers including Ambimbola (1988) are not in favour of the word 'misconception' which has its roots in epistemology which suggests that the students' view is incorrect and that they are empty vessels into which knowledge is pumped.

Ambimbola (op. cit.) and Hewson (1981) are however in favour of a new philosophy of science which views learning as 'a process of conceptual change'. Within this view the term alternative conception is preferred to the word 'misconception'. It should however be noted that these terminologies reflect these researchers' points of view. There are other points of view as well (section 1.5) and numerous researchers have written about children's ideas under these different headings (eg. Driver, Watts etc. etc.).

2.8 Misconceptions related to hydrostatic pressure

Language difficulties can lead to problems in acquiring science concepts, however difficulties in acquiring science concepts are not always related to language. This section looks at identified problems in learning the specific concept of hydrostatic pressure.

2.8.1 Previous research findings

In an investigation of various aspects of hydrostatic pressure, Clough and Driver (1986) found that the majority of 12 year old and sixteen year old children, had no problem with the relationship between the pressure and depth, (60% and 87% respectively). In contrast, when knowledge of the direction of pressure was tested, the figures for correct responses were only 13% and 31% respectively. In addition, over one third of the 87 children interviewed thought that downward pressure was greater than sideways pressure.

Kariotogloy et al. (1990) have identified the following models which school children were found to operate with when considering liquid pressure:

(a) packed crowd model - the pressure is greater in a narrow container than a wide container.

(b) pressing force model - there is confusion between pressure that prevails in a liquid and the pressing force invoked when in contact with the liquid. This model is expressed by attributing vector characteristics to pressure.

(c) liquidness model - pressure is seen as a property of the liquid. This can be seen from statements such as '... the pressure that water has ...' and the pressure that there is in the water'. These statements are often connected by suitable application of the relation $p = \rho gh$.

(d) the liquid as a pressure transmitter is thought to transmit pressure only in preferred directions, such as downwards.

The last point above (d), highlights difficulties the students have with Pascal's principle and also in determining the directions in which pressure acts in a liquid. The latter is partly addressed by Flint (1984) in an experiment in which use is made of spring balances hung upside down in water and tethered at the bottom by a rope. In this experiment force due to upward pressure can be measured by means of the spring balance. Since it is upside down, as the depth of water above the top position of the spring balance increases, so does the reading on the spring balance and vice versa. This experiment may be done with water and brine to show the effect of density on pressure. However this experiment only provides evidence for upward pressure.

Kuethe (1991) reports that even when students can recite the correct definition of pressure, misconceptions such as 'pressure is a form of energy' are displayed even at graduate level.

Confusion around hydrostatic pressure, took an unprecedented dimension when

Atkin (1989) incorrectly suggested that when three water jets are at different depths of water, it would be the middle one and not the bottom one which goes furthest from the container as reported by school books. This error can be avoided by taking note of variables which need to be controlled such as getting the holes to be the same distance from the frame of reference, using three containers instead of one (Ryan, 1991).

Although Atkin (op. cit.) made an incorrect claim, these misunderstandings are perpetuated in some school text books.

2.8.2 Misunderstandings perpetuated by textbooks

Some of these misunderstandings (reported in research articles) seem to originate from both the language used and the manner of presentation of the topic.

2.8.2.1 The language used in textbooks

Kariotogloy et al. (1990) point out that the language used in textbooks also provides obstacles for children in the understanding of the topic of pressure. Although these researchers do not suggest a solution, they point out that the textbooks alternately reflect pressure as a scaler and as a vector. This can be identified from expressions such as '... there is pressure...' and '... pressure is exerted...' respectively.

McClelland (1987) like Kariotogloy (op. cit.) found that the language used by authors shows that vector properties are wrongfully attributed to hyd[illegible]atic pressure and McClelland, (1991) suggests that this might be because 'the everyday meaning of pressure has invaded and usurped the scientific meaning'.

Reid (1991) reports that some textbooks cause problems for children by using a language which reinforces or creates misconceptions later. This is illustrated by a quote from a geography book 'the force of millions and millions (of molecular collisions) is called pressure' which fails to make a distinction between force and pressure.

2.8.2.2 The methodology of presenting the topic

The manner of presentation of the topic of pressure also tends to be confusing. Solid pressure is presented as a vector, some popular examples being the pressure caused by a woman wearing stiletto heels or that of a skier. However when a transition is made to liquid pressure as a scaler, this transition is not explained and the children are left confused and need to figure out how to bridge the gap (Kariotogloy et al. op. cit.). It is further noted that the surface of a liquid, is not explained, for example whether the surface is inside the liquid, or around its limit or if it can sustain force in any direction (Kariotogloy, et. al op. cit. p. 94).

It is suggested that a teaching strategy should be used which considers that conservation of a derived quantity, for example volume can only be achieved when conservation of its constituent quantities has been attained. It is suggested for example that breadth and length should be considered before area (Robertson and Richardson, 1975). This suggests that the concepts of 'force' and 'area' should be mastered before the concept of pressure is introduced.

2.8.2.3 A survey of school books on hydrostatic pressure

The following difficulties which include both conceptual problems and the approach to teaching the topic have been identified.

(a) Fourie et. al. (1988, p.26), simply define hydrostatic pressure as 'pressure in liquids' rather than 'pressure in stationary' liquids. It is believed that it is such inaccurate definitions which lead to situations where hydrodynamics is confused with hydrostatics (see notes taken in the control classes, section 8.4.1.2)

(b) Hydrostatic pressure at the bottom of a container can be calculated by simply dividing the weight of the water by the area of the bottom of the container (Brink and Jones, 1988).

It is incorrect to make this general statement because this will only work for containers of certain shapes.

It is however recognised that it is not unusual for people who have done some physics to have this difficulty when they have not been exposed to a situation where this division is not applicable (Arons, 1990).

(c) A cube in equilibrium in water will be balanced by two equal but opposite forces in the vertical plane (Brink and Jones, 1988).

This can only be true if the weight of the cube is ignored. However this is not mentioned.

(d) Often a cork is immersed in water and the fact that it rises is said to explain the fact that liquid exerts pressure in the upward direction (Van Dyke et. al., 1985, Fourie et. al. 1988 and Muller et. al., 1975).

The problem with this explanation is that it may lead the children to conclude that there is upward pressure only on an object which floats. Problems may exist for objects with a density equal to or greater than that of water.

(e) While Pascal's principle is correctly stated together with the condition that the liquid should be enclosed, an example given shows a liquid which is not enclosed (Van Dyke et. al. 1988).

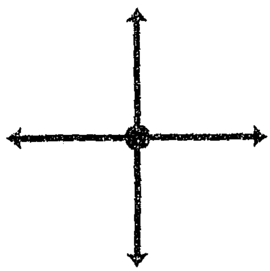
This may cause confusion in the children's minds when the significance of some term such as 'enclosed' is ignored.

(f) Some textbooks such as Van Dyke et. al., 1985, Fourie et. al. 1988 and Muller et. al., 1975) do not explain why a liquid exerts pressure in the sideways directions.

The explanation is given by only a few books namely that pressure in a liquid is due to the weight of the liquid and that it is because of the property of liquid molecules to slide over one another that this pressure is exerted in all directions.

At least one book used the direction of pressure in solids as a link to introducing pressure in different directions in liquids. This book (Fourie, et. al. (1988)) however reports that solid pressure is only downwards. It would appear from this statement that the author had in mind the pressure due to the weight of the solid. This may lead to problems where learners think solid pressure is downwards even if the force exerted is in any other direction. It could have been more meaningful to say that solid pressure is only in the direction of applied force.

Some diagrams such as the following are misleading.



The diagram is intended to illustrate that the pressure in liquids is exerted in all directions. It is noted that the arrows start from a clearly indicated point in the middle and extend outwards. This may be interpreted by the pupils to mean that the dot in the middle is an object and that the pressure acts away from the object. This would then introduce a new alternative conception.

The concept of hydrostatic pressure, seems to be problematic even to experts, for instance, how does one show whether hydrostatic pressure is a scaler or a vector?

2.8.3 Is hydrostatic pressure a vector or a scaler?

Much of the literature (Sommerfield 1950, Hudson and Nelson 1982, McClelland 1987, Kariotcgloy et al. 1990) reports that hydrostatic pressure is a scaler quantity. While most of the authors use phrases such as 'pressure acts' or 'pressure is exerted', McClelland and Kariotogloy take a radical stance, in pointing out that such expressions implicitly attribute vecıor properties to hydrostatic pressure. This claim is made despite the fact that the latter defines pressure as 'P'.

$$P = \lim_{A \to 0} \frac{F}{A}$$

where P is a vector.

It is a questionable explanation to say that because pressure is always acting perpendicular to a triangular portion of a liquid regardless its orientation, is sufficient proof that hydrostatic pressure at a point does not have any particular direction and is therefore a scaler as in Hudson and Nelson (1982). This same example and reasoning can be used with a conclusion that pressure in a liquid is exerted in all directions, thus implicitly saying it is a vector.

A second problem in trying to prove that pressure is a scaler by regarding area as a vector is unacceptable since the quotient of two vectors is not defined (Warren, 1979). The following mathematical trick is offered as a solution:

$$P = \frac{F}{A} = \frac{F.A}{A.A} = \frac{F.A}{A^2}$$

This attempt is however scoffed at by McClelland (op. cit.) who points out that the square of an area is difficult to visualise.

A more accommodating view says that hydrostatic pressure is a vector although its intensity is a scaler (Rouse and Howe, 1953). The scaler property is explained by the fact that the magnitude of the pressure at any point in a liquid is the same in all directions.

Since pressure is introduced in Standard 7 (before the children start learning about vectors) in South Africa, it is not clear whether the authors regard pressure as a vector or a scaler. However using a strict language such as in Kariotogloy et. al., op. cit.), it would seem that the South African textbooks also regard solid pressure as a vector but alternate between a vector and a scaler when it comes to hydrostatic pressure.

2.9 Summary of the theoretical positions regarding science learning

In general, misconceptions regarding scientific concepts have both a language and a conceptual dimension. These obviously apply to the specific case of hydrostatic pressure which is the focus of this study.

The following are some of the different perspectives reported in the literature regarding language problem.

(a) vernacular (here an African language) is advantageous as a medium of instruction
(b) English is advantageous as a medium of instruction
(c) the choice of medium of instruction is not an important contributing factor towards understanding.
(d) a mixed language approach can aid learning.

The following are some of the ideas regarding conceptual difficulties

(a) teaching strategies involving conceptual conflict will improve learning.
(b) textbooks perpetuate misconceptions.
(c) daily experiences perpetuate misconceptions.
(d) the language used may give rise to conceptual difficulties.

2.10 Appropriate research methodology

Several approaches including interviews and field notes were followed to uncover difficulties experienced by teachers and pupils in the concept area of hydrostatic pressure.

2.10.1 Conducting interviews

Arguably, anybody with the necessary skills can conduct an interview. However there are different opinions in this matter.

Cohen and Manion (1985) report that interviews as a research tool can range from formal, through less formal and finally informal, i.e. from a situation where set answers are asked and recorded on a schedule through a situation where the interviewer is at liberty to rephrase and even change the order of the questions to a situation where the interviewer follows a more casual approach and only raises questions during the course of a discussion.

The advantage of interviews is that the interviewer is available to clarify questions when the interviewee's interpretation is different from that intended (Cohen and Manion, 1985). In preparing for interviews, Cohen and Manion suggest that the following be borne in mind:

(a) educational level of the interviewees
(b) relationship which can be developed between the interviewer and the interviewee.
(c) the nature of the subject content.

The following are futher given as guidelines for the analysis of interviews.

(a) transcription of the interviews
(b) bracketing, i.e. one should be able to look at the interview situation as if one is not part of the situation.
(c) listen to the interview for sense as a whole

More specifically, Piaget (1973) suggests a technique that entails setting up a problem, making a hypothesis, adapting conditions to them and finally controlling each hypothesis by testing against the reaction stimulated in a conversation. In addition Piaget (op. cit.) and Posner and Gertzog (1982) suggest a flexible approach from the interviewer using the planned questions only as a guide and never following them rigidly.

The interviewing techniques used by Piaget and Gertzog are called "interviews about instances" and are discussed in detail in White and Gunstone (1992). According to White and Gunstone (op. cit.) there are variations of this interview strategy ranging from the use of diagram to the use of real objects as Piaget did. These objects and/or diagrams are used to probe the children 's construction of meaning based on questions posed regarding instances or non-instances of a concept. Follow up questions (such as 'why do you say that?' 'what will happen to the object?' etc.) are important to probe understanding during the interviews. The questions posed should depend on what the interviewee says. It is therefore impossible to determine the form and sequence of follow-up questions in advance although the interviewer should have a guideline in mind.

It would seem that for some researchers, it is not only the interviewing skills which count, but also who the interviewer is. Hewson (1982), for example had reservations with a person from the same cultural group as the interviewees conducting the interviews. In her study, she found that her Mosotho research assistant (a psychologist), often had a similar life view to the interviewees, and was therefore not suitable as an interviewer. On the other hand, Kamara and Easley (1977) reported advantages to having an interview carried out by a person sharing a culture with the interviewees. These include the ability to use the experiments to evoke familiar activities done at home as well as minimising anxieties invoked by the school language.

Once interviews or classroom sessions had been recorded, the tapes must be analysed.

2.10.2 Analysis of tapes

Analysis of tapes is a difficult task, different researchers have tried different techniques to make the task manageable, for example Muller (1986) and Rollnick (1988) introduced some conventions to show their experiences and action taken such as, inaudibility, field notes, code switching etc.

Erickson (1979) developed a method of analysing transcribed data to form a conceptual profile inventory. This method was developed further by Hewson (1982) and used by Rollnick (1988) among others.

Williams and Buseri (1988) developed an appraisal schedule to analyse teacher talk. The appraisal consisted of eighteen categories classified as follows:

(a) questions 1-3 'main structural features' in most lessons.

(b) questions 4 and 5 content related

(c) questions 6-9 'interactional features', eg. whether pupils are given enough time to think about a question posed before answering.

(d) questions 10 and 11 deal with judgement involving the negative and positive features. These involve among others repetitions and rephrasing.

Using the explanation appraisal schedule, Williams and Buseri (op. cit.) analysed twelve lessons given by Nigerian teachers. Following the analysis the lessons were divided into 'fast peddlers'(n = 5) and 'soft peddlers'(n = 70). The two groups had a few things in common eg. repetition and rephrasing where necessary. However in general the fast peddlers were found to be insensitive to pupil problems.

The above categories of questions show important features which can be looked for in a transcript, which can ultimately lead to classification of a lesson as good or bad. The above methodologes were taken into consideration when transcripts were analysed (chapter 4).

2.11 Questions arising from th literature

Two problems not necessarily unrelated emerge from the literature, namely, language and conceptual difficulties in science. It has emerged that pupils acquire these difficulties through one or more of the following

(a) their everyday language
(b) the language of science
(c) the language used in some school textbooks
(d) inaccurate subject content in some school textbooks
(e) improper presentation of the subject content
(f) failure by teachers and school books to take the children's everyday experiences into consideration.

Published research such as Sutton (1980), Howard (1989) and Johnstone and Cassels (1978) report an awareness of the problems associated with the learning of science in English even by first language speakers. In their study with English native speakers, Johnstone and Cassels (1978) have reported that by simply rephrasing questions or replacing words with more familiar ones understanding among the pupils is enhanced.

In an English second language situation other researchers such as Case (1968), Rollnick (1988), and Strevens (1971, 1976) report on problems associated with learning science in a second or a foreign language. Language therefore needs to be addressed for all population groups especially those learning in their second language.

In an African context, Rollnick (1988) found that communication is facilitated when a mixture of English and the students' vernacular is used and that students spontaneously switch to their vernacular in their discussions.

The second area is the extent of conceptual ficulties. A lot has already been written on misconceptions in the South African context, such as Stanton (1990), on D C circuits. Although some research on hydrostatic pressure has been done elsewhere, for example McClelland, (1987), none of the published literature encountered so far was done in the African context or looked at language effects as well as conceptual problems.

The constructivist theory would seem promising in helping pupils to make sense of the new content by considering their preknowledge (Hewson, 1982; Driver, 1989). In addition, the learners' culture needs to be taken into consideration, (Ogunniyi, 1986, Atwater, 1986). Teachers can then be made aware of what there is in the culture which can facilitate or inhibit the learning process. Such teachers will be in a position to identify culturally biased responses and react to these accordingly. Conflict strategies can be used to remediate pupils' learning problems.

It was found appropriate to identify and try to remediate conceptual difficulties related to hydrostatic pressure in the African context.

In order to assist practicing teachers, it was decided to address known conceptual and language difficulties directly in a new teaching package. The package would also serve as a guide on how previously unidentified misconceptions can be addressed.

3.0 CHAPTER THREE- Research design and modifications

3.1 Introduction

At the time of this research, conditions in schools in South Africa were problematic, and for this reason the original conceptualisation of this study included contingency plans for such things as pupil stay-aways and teacher chalk-downs. Although a relatively cost effective and efficient approach was used in the initial design of this research, the implementation problems made the original research design impossible.

This chapter first shows an overview of the research, then the original research design and finally the modifications effected due to the problems.

3.2 Overview of the research

Figure 3.1 shows the relationship between the activities and the chapters in which they are detailed.

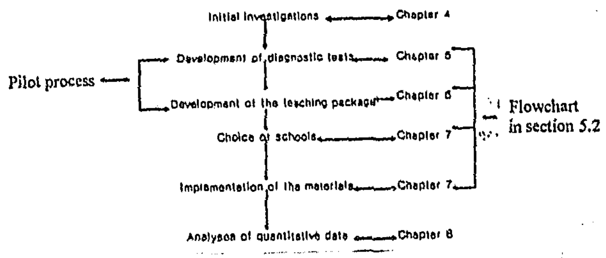


Figure 3.1: Different activities

The word 'diagnostic test' in figure 3.1 refers to either a conceptual test, a language test or a combination thereof.

Difficulties around the concept of pressure are not as well documented as those around force. It was therefore of interest to find out if pupils have difficulties in a concept which also needs an understanding of the concept of 'force'. Hydrostatic pressure was identified as such a concept.

The first phase of the study was concerned with preliminary investigations to identify possible language and conceptual strategies used in schools when teaching hydrostatic pressure with a view to using them as a starting point of this research.

In this phase the researcher sat in on classes where lessons on hydrostatic pressure were given by school teachers and tape recorded these lessons. The difficulties experienced by the teachers and pupils as well as the strategies used by the teachers were used to identify areas for further study.

The second phase was the design of a multiple choice test to identify pupil ideas about pressure. The process started with an open ended conceptual test which was administered to student teachers at a university to identify their ideas about hydrostatic pressure. Their responses were used to construct the first draft of a multiple choice conceptual test. Language questions were added to the test before being administered at an 'alternative' school as a prepilot.

The third phase started with the modifications of the tests. The test was split into separate conceptual and language tests. Existing language tests designed by Cassels and Johnstone (1985) were modified to construct new language questions. The conceptual test was validated with the College of Science students. The language tests were validated with English teachers whose vernacular was not English. The language tests and the conceptual test were then piloted at a school.

The fourth phase was the design of activities that addressed the same concepts as those used in the multiple choice test. An important feature of such activities was that they should be easily demonstrated in simple experiments for use in interviews.

These experiments were used in interviews with school children where the misconceptions were probed further for development of the teaching package. The interviews were tape recorded. In addition, strategies based on constructivism for remediating the misconceptions were tried out during the interviews.

The fifth phase was the design of a teaching package. Misconceptions which emerged in the fourth phase were incorporated in the design. This was followed by the writing of a teaching package.

The sixth phase was the validation of the teaching package and the identification of schools which would participate in the final implementation.

The seventh and final phase was implementation of the teaching package and its evaluation.

3.3 The original research design

3.3.1 Problem

Alternative (or mis-) conceptions have been reported widely for science learners, particularly in the Western context on such topics as force, for example Clement (1982). Despite the fact that most of these students were learning in their vernacular, language is often mentioned as one of the factors contributing towards the existence of alternative conceptions in science (sections 2.4 and 2.5). This indicates the problematic nature of the language of science (Merzyn, 1987), which may be exacerbated when children are learning in a second language. However whilst some research has been performed with English second language students very little has been conducted with students speaking a language of an African origin. In general there is dearth of research into children's ideas in Africa although some work has been done, for example Moji and Grayson (1997).

It appears that difficulties in science include both the understanding of concepts and of the language used to explain the concepts.

Part of this study therefore looks at language strategies and other teaching techniques that can be used to teach hydrostatic pressure to junior high school pupils.

3.3.2 Population and sample

The population was standard 7 (nominally 13 to 14 year old) English second language children in South Africa.

The intended main sample was six schools in Lebowa (previously a 'homeland' in South Africa), N = about 360. Three of these schools were experimental while the other three were the control schools. In addition in the pilot phase an experimental and a control school in Johannesburg, South Africa's largest city, were used.

The sample can be considered to be representative of the majority of the South African standard seven population even though all the pupils spoke Sepedi. This claim is supported by the fact that although black languages in South Africa can be divided into two main groups, namely the 'Sotho' and the 'Nguni', there is common ground between the grammar rules of languages across the two groups. In addition within the homeland itself, one gets pupils from other parts of the country (since many parents from the big cities often send their children there to boarding school). Also the type of schools used were representative of DET schools throughout the country.

3.3.3 Preliminary investigations

Ten schools were visited for the purpose of identifying language strategies used by the teachers as well as possible difficulties they might be having with their teaching strategies. In addition, 10 interviews with pupils and 4 with teachers were carried out to further probe issues which emerged during the lessons.

Student teachers studying to teach physical science were used to identify misconceptions in a pencil and paper test. These are students who graduated in science with a major in at least one of chemistry or physics. Because of the unrest situation in the country at the time, they were chosen as a convenience sample to be used in the development of the conceptual test.

An 'alternative school' was used as a prepilot to validate the test instrument.

3.3.4 The pilot study

There were two pilot schools. One school was an 'alternative school' (see section 1.2 for a description of alternative schools) in Johannesburg and the second was a state school in a rural area of the Northern Province of South Africa.

The rationale of using the two schools was that the children from the two situations may be very different because of a difference in their life styles and for that reason different difficulties may be uncovered.

Finally the *College of Science students were used also as a convenience sample for further pilot of the conceptual test.

3.3.5 Hypotheses

(a) There is no correlation between performance in language tests and performance in a science conceptual test on hydrostatic pressure.

(b) Scholastic achievement for learners will not be significantly different whether

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*The College of Science is a programme for students who can not be taken directly into the 3 year BSC degree at the University of the Witwatersrand because of inadequate academic background. They are enrolled in a special 2 year programme after which they join the 2nd year of the 3 year mainstream curriculum.

or not language issues are addressed in teaching.

(c) All teachers use the same language strategies in teaching science.

(d) Scholastic achievement for learners will not be different whether or not constructivist strategies are used in teaching.

(e) Achievement on the conceptual test will not differ significantly between children using intervention materials and those using conventional materials.

(f) The children's gender will not significantly affect the children's performance in science concepts relating to hydrostatic pressure.

(g) The age of children will not significantly affect their performance in science concepts relating to hydrostatic pressure.

(h) The socio economic status of parents will not affect the children's performance in science concepts relating to hydrostatic pressure.

3.3.6 Arrangements for using the schools

Permission to visit schools used in this phase (preliminary investigations) was obtained directly from the schools.

Permission to use the schools in both the pilot and the main research was formally obtained from the (then) Lebowa government.

The following steps were followed to obtain official permission to work in a school.

(a) A letter was written to the Lebowa government's liaison officer requesting permission to use schools in circuits mentioned in the letter.

(b) The government's liaison officer would then write letters to the various circuits informing them of the request and asking them to write similar letters to school principals in their circuits.

(c) The principals would then inform their science teachers to expect the researcher and to offer their cooperation.

(d) The government's liaison officer would write to the researcher informing him that permission had been granted.

(e) The researcher would then identify preferred schools in the circuits and ask the teachers involved if they were keen to work with him.

(f) Lastly when the relevant science teacher was keen to be involved, the researcher would confirm with the principal that the school would be involved. This combined 'bottom up' and 'top down' approach was taken to enhance cooperation with the teachers as well as sticking to the rules and regulations.

3.3.7 Workshop for school teachers

A teachers' workshop was held to

(a) validate the experimental materials and
(b) identify teachers who would like to participate in the research.
Details are discussed in section 5.6.

3.3.8 Statement of assumptions

The following assumptions were made:

(a) None of the teachers involved held misconceptions in the topic of pressure by the time the topic was taught - all the teachers involved received assistance from the researcher.

(b) All topics serving as prerequisites to the topic of pressure had been adequately learned by pupils - the teachers received their plan of work from the Department of Education and generally followed that sequence of teaching.

(c) Knowledge of the physical science content was comparable among the teachers - they had all received tuition in physical science up to standard 10.

3.3.9 Limitations of the study

Due to some factors beyond the researcher's control there were the following limitations to this study.

(a) Teachers in the control groups were allowed to use their own language strategies. It is therefore not easy to measure effects of language strategies as there was an overlap in language strategies used in the experimental and the control groups. However an attempt to measure this was made by sitting in different classes in both the experimental and the control groups to take detailed notes which included information about the teaching strategies.

(b) As a service the control teachers were given support in the making and use of low cost equipment where facilities were not adequate. This was done since the presence or absence of experimental work was not part of this study. The experimental group therefore did not enjoy any advantage over the control with the use of the low cost equipment.

(c) The socio-economic status of some parents may have been inaccurate because being unemployed, having lower educational level or earning a meagre salary does not necessarily mean a lower socio economic status, for instance the parent may have inherited some wealth. However in reality such instances are rare.

(d) Although no effort was spared to make teachers in the experimental and those in the control groups comparable, it should be noted that there will always be a human element which will make any two individuals different in their teaching approach. However it is hoped that by observing the lessons the researcher has identified the differences and made the final analysis with the differences in mind.

3.3.10 Expected problems and contingency measures

One of the major problems in South Africa at the time of the field work, was the fact that there was endemic confrontation between the government and people at grass roots level because of the policies of apartheid. These policies often attracted protests and mass action from various political organisations. Those problems then affected research related to education when field work coincided with stay-aways from schools by teachers or pupils.

The following problems had been anticipated because of the political climate in South Africa at the time of the research:

(a) Pupil boycott

(b) Teacher stay-away (chalk down)

As contingency measures, the following precautions were taken:

(a) arrangements were made with as many schools as possible. Permission had been obtained from the Lebowa government to use any school in the homeland. In addition, arrangements with other former 'homelands' had been made in an unlikely case of a boycott which would embrace the whole of Lebowa.

(b) the use of a very large sample initially in diagnostic tests.

With the above contingency measures, it was hoped that the problems that might arise would have minimal effects on the findings of this research.

3.3.11 Analysis of Results

Pearson's product moment was to be used to check for correlations between performance of the students and the following variables

(a) environment
(b) socio economic status
(c) gender

In addition a G. L. M. (General Linear Model) one way analysis of variance procedure followed by the least square t-test was performed. All these analyses were done with the use of the mainframe computer of the University of the Witwatersrand.

3.4 Problems during the implementation of the research design

Despite careful planning, which incorporated contingency measures in the research design, other unexpected problems emerged.

There were various problems which although not directly related to research, influenced the pace of research. As mentioned in section 3.3.10, some of these problems were expected while others were not.

The idea of using two pilot schools could not be implemented because of disturbances at the urban school. The school had financial problems and attendance was not regular. At one time there was a teacher 'chalk down' at the school because the teachers had not received their salaries for months.

Finally, the deciding factor with the urban school was the fact that the teacher felt that since she was far behind in her syllabus, she should concentrate on the biology part of general science. This was done at the expense of the physical science part. She gave as her reason the fact that she had started teaching a section of biology and that by the time she finishes, the yearly examination would be just around the corner.

In an attempt to cause as little disruption as possible to the teachers' work programmes, each school followed its usual program. As a result the topic of pressure was taught at different times at different schools. While different teachers have a different pace of teaching, this should not have caused a problem had the timing of the topic not sometimes coincided with stay-aways by teachers, pupils or both.

The consequence of the difference in the timing of teaching at different schools was that some schools taught the topic when there was a deadlock in negotiations between various political parties in South Africa or when there were problems at the school, resulting in disruptions of the teaching process.

A two day stay-away was called by one of the political organisations as a strategy to break the deadlock. Although the stay-away was officially on a Monday and Tuesday, most school children stayed away for the rest of the week. Consequently there was a week's break in teaching the topic. Some children were taught without any such break. Since this happened at a time when implementation of this package was being carried out, it is not known how this break affected the children's performance in the post test.

Circumstances moved from bad to worse when a teachers' union called a strike over the government's refusal to recognise them. By the end of the strike, the end of year examinations were due to start. As a result these schools could not be involved any longer. This further reduced the experimental schools by two. However since a contingency measure of involving as many children as possible had been taken, the number of children already involved in the experimental school was still comparable to the number of children in control schools.

There were also problems at individual schools such as a strike by school pupils at one of the schools during which some demands were put to the administration. Once these were met, the children, possibly feeling victorious, became uncontrollable. Classes were attended at will and the children came late to school. The teachers had lost control and could not do anything about it. As a result this school had to be replaced with another one.

However statistical analysis was performed to check if the current schools were still a valid sample (section 8.2.3) and it was concluded that the loss of two experimental schools as well as one control school would not invalidate the results of this research.

The next problem was entirely different. This was caused by the fact that a teachers' workshop was organised at short notice where teachers were to be briefed about an educational initiative about to be launched in their area. Again this lasted for a week. As a result science teaching in the target classes could not take place as the teachers were engaged in workshops related to the initiative.

Although there was reason to believe that the teachers were rendering as much cooperation as they possibly could, circumstances out of their control such as illness by either the teachers or their children sometimes inhibited the smooth running of the lessons. This happened for both experimental teachers resulting in absences from school.

It also emerged during the field work that teachers with the same academic qualifications and teaching experience were not necessarily comparable because:

(a) some were changing teaching subjects frequently

(b) others were teaching science only nominally - actual teaching being done by their friends with a better science background. For at least one of them, the understanding of being involved in research meant that the researcher had to do the teaching for her. When this could not be done, she was no longer willing to participate.

The above facts suggest that although all the teachers who eventually taught in the experimental and the control groups had similar academic qualifications as well as a comparable nominal length of unbroken service in the teaching of science, their effectiveness in teaching science was not always comparable. This suggested that in the analyses of results this had to be considered.

It should be noted that while some contingency measures were taken for disruptions at individual schools, by making arrangements with many schools, it was not possible to take contingency measures for the scope of problems which emerged. However, modifications to the original plan were done in the field in order to carry on.

3.5 Modifications to the original plans

Due to difficulties described in section 3.4, the original plans were modified as follows:

3.5.1 The main sample

All schools where insoluble problems were experienced (described in section 3.4) were replaced.

The final sample was four schools. These were one experimental (2 classes) (N = 390) and three control schools (one class each) (N = 234) in the rural areas. All four schools had poor laboratory facilities but even these were not fully utilised by teachers.

The schools were generally comparable in terms of teacher quality and teaching facilities available. However the control schools had a smaller pupil/teacher ratio (80:1) - half the ratio for the experimental school. The experimental school had a pupil/teacher ratio of 160:1 in standard 7, making it possibly one of the most populous in South Africa.

The experimental school had two classes while each of the control schools had only one class each.

One teacher was responsible for the teaching of general science in each class, bringing the total number of teachers involved to five. The total number of children involved was 624. However due to the absence of some pupils when the post-test was administered and some information missing in some of the questionnaires, the final analysis was based on a sample of 571.

3.5.2 The pilot study

The pilot study was a process carried out at different institutions. The test instruments were first piloted at an 'alternative school' followed by the College of Science and finally a rural school.

The final pilot study was only conducted at a rural school in Lebowa. However since there is some evidence that better performance on science related concepts is shown by urban children (Rutherford and Nkopodi, 1990) it was felt that the rural children would display all the possible problems with the test. In fact since the urban children are exposed to more English in their everyday lives, it was thought that the children in the urban school were likely to understand the instructions better and would therefore have fewer difficulties in understanding the worksheets than the children in the rural school.

Details of the test instruments, the result of the pilot study and the modification of instruments are given in chapter 5.

3.5.3 Analysis of Results

The results obtained in the final study were analysed quantitatively as well as qualitatively.

Quantitative analysis of results was started using calculations of discrimination and difficulty indices of the test instrument. The former was done to see if the construction of the test was good enough for the test to be used again. The latter was done to see if the test was at a level appropriate for the pupils.

Item analysis can be used when only one answer was correct in all the questions as is the case in this research, it was important to find out how the correct answer discriminated between the top 1/3 pupils from the bottom 1/3 pupils. The following formula (Crocker, 1974) was used to calculate the discrimination index D.

$$D = \frac{H-L}{N}$$

where H = sum of scores in the top one third group

L = sum of scores in the bottom one third group and

N = no. of pupils in one of the groups (the number is the same in both groups)

Crocker further suggests that discrimination indices below 0,3 are doubtful and that those above 0,3 suggest that the question was good enough to be used again. The following formula was used to calculate the facility indices:

$$R = \frac{n}{N} \times 100$$

where R = facility index

n = the number of pupils obtaining the correct answer

and N = the total number of pupils.

By definition, the higher the facility index the easier the question and vice versa.

After calculations of discrimination and facility indices a univariate normal plot was done to see if the mean scores on conceptual tests for different groups (experimental and control) were normally distributed. This was found to be the case.

Subsequently the analysis of results was done at different levels of complexity in the following order

(a) descriptive statistics

This entails basic comparison of the experimental and the control groups using the mean, percentage and standard deviations of the scores obtained.

In descriptive statistics, the following criteria were used to compare the experimental with the control groups.

(i) *for each group, scores obtained in the pre - and post-tests were compared.*

(ii) for each group the percentages giving the correct reason for the correct answer in the pre- and the post-tests were compared.

(iii) points (i) and (ii) were compared between different groups.

(iv) the numbers and percentages of children consistently obtaining the correct answer in both the pre -and the post-test and those changing to either the correct or incorrect responses were looked at.

A t-test on proportions was used to determine if the percentage of pupils obtaining the correct answer in the post-test was significantly different from the corresponding percentage in the pretest. The following formula was used:

$$Z = \frac{P_1 - P_2}{\sqrt{\frac{P_1(1 - P_1)}{N}}}$$

where $P_1 = a/N$ and $P_2 = b/N$

a and b are the numbers of those students obtaining the correct answer in the pre- and the post-test respectively and N is the number of pupils writing both the pre- and the post-test in that question.

The two percentages were regarded as significantly different at 0,05 level if the above ratio, $-2,32 < z < -1,645$ and significantly different at 0,01 level if $z < -2,32$.

Descriptive statistics were followed by a calculation of Pearson's product moment correlation.

(b) Pearson's product moment correlations

This entailed calculations of Pearson's product moment correlations for the dependant (post-test score) and the independent (pretest score) variables.

Finally covariate analysis of the results was carried out.

(c) analysis of covariance (ancova)

Kerlinger and Pedhazur (1973) state that covariate analysis is a form of multiple regression, that is, an analysis which studies the effects of several independent variables on a dependant variable. Covariate analysis and analysis of variance are two forms of multiple regression, however covariate analysis, unlike the analysis of variance, corrects an effect of a chosen concomitant variable (the covariate).

Since it was realised that the different groups might be starting with different levels of preknowledge (the covariate), it was essential to use a statistical package that would compare groups which are usually not comparable. As the ancova model met this criterion (Pedhazur, 1992) it was used (This model, unlike the anova, takes covariates into consideration). The ancova model was used to study effects of the following variables on pupil achievement:

(a) age
(b) gender
(c) parental socio economic status.

In the light of the fact that teachers with the same qualification and nominal teaching experience did not necessarily have the same abilities, it was felt that to have a more comprehensive analysis, their teaching abilities should not be assumed to be comparable. This made it necessary to look at the teaching styles of various teachers (section 8.4.1) so that the analysis could be done qualitatively as well.

A modification was therefore planned for the analysis of results to include teaching strategies. In order to achieve this, the researcher sat in on most of the lessons, took notes and recorded the lessons.

The teaching strategies, and subject competence identified in the notes and lesson transcripts were then related to the scores obtained by various groups in both the conceptual answers and the reasons given for the correct answers.

Finally the quantitative and qualitative analysis were used to supplement each other and provide a more comprehensive picture.

3.6 Chapter summary

This chapter discussed a planned research design together with circumstances which led to the forced modification of the design as well as the modified design.

The original research design was considered suitable for the South African situation. Since it was planned for third world conditions, a geographical area forming part of the educationally most disadvantaged in South Africa was chosen. Both schools and teachers in the experimental and the control schools were chosen according to a certain criteria in an effort to make them comparable (section 5.6).

In the research design the volatile political climate of the day in South Africa was considered. Contingency measures, including initially taking a larger sample than needed, were taken in case of possible disruption of normal schooling at some of the schools. Although this was of help, the disruptions took unprecedented dimension, thus making it impossible for the planned contingency measures to be sufficient. The researcher, under pressure of time had to modify some of the planned activities and part of the sample in the field. Finally it was a convenience sample that was used. Quantitative methods were used to check the suitability of the data collected for this study. It was found that despite the forced changes the data collected remained suitable for this study. Analyses of the results was also modified to suit the data collected.

4.0 CHAPTER FOUR-Qualitative data capture - lesson audits and interviews

4.1 Introduction

The literature survey (chapter 2) has shown an awareness by many researchers of the language difficulties that might influence learning in science lessons although none of the research encountered has reported findings about difficulties derived from observation of classroom lessons.

This motivated the classroom observations followed by interviews documented in this study. *Both were audiotape recorded.*

Both the lessons and the interviews were important to identify conceptual difficulties (misconceptions). In addition the lessons revealed teaching strategies used by the teachers while the interviews enabled the researcher to probe issues which were not clear in the lessons due to fact that often pupils talked very little in class.

Misconceptions which have been identified will be categorised. However, it should be noted that the categories are so intertwined that the reader, or a different researcher may categorise them differently.

Language and conceptual problems have been identified from both teachers and pupils. The identification was done in three groupings. The groupings were:

(a) English 1st language teacher with English 1st language pupils (N = 30)
(b) English 1st language teacher with English 2nd language pupils and (N = 36)
(c) English 2nd language teacher with English 2nd language pupils (N = 52)

The language groupings have been identified for purposes which may be of interest for future research. However for this research only the strategies used and the difficulties identified are important. No claim is made regarding the connection between the strategies used and the groupings.

The lesson transcripts are reported first and then the interviews. Common ground between the two is then identified.

4.2 Recording of the lessons

As mentioned in section 3.2 (chapter 3), the first phase of the main field work involved identifying possible language and conceptual difficulties and teaching strategies. To do this, ten lessons were recorded in Johannesburg, Kwa-Ndebele and Lebowa. Kwa-Ndebele and Lebowa were two of South Africa's 'homelands'. The classroom settings of the lessons where the teachers were second language speakers were similar, as described in section 1.2. However the English first language speaking teachers had smaller classes (30 and 36 children in a class), the schools were well equipped and the teachers highly qualified (both had a university degree).

Since, in general, teachers spoke loudly while the pupils spoke softly, it was decided to put the tape recorder in the middle of the classroom. This enabled the tape recorder to record with nearly equal efficiency utterances from all corners of the class. However teachers were always the most audible despite them usually being the furthest from the tape recorder.

All lessons were transcribed verbatim by the researcher.

4.3 Methodology of transcribing taped material

There were issues which were considered in all transcripts.

4.3.1 Protocol

The protocol for transcribing was the following:

(a) Repetitions were typed fully.

(b) Statements where articles were not properly used were underlined.

(c) Code switching was indicated in bold. At times code switching would be found between three languages such as English, Zulu and Sotho. In that case it would be indicated in brackets whether an utterance was made in Zulu or Sotho. Where an English word was modified to sound Sotho or Zulu, the word was typed in English and underlined.

(d) Incomplete sentences were indicated by '...'. This would precede or follow a statement depending on the position of the omission.

(e) It was indicated in brackets whether part or a whole sentence was inaudible or unintelligible. An utterance was said to be unintelligible when the talking was loud enough to be heard but impossible to comprehend or transcribe what was being said.

(f) There were some utterances which could not be translated into English. These have been written as they were said An example is 'hmm'. This is used to mean 'yes'(a more formal yes in Sepedi (N. Sotho) is 'ee'). The word can also be used as a question, 'hmm?' which means 'what'? or 'I beg your pardon?' In both cases there are more formal and better accepted ways of saying the same thing. Finally the word may be used as 'hmmm....'(saying the last 'm' longer). This means the same as the English 'umh...' That is, in this way it is used to 'buy time' while the speaker is still thinking about what to say. Finally the word can be repeated in quick succession such as in 'hmm, hmm'. In this way it means 'no'. These utterances are more commonly found in lessons than interviews. Interpretation of the audiotapes can therefore only be done efficiently by a person fluent in the vernacular used in the session being taped.

The following symbols were used in the transcripts to identify the speakers.

P(s) - Pupil(s)

T - Teacher

T+P(s) - Teacher and pupil(s) speaking at the same time. Often the teacher started a sentence which was then completed by a pupil or pupils.

4.3.2 Difficulties in transcription

Difficulties experienced in transcription related to both the language used and the logistics of transcribing.

In one of the lessons code switching was done between English and Ndebele. The researcher, although having a working knowledge of Ndebele, was not competent enough in Ndebele to do the translation. Assistance was therefore sought from a science student at a technikon who was fluent in English, Sepedi and Ndebele. The assistant in the presence of the researcher translated Ndebele utterances to Sepedi. The researcher would also listen to an Ndebele utterance and compare it with its English translation. Agreement on the most appropriate English translation would then be reached. In this way the accuracy of the translations could be checked.

Even with language problems sorted out, transcribing the lessons proved to be an enormous task and very time consuming, without an assistant. However the difficulty of transcribing the exact words without rephrasing, omissions and additions of words not said was realised. It was therefore decided not to use an assistant for transcribing. It was felt that the assistant was likely to be more impatient than the researcher (who was aware that any errors were likely to affect his findings). However, despite this, the researcher being an English second language speaker himself possibly added syllables attributable to second language speakers to words made by first language speakers. Since the researcher was conscious of this, it is felt that the number of such incidents would be minimal. A final check on random transcripts was made by an English 1st language speaker. Indeed some errors were found and the transcription was repeated.

The procedure followed initially was to write the transcripts by hand then copy these into the computer. This lengthy process increased potential errors because each step could have its own errors. In order to minimise the chance of errors and the time required in checking the text, the hand writing step was omitted and instead head phones were used and typing into the computer done directly from the tapes.

Because the children sometimes spoke very faintly, the tape was inaudible in places. It was often necessary to listen to the same tape several times.

Group interviews were more difficult to transcribe than individual interviews because it was not always easy to distinguish between different speakers.

4.3.3 Focus for analysis

Taking account of the methodologies (discussed in chapter 2) used by Muller (1986), Hewson (1982) and Williams and Buseri (1988), the present study analysed the transcripts using:

(a) the accuracy of the content

(c) misconceptions displayed by teachers and pupils

(c) repetitions, rephrasing and any other strategy to clarify language used. The strategies identified in the different transcripts were then categorised.

Although there were differences in different lessons, it was found that in general, the teachers were expository, and pupils asked very few questions, usually when they were at a complete loss. The questions from pupils have thus something in common with results obtained by Sinclair and Coulthard (1975) who reported that in communication between the teacher and pupils there are unstated rules which govern exchanges regarding who must speak and what to speak. Indeed Hornsey and Horsfield (1982) in their study where pupil controlled groups were tape recorded and transcripts analysed, found that, in the absence of a teacher, pupils freely ask a lot of questions some of which show a measure of creativity whereas this was not the case in the teacher's presence.

Since both the language and the conceptual difficulties were of interest, it was important to analyse the transcripts for both of these. The language difficulties included vocabulary, articles and the use of the passive voice.

Because of the speed of writing and the concentration required from the listener, it was not always possible to identify these difficulties by merely sitting in the lessons, but was easier to identify these difficulties from the transcripts.

Transcripts are numbered by line only if at least one numbered line is referred to in the discussion.

Both the lessons and the interviews revealed language and conceptual difficulties. This showed that the problem of language was not only restricted to the pupils, but applied also to teachers whose mother tongue is not English and to some extent to teachers whose vernacular is English.

4.4 Analysis of language issues

The various aspects of language problems showed that there were difficulties associated with both the language of science and everyday language used in science.

4.4.1 The language of science

Some of the literature relating to the language of science was discussed in section 2.5. Here evidence from the lessons supports the discussion.

4.4.1.1 Technical words in science

Technical words are words used in science but normally not in everyday language. One of those words is 'static'.

During one of the taped lessons a pupil asked what the suffix 'static' in the word 'hydrostatic' meant. The teacher asked assistance from the researcher who only remarked that the word meant 'stationary'. The teacher then explained that the suffix meant 'that which has potential energy'.

T: We did that last day. We did explain this. What did static mean last day when we were doing static electricity? What does static mean?
P: Static electricity.
T: ... is the energy when we talk about electricity. What do we mean by static electricity? (whispering) *Energy stored. Can you help us sir?*

I: Static means stationary.
T: Something that is at its potential stage.
P: (inaudible)
T: Static means something that has potential. It has energy, but this energy is at rest.

P: A battery has potential energy, eh... the cell.

T: The energy that is stored in the cell is potential energy, because once you make use of that then the energy becomes kinetic. So instead of using pure water that is we are going to use water that is ...'

This is an error likely to be made by someone who knows about the connection between the position of an object relative to a frame of reference and its potential energy. This example shows that one can acquire a misconception simply because one does not understand the meaning of a word.

It should be noted that the teacher only revealed the misconception after she had been told that the word 'static' meant 'stationary'. This means the word 'hydrostatic' did not make sense to her as 'stationary water'. Instead instances of stationary objects were associated with potential energy, it was thought the use of the word means that we are talking of the potential energy of such an object.

The possibility of the word stationary not having been understood seems likely.

4.4.1.2 The use of words which condense many ideas

Words in science are used in a manner that conveys a lot of meaning to an expert.

One teacher displayed a misconception related to Pascal's principle caused by misunderstanding the word 'uniform'. He experienced difficulties with the fact that the pressure applied was transmitted uniformly in all directions throughout the liquid. He told the pupils that the word 'uniformly' means the same. Therefore he claimed that the statement says 'pressure will be the same throughout the liquid'. This he explained can not be true because the pressure increases with depth.

The extract below illustrates the discussion between the teacher and pupils that led to the conclusion that there was an error in the textbook.

T: *If you check in that book. Open up your books, there on page 25. Pressure in a liquid is transmitted uniformly i.e the same throughout the liquid. They say this is known as Pascal's principle.*

The problem with the word 'uniform' is the fact that it carries a lot of information. This word means

(a) 'Unchanging in form, quality and quantity' (Collins English Dictionary)

(b) continuous (not discrete) in the context in which it is used in Pascal's principle.

There is no exact translation of this word in any of the South African black languages. The teacher's attempt to make sense of this word in terms of his vernacular could therefore not have succeeded.

Whilst the teacher had problems with Pascal's principle, he too constructed a meaningful interpretation (to him) of Pascal's principle to suit his preconceptions. The following excerpt illustrates a modification to the principle to suit him.

T: ... pressure. So it can only be correct to say pressure is exerted equally ... right? or is spread equally at what?

P:(inaudible)

T: ... at the same ...

Ps: level

T: We can say same level or same depth. Are you okay?

Ps: Yes

This misinterpretation led the teacher to think that there was an error in the book,

(which is sometimes the case - see section 2.8.2)

T: There is an omission there that is ... that is left out. Pressure can not be the same in all directions. What about the depth? ... because I have just talked about the depth. The importance of.... We said just now the deeper the hole the greater the .... (by a 'deep hole' the teacher refers to a hole which has been made at a greater depth of water)

Ps: ... pressure

T: So according to this book ... I think it was just a mistake somewhere somehow, alright?

P: No

T: Oh you say no, yes ... ?

P: (inaudible)

T: Someone will correct me thanks. I have made a mistake, the book is always right. The book is always right.

Ps: No

In this example the teacher has understood well the fact that the pressure increases with depth. However he misinterpreted the principle due to misunderstanding of the language used in the text book. He sarcastically showed the students that the book was 'wrong'.

The teacher was confident enough to venture that this principle should be amended to read that 'the pressure will be transmitted uniformly at the same level', that is, Pascal's principle can only apply at the same depth because the pressure is the same at the same depth. This is shown below.

T: ... so you must always (inaudible) *whenever you are going to write this principle please, always include the same depth.*

Ps: (unintelligible)

T: In this holes here (holes at different levels), *pressure is not the same, that is what I am trying to point out to you. Now this principle only applies to holes or pressure at the same .... , at the same height. Are you with me?*
Ps: Yes

It would appear that failure to understand the word 'transmitted' was coupled with the use of the passive voice.

4.4.1.3 The use of the passive voice

The use of the passive voice creates an unstated qualifier which leads to different interpretations of the same statement. This can be seen in the statement of Pascal's principle' as stated here: 'Pressure exerted in an enclosed liquid is transmitted undiminished to all parts of the liquid'.

This statement does not explicitly say that the extra pressure is transmitted. The transcript below shows how the teacher confused the pressure due to the weight of the liquid with the extra pressure.

T:... if it is there the depth, i.e the deeper you go the greater the ....
Ps: .... pressure
T: ... the greater the pressure so with that respect pressure is not the same, pressure is not exerted equally the same, alright? But then at the same level, for instance equal holes here, then pressure at this height or at this level in the liquid is the .....
Ps: ...same
T: ... then this principle is correct, it holds. Are you with me?
Ps: Yes

The transcript above shows that the teacher thought that it is the pressure caused by the weight of the water which is transmitted all through the liquid. The teacher went on in a bid to convince a more hesitant child with the following words:

T: *Does this principle exclude this case? Does it specifically exclude this case whereby there is different pressure at different levels? I mean these holes are at different levels.*

In summary Pascal's principle poses many problems related to language. Pascal's principle is often stated as 'pressure exerted on an enclosed liquid is transmitted uniformly throughout the liquid and in all directions.'

Looking closely at the principle, the following language problems can be identified.

(a) Confusion between the concepts 'the same' and 'uniform'.

It is possible to confuse the words without confusing the concepts, but in this case it would seem that the concepts are also confused. It is possible that the absence of the concept of 'uniform' in the teacher's vernacular may be a contributing factor.

(b) The meaning of the word 'transmit'.

This word which means to move something from point 'a' to point 'b' without the facilitator of motion changing position also involves a concept which does not exist in the vernacular.

(c) What it means to say pressure is 'transmitted equally'.

(d) The identification of the pressure which is transmitted.

There is an unstated assumption in the statement that the expert and the novice refer to the same pressure. This situation may bring difficulties to anybody regardless of their mother tongue and English competence.

(e) Direction in which the pressure is transmitted.

It seems the main problem was the use of words in a single statement which brought together several ideas at the same time, possibly as well as the use of the passive voice. There were also some minor probiems associated with individual words.

Similar difficulties were identified from four teachers in interviews. These four teachers misunderstood the words 'transmitted equally' used in the statement of Pascal's principle and took it to mean that the pressure was divided equally at all points in the liquid.

In all cases the teachers had no problem with the word 'equally' but they became confused when the word was used to bring across the science concept.

The teachers had the view that when an additional pressure is exerted on an enclosed liquid, that pressure is divided equally to all points that were being looked at in the liquid. They said the words 'transmitted equally' used in the textbook gave them that impression.

Asked what would happen if the number of such points were increased, one teacher said she realised that she had a misconception because as the number of such points increases, ultimately there would be 'no pressure left to be transmitted'.

4.4.1.4 The use of the language of mathematics

The language of mathematics is often taken for granted in science teaching which may result in failure to understand the science concept.

Some of the words used in the language of mathematics are not easy for pupils. For example in one lesson given by a first language speaker to second language speakers, the pupils were asked to calculate an area given that the length is 1 m and the breadth is 1/2 m using the formula length times breadth. One pupil responded by saying the answer was 'one and half'. The answer only became c'ear to the pupil when he was asked what a half of one rand was, to which the pupil responded it was 50 c. This shows that the pupil maybe had a problem with the word 'times'.

The discussion follows below:

T: Length is ...?
Ps: One.
T: Breath is ...?
Ps: Half.
T: Okay what is length times breadth then?
P: One and half.
T: One times half is one and half? What is half of one rand?
P: 50c
Ps: (laughter)

Even in higher standards the word 'times' remains problematic although on a different level. As an example, no school graduate in science is expected to obtain an incorrect answer to the problem : 'What is 1 times 1/2'. However anecdotal evidence shows that if they are asked the question : What is the difference between 1 times 1/2 and 1/2 times 1, some may obtain incorrect answers.

The answer to the problem is known but the procedure which the problem requires is not known, yet the procedure is imbedded in the word 'times'. It is clear that the children did not ur[illegible] they needed to obtain a half of 1. It can be seen that the word does not just require a final answer but actually specifies the method of getting to the answer. In fact even the word 'difference' may be confusing to a mathematician who may interpret the question to mean a subtraction problem.

The above has shown that not only can a word become a hindrance to communication between two people, it can also become a hindrance to understanding new concepts.

4.4.2 Everday language used in science

Difficulties uncovered in this section support the discussion around language in science (section 2.4).

4.4.2.1 Incorrect use of articles

Problems in communicating with children who can not use articles properly have been reported elsewhere, for example Case (1968) (section 2.4). This appears to be true even with teachers. However it would seem that this confusion only happens if just one party knows how to use the article properly. The following transcript illustrates the problem.

T: Right what is the other word that we can use for the water that comes out from the hole? The water will ...? The water will ... ? ... leak. The water will leak from the packet. Now let's look at this. One of you must come and pour water. We have a tin with a hole. That's for water. Come this side Tando. Just fill it up. (pupil starts pouring water) *So water leaks at the ...*
T+Ps: bottom.

In this case, both the teacher and pupils have problems with the correct use of articles. Therefore none of them finds a difference of meaning due to an incorrect use of an article, instead communication remains smooth. Interpretation of a statement among people who can not use articles properly relies almost entirely on the context in which the statement is made rather than the article.

The use of the article 'the' by the teacher suggests that reference was made to a word she had told them before. However none of the children knew the word. Asked later the teacher confirmed that she was teaching the topic for the first time and that the word had never been mentioned before in her class. In this case meaning is obtained by recognising the context of the statement rather than the proper use of the article. An English first language speaker would use the word 'another'.

Although articles did not seem to be a problem in communication between teachers and pupils, they do seem to have been in the interpretation of Pascal's principle by some teachers (section 4.4.1.2). The principle is stated as 'If pressure is exerted on an enclosed liquid, then the pressure is transmitted uniformly throughout the liquid and in all directions'. It is possible that failure to distinguish between the pressure transmitted and the pressure due to the weight of the liquid may have been a consequence of an inability to understand the article 'the'. This article says that the pressure just mentioned (not any other) is being transmitted.

4.4.2.2 Familiar words used in a scientific context

It happens that words used in everyday life are sometimes encountered in a science context where the meanings may be more precise or even totally different. This is frequently the case for English first language speakers although it is often true for second language speakers as well depending on their proficiency in English. The following sections look at the situations in the different language groupings.

English first language speakers

The first language teacher with first language pupils did not escape language problems. The next paragraph shows a 'loose' usage of language by the teacher.

T: Pascal studied Pressure in liquids and he discovered that if you exert a force on any fluid, any liquid not necessarily water, in a closed container, that force is equally and evenly distributed throughout the liquid and in all directions, and Pascal named *this little discovery of his Pascal's principle and Pascal's principle can be stated like this: 'If pressure is applied to a liquid, the pressure is transmitted equally in all directions and to all parts of the fluid'.*

Pascal's principle is accurately regurgitated yet the word 'force' is used instead of the word 'pressure' when her own words were used. This may at its worst mean that she had that misconception herself and may lead pupils to confuse the concepts of pressure and force. This is due to the indiscriminate use of the two words in everyday life.

From the transcript below it can be seen that the concepts are not confused by the teacher, yet this was done in one case when her own words were used.

T: No. 12. Explain the difference between force and pressure. Yes at the back.
P: Pressure is the amount of force exerted on a unit area and force is a push or a pull.
T: Right force is a push or a pull and pressure depends on force and area. That is the main crucial difference.

It would appear that errors in the usage of scientific language do not necessarily mean the language user has a misconception. Problems of a different nature were encountered with second language speakers.

<u>English second language speakers</u>

This research has shown that meeting an everyday word in a science context and problems associated with it, are not restricted to first language speakers. This became evident when some students switched to their vernacular to explain that potassium permanganate is 'makgonatsohle' in Sotho.

Later questions based on the code switching were asked. The question was whether potassium permanganate could be used to cure coughing. The following is an extract from the lesson:

1 *P: What is potassium permanganate?*

2 *T: Potassium permanganate?*

3 *Ps: Makgonatsohle.*

4 *T: We often say it is 'makgonatsohle'. Why?*

5 *Ps:* (unintelligible)

6 *P: That means if I cough I can use permanganate.*

7 *T: No* (Start arguing for and against)

This suggestion (line 6) was a direct consequence of the child's understanding of potassium permanganate's Sotho name. The word means 'that which can do anything'. This name originates from the fact that traditionally many black people in South Africa have used potassium permanganate for different purposes, such as to

(a) cure various poultry disease by putting a few grains in water to be taken by poultry.

(b) drive away snakes by sprinkling potassium permanganate solution around the yard.

(c) treat wounds by washing with the solution.

(d) make illegal backyard abortions by drinking the solution during pregnancy.

Presently its use in these ways is no longer widespread (if at all).

The above discussion shows how problematic words that are not science specific can be. Johnstone and Cassels (1985) found this to be the case with words used in everyday life. This problem can now be extended to some words not used in everyday life (by a pupil). The fact that the word 'makgonatsohle' is a coined word in his vernacular, allowed him to break the word into two parts 'makgona -' (that which can do) and 'tsohle' (anything). In this case the parts of the word are used in everyday life. A similar result has been found with the Dutch language where the word 'koolstof' (Carbon) was interpreted to mean a gas, either harmless or poisonous (Bouma and Brandt, 1990). The children reportedly broke the word into 'kool' (coal) and 'stof' (powder). Some children therefore interpreted this as 'coal powder' while others interpreted this as 'gas'.

The similarity is that both Johnstone and Cassels's research and this research have revealed that if an everyday meaning can be attached to a word, then that meaning tends to be confusing when the word is encountered in a science context.

<u>4.4.2.3 Possible unexplained language problems</u>

Some of the language problems encountered are difficult to explain. However tentative explanations are suggested.

<u>Words that sound alike</u>

It seems words that sound alike may cause confusion as the example below illustrates.

1 *T: Gregory, what does enclose mean?*

2 *P: Enclose?*

3 *T: Yes.*

4 *P: Is ..., is to come together.*

5 *T: Do you say it is to come together?*

6 *P: Yes.*

7 *T: Treasure what do you say? What is to enclose?*

8 *P:* (inaudible)

9 *T: Enclose*

10*P: incompressible* (inaudible)

The above extract shows a typical problem brought by words which sound alike. The word 'enclose' sounds much like 'close together'. This is shown by the child who thought the word 'enclose' meant 'to come together' (line 4).

The second child confuses the words 'enclose' and 'incompressible'. It is possible the child's answer may have been affected by the near similarity of the first three letters of each word.

Difficulties with thinking in three dimensions

The following excerpt shows what seems to be a combination of problems with both language and spatial thinking.

T: What is to enclose?

P: Something put together in something.

T: Something put together in something. Something put together in something. Okay.

It seems that the pupil had an idea of the correct answer, however it would appear that the problem was expressing the answer in words. The use of the word 'something' in different contexts in one sentence is confusing. This sentence in better English would be 'One thing put inside another'. The pupil's explanation is a direct translation from the vernacular which the English first language teacher either did not pick up or was uncertain about as shown by his repetition of the phrase.

This child's answer is not entirely incorrect. It may be regarded as correct in a two dimensional space as figure 4.1 shows.

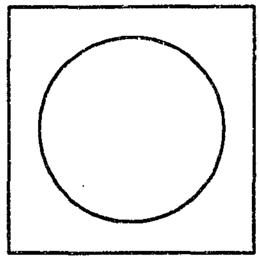


Figure 4.1: Enclosed circle in two dimensions

The circle is enclosed by the rectangle in a two dimensional space. This is not necessarily correct in three dimensions. In a three dimensional space the circle remains unenclosed, viewed from above. The rectangle will have to be extended to form a box in order to enclose the circle as shown in figure 4.2.

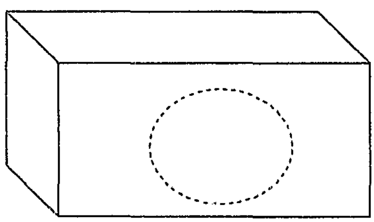


Figure 4.2: Enclosed circle in three dimensions

The above situation raises the question of whether the real problem in explaining what the word 'enclose' means is a problem related to spatial thinking. Since the child's age was about thirteen, this might indicate the child's stage of development has not reached the formal operational (following Piaget's stage theory).

The above discussion has shown that language difficulties can lead to conceptual difficulties.

Language difficulties do not always affect the understanding of science concepts directly. In some cases problems in science arise due to problems in mathematics which in turn may arise because of language difficulties.

Difficulties with Pascal's principle have shown that the understanding of individual words is not enough to understand the whole. The understanding of individual words is merely a step towards understanding the interrelationship between different words from which the understanding of the concept being conveyed may follow. Other misconceptions were perpetuated by school books (section 2.8.2).

4.5 Language strategies used in the lessons

Several language strategies were observed in the classrooms. These included simplified language, hand signals, local examples and code switching. There was an overlap between the strategies used by people of different language groupings in the recorded lessons.

The discussion of taped lessons from each of the language groupings includes both language issues and general teaching strategies because the two cannot always be separated.

It is however possible that some actions which might be identified as 'strategies' may not be seen as such by the teachers (who can not always explain their actions). Individual teaching strategies will be discussed first and then some of these will be synthesised to form models of addressing language difficulties.

4.5.1 Individual language strategies

These are the observed strategies reported in isolation as they were used.

Unusual use of language in science

An English native speaker defined pressure as 'the amount of force exerted per unit area'(see the extract below).

T: Pressure is the amount of force exerted per unit area. Did you all get that as your answer?
P: yes ma'am
T: 1b. In what unit is pressure measured?
P: inaudible.
T: Pascals Right number two . Why is it easier to cut with a sharp knife than a blunt one? Hands up please. Why is it easier to cut with a sharp knife than a blunt one?

Since first (and second) language speakers at higher levels of education do not speak of 'the amount of force' but 'force', it is possible that this was done to make it easy for pupils to appreciate the fact that pressure refers to the concentration of force on a particular area. The following situation encountered with another teacher would seem to reinforce this suggestion

T: What does the amount of pressure exerted depend on? ...the amount of pressure exerted what does it depend on?
P: The amount of area and the amount of force.
T: Exactly, size of area and the magnitude of the force.

It can be seen that once the children have obtained the correct answer using the unusual word, the teacher then resorts to the more usual word used in science.

However it was not put explicitly to the children that was the language which should be used in the future.

There are situations where it is questionable whether the language used was at the children's level as in the following question asked by an English native speaker to pupils of her own language group.

T: What is the equivalent unit of the Pascal? ... the equivalent unit of the Pascal. Remember we did it on the board with a formula ... force ... here at the back Newton what?

P: (inaudible)

T: Yes at the back.

P: Newton squared.

T: Almost. Try again.

P: Newton per square metre.

T: Newton per square metre ... force per area. How do you convert Pascals to Kilopascals?

The 'equivalent' unit of the Pascal was asked in the question above. The construction of the sentence in which the word 'equivalent' is used, is not normally used in this way in everyday communication. This sentence could have been rephrased as 'What is a unit equivalent to a Pascal?' The word 'convert' is not normally used in everyday speech and needs to be addressed. However since the children speak English as their mother tongue, it might have been that both the sentence construction and this word were not problematic.

Rephrasing

Rephrasin of a statement was noticed in a first language situation as shown below.

T: What does the amount of pressure exerted depend on? ...the amount of pressure exerted what does it depend on?

The passive voice was used in both phrasings above. It is therefore not clear if the rephrasing made the statement any clearer.

Use of familiar examples

This strategy was identified in both the first and the second language situation.

The children were asked to give relevant examples themselves which shows an awareness of the need to use familiar examples on the part of the teacher. This is shown in the following excerpt.

T: Right, who can think of an example in everyday life where Pascal's principle is used, in a closed container. Yes?
P: Hydraulic lifts.
T: What is hydraulic lifts.
P: They use it for a car at a garc e to lift up a car for...?
T: Right, hydraulic lifts. Anything else?
P: Hydraulic brakes in a car.
T: Hydraulic brakes in a car. Anything else?
P: Pistons.

It would appear that in some situations as below, the use of familiar examples was combined with code switching.

T: When a car brakes .... (omission) (Ndebele) ***'Do you know brake fluid?'***
Ps: Yes/No'

The transcripts above show that more than one language strategy can be used at the same time. Multilingualism may thus be advantageous.

Repetition

Repetition of a sentence with very little rephrasing was noticed in a second language situation. This is shown below:

T: Right, give me examples at home, for instance if you can, what happens to the water in the bucket with a hole at its bottom? What happens to it if you pour water?
P: The water comes out from that hole.
T: The water comes out from the ...?
T+Ps: hole.

In the transcript above, the first step in addressing language was to ask the pupils to describe what would happen if water was in a bucket that has a hole at the bottom. The sentence was then repeated. When one child gave an answer, the rest of the class were made to repeat it.

Although it is difficult to explain the reason for the strategy above, it is possible that the children being English second language speakers could make sense of some words only after the teachers has repeated them. The reason for getting the children to repeat the words may be to get them used to pronouncing the English words. It may also be a way of getting them to memorise the words.

Use of drawings

This was identified in an English first language situation.

T: Pistons. Let us just do a quick diagram of a piston. Does everyone know what a piston is?
Ps: Yes, Yes.
T: Who is going to tell me what a piston is? Hands up please. Yes at the back.
P: ... pumping petrol through the carburettor.
T: Right, in other words, it is a closed container that looks like this ..., with a plunger in the top and that plunger can be above in line, in other words, it can compress the fluid that is in this closed container.

Despite the fact that the answer was a unanimous 'yes', she not only went further to ask the question, but went to the extent of drawing a piston on the board.

Use of synonyms

This strategy was identified in a second language situation.

This was done by asking the children to give one word for the description they had given as below.

T: Right what is the other word that we can use for the water that comes out from the hole? The water will ...? The water will ... ? ... leak. The water will leak from the bucket. Now let's look at this. One of you must come and pour water. We have a tin with a hole. That's for water. Come this side Tando. Just fill it up. (pupil starts pouring water) *So water leaks at the ...*
T+Ps: bottom'.

When it was clear that the new word was known, a synonym was introduced. In the extract below, the word is 'leak' and the synonym is 'squirt'.

T: ... because there is a hole, right? ... and then what happens at home if you have not closed tightly the tap? (pause) *What happens if the tap is not tightly closed? You Thabiso.*

P: The water leaks out.

T: The water squirts, neh?

Ps: Yes

Here it is not mentioned that it is another word for leak. However by not disagreeing with the children when the word 'leak' is used and at the same time using the word 'squirt' where the children had used the word 'leak' the children are taught a new word. It is however possible that this strategy may confuse the children because for English first language speakers, the word 'squirt' is associated with high pressure while the word 'leak' is associated with low pressure.

Use of antonyms

This strategy was identified where the teacher was a first language speaker and the pupils were second language speakers.

The following extract shows how the word 'compress' was consciously addressed. Apparently it was found difficult to explain the word 'incompressible' directly. The strategy was therefore to consider 'compress' and then show that the two words have opposite meanings.

The teacher was trying to show the connection between the surface area and the magnitude of fo..e in Pascal's principle.

T: If you try to push water up you can not squeeze it. If you take for instance a gas syringe, you know there is an injection that they use (inaudible).

Ps: Yes.

T: You all had an injection neh?

Ps: Yes.

T: ... you do not put anything in it, and you squeeze, what happens to the air?

P: ... squash up.

T: It will squash up?

P: Yes.

T: ... and if you take off your finger?

P: goes up.

T: It will go up quickly, it will not even make any noise. So we say we have compressed the air, alright? We have compressed the air ... and if we take a small syringe we can push it down until it gets to this position here. That air is compressed. So we can compress the air. Can we say the same with water?

P: No

T: ... compress the water. Will it change?

Ps: No.

T: ... so what do we say? Water is ...?

Ps: incompressible.

T: ... incompressible, so air can be compressed but water is incompressible. (speaks slowly as he writes on the board) *...air can be compressed but water is incompressible. Water cannot be compressed, incompressible and there are lots of things like this. Whenever something is incompressible* (inaudible) *you can push it down and there is something that stays constant throughout the water. What is it that stays constant throughout the water?'*

It can be seen in the above extract of the teacher's lesson that a familiar situation (of an injection) was used to explain the word 'compress'. Even this was not assumed. This can be seen when the question is posed 'you all had an injection neh?' Only when the answer is affirmative is the example of the injection used. This proves to be familiar enough.

The meaning of the word 'incompressible' was introduced by contrasting the two words. This was done by contrasting properties of water with properties of air. This can be seen in lines 21-25. Since the original problem was to address the word 'incompressible', it would appear that it was easier to address the word rather than its negation.

Building up the vocabulary

The meaning of a new word is reinforced by using the word in a question and immediately following up the question with a second question in which the known word 'leak' is used. This strategy was identified in a second language situation.

T: The water squirts. Why is the water squirting? Why? Why is the water leaking from a container which is having the holes at the bottom? Why?

The transcript below shows how the technical word 'hydro' was introduced.

T+Ps: Pressure of liquids. Right.
T: Pressure in liquids is sometimes called ...?
T+Ps: Hydrostatic pressure.
T: Hydrostatic pressure (writes on the board). What do we mean by the prefix hydro ...?
P1: water.
P2: liquid.
T: Li ..., hydro means ...
T+P: liquid. Right'.

It can be seen that this word was introduced in a similar manner to the word 'squirt'. This means first words known to the children were used and then the new word was introduced to let the children know that a better alternative exists.

Use of analogies

This strategy was identified where the teacher was a first language speaker and the pupils were second language speakers.
This was the case when the word 'enclose' was encountered.

The excerpt below shows how the analogy was used.

T: You can think about a jail. If a person is held shackled in a jail, that person can not get out. If you put water in a tin, the water can not get out. If I just put water onto the table the water flows all over the show, right? The water is not in a jail. You have got to have something like here, the water can not get out, can not escape. It has got bars and metals. The water has been imprisoned we can say. Enclose, it is incapable to do something. Just like the water on a table in a jug. It is enclosed in a jug. So enclosed means taking pain of some kind or another. That is what enclose means.

In explaining that the word meant completely surrounded an analogy of a prisoner was made. It is said the prisoner can not escape because he is completely surrounded by the walls. In the same way if pressure is applied onto a liquid that is not enclosed it will escape and splash all over.

Use of context in which the word is used

In order to consolidate the meaning of the word 'enclose' an illustration of the significance of its meaning in Pascal's principle was given.

T: Why do we say that is because if the water is just around here ... I want you to think what will happen. I have a table and it has got water on top and I come along here and I drop a book onto the table. What is going to happen to the water?
Ps: It is going to spill.
T: It is gonna splash in all directions. Do you think the pressure in the water is going to be equal in all directions?
Ps: No.
T: No, that is why we say that it is only when the water is closed in a system like this or a jug that we can talk of pressure being distributed throughout the liquid or the fluid... is transmitted in other words we are looking at ...Anybody knows what transmitted means?'

The above discussion shows that the liquid had to be enclosed for the pressure to be equal in all directions.

A drawback of an analogy can be seen in the above explanation. It is an oversight on the teacher's part to say water in a jug is enclosed. This is not the case unless the jug is covered.

Looking at the concept at the microscopic level

A question that has been asked in the transcript below requires insight into Pascal's principle.

T: I have got water in here, it is a liquid, I have got a piston on that side and I have *got another piston on this side over here. If I push it here, the force on this side over here is it going to be the same?*

Ps: No.

T: Why not?

P: (inaudible)

T: ... because is ...?

P1: ... small area.

P2: ... small area inside.

T: Why should the area make any difference to the force?

Instead of regurgitation of the principle, the children are asked to look at the effect of area on force. This shows an attempt on the part of the teacher to get the children to understand the principle in a way that they can relate to everyday life.

Getting the children to consciously think about meanings of words

In the following example, the teacher first found out what the children understood by a particular word before helping them. This can be seen when the words 'enclose ' and 'transmit' were first encountered.

The following question was asked.

T: Now we have got a lot of words which are not perhaps understandable at this stage. There is a word there, enclose. What does the word enclose mean? Anybody got any idea? Although in general there was awareness of language problems, the following situations identified from a second language teacher highlighted an incident where language problems were not adequately addressed.

T: Okay, water will not be transmitted. You know the word transmit, neh? Water won't be transmitted so effectively here you can see it is (inaudible)...' (the teacher just assumed a positive response to a rhetorical question).

Use of code switching

While code switching has its own merits, it also has its drawbacks. It would appear that code switching can facilitate learning but it seems to be true that code switching can sometimes be a hindrance to learning. Incidents of both scenarios were found.

The following is a discussion of instances in which code switching was used as an aid.

(a) Remonstrating with the pupils as in the following example.

T: Don't say no, how is it going to be? (pause) **(Speaks Ndebele).** ***'Let one explain to me because I know you like to speak in chorus'.***

By using the vernacular, the seriousness of the remonstration is emphasised. The use of a second language might give an impression of 'window dressing', i.e. one can express one's emotions better in one's vernacular.

(b) To make the meaning of an English word clear as shown below.

1 *T: Pressure in liquids* ...(inaudible). *Is it transmitted* (pause) *uniformly throughout*
2 *the liquid? Is this correct?*
3 *Ps:* (mixed answers) *Yes/No*
4 *T:* **(Ndebele) 'Is this uniform/the same?'**
5 *Ps:* (Most say) *No*
6 *T:* (inaudible) ... *Yes* ...
7 *P: The holes are not the same.*
8 *T: sorry* ...
9 *P: The holes.*

10 *T: The holes are not the same?*

11 *P: Yes*

12 *T: Which holes?*

13 *P:* (inaudible)

It seems code switching was used when it was thought that pupils' answers were influenced by misinterpretation of the English word 'uniform' as shown by the fact that the number of children saying 'no' was about the same as the number of children saying 'yes' when the question was posed in English but those saying 'no became a majority when the question was repeated in the vernacular.

Whilst the children had reservations about the teacher's explanation, their natural assumption as children, namely that the teacher knows best led one child to come out with an explanation that justifies the teacher's answer. This however seems to suggest that the child was attempting to construct meaning from the discrepancy between the explanation given by the teacher and what he observed from the experiment.

The child said what he thought the book said could not happen because the holes were not the same (size) (line 7). Their interpretation was that the water jets from two holes would go the same distance from the containers even if the holes were situated at different levels in the container.

It is possible that this child might have been trying to justify that answer simply because that was an interpretation given to the statement of Pascal's principle as it appeared in their textbooks.

Whilst the above exchange was all in English, the significance of the child's explanation is the fact that the explanation only came after code switching was used.

(c) To invite the students to participate as below

The teacher was trying to get the children to give examples of situations where Pascal's principle was applied. When the children could not respond the vernacular was used.

T: ... where else do we use it? Okay (Ndebele) ***'look the one sitting there'****... water exerts pressure in this fashion neh.* **(Ndebele)** ***'I say'*** *where do we use it in everyday life?* (Ndebele) ***'Have you ever seen'*** *an instance in everyday life where this is relevant? Okay let us have a look into that one but I do not want to spoil you.* (Ndebele) ***'That water in the tank'*** *why do we have this water coming out very strongly from the tap.*
P: What?

Although the attempt was unsuccessful, the teacher obviously felt that if the pupils had met an example then they were more likely to articulate it in their mother tongue.

(d) Invitation to the children to use their vernacular

The vernacular was used when it was clear that the children were not responding as below.

T: Yes ... (inaudible). *Say something. You do not want to. Okay, look some of you today do not want to speak because you are made to think* (inaudible) *... it is a must. You know you are made to understand you must use English but if you ...you have a right to express yourself with your mother tongue no problem.* **(Ndebele)** ***'Explain in Zulu or Sepedi'.***

The above extract shows that the pupils were not participating as actively on this day as they normally would have done on other days. The teacher's utterance implies that usually a lot more vernacular is used and suggests that by thinking that they have to use English their capability to participate is reduced. It is not known whether the presence of the researcher discouraged some of their usual activities such as the use of the vernacular.

Code switching is used as an indirect invitation to the children to do the same.

(e) Code switching was used for emphasis as in the example below

Double code switching (English - Ndebele - Sotho) is used either to increase the level of emphasis or to reach children who speak either Sotho or Ndebele but cannot speak the other African language.

Ps: same

T: same ... is transmitted uniformly, yah.

No **(Ndebele)** ***'look the statement says'*** *this statement says neh, Listen to the principle, the statement says pressure is exerted right?* **(Ndebele)** ***'pressure throughout this liquid is the same'*** **(Sotho)** ***,'...is the same all over',*** *so is that correct? That is what I want to know?*

<u>Drawbacks of code switching</u>

The word pressure does not exist in Ndebele or any South African black language. This is why the prefix 'e' is attached to the word 'pressure' to make it sound Ndebele. Similar strategies are used in other black languages as well when a word is adopted.

P: (inaudible)

T: You do not understand the information Victor. **(Ndebele)** ***'Do you see this, the statement which says'*** *pressure in liquids is transmitted. '<u>pressure</u>' in liquids* (Ndebele)*'* ***'you know '*** *is spread uniformly neh. In other words* (Ndebele) ***'equally all over here, you see'*** *throughout this. I mean throughout the whole liquid. Throughout this whole liquid* ***'epressure'*** *is the what? ... is the ...*

The above extract shows a drawback of code switching. In Ndebele and Sepedi (possibly in other South African black languages as well) the words 'uniform' and 'equal' are represented by only one word. Translating the word 'uniform' to the vernacular may reinforce the misconception, depending on the interpretation attached. The misconceptions is that the statement 'pressure is transmitted uniformly throughout the liquid' means that the 'pressure is the same throughout the liquid.'

Th difference between the two words is subtle. 'The same' is referring to discrete quantities or objects, while 'uniform' is referring to a continuous process.

The implication of the above is that a lot more care should be taken when code switching, i.e the translation should reflect the exact meaning. This can be done in this case by contrasting the meanings of 'the same' and 'uniform'.

A close look at lessons given by two of the teachers was used to construct models of language strategies.

4.5.2 Models of language strategies

It can be seen that the language strategies were used in the following order by one native English speaking teacher with black English second language speaking school children.

(a) The first step was to identify the children's understanding of a particular word (section 4.5.1) (p. 94 - Getting the children to consciously think about meanings of words).

(b) If their understanding was incorrect (section 4.5.1), the next step would be to identify familiar (to children) instances in which that word can be used (p 89-91, line 6 - 'Use of antonyms').

(c) The next step was to identify instances where the opposite of that word would hold (pages 89-91, lines 6 to 16 - 'Use of antonyms').

(d) Lastly the instances and the non instances of the word would be contrasted to consolidate the meaning of the word (p 89-91, lines 21 to 25 - 'Use of antonyms').

Another teacher (both teacher and pupils were English second language speakers) used strategies which are summarised below. These show a second model.

(a) Firstly she would find out if the children knew about a particular situation, eg. water in a bucket with a hole at the bottom (p. 86-87 - 'Use of familiar examples').

(b) Secondly she would find out if a word that describes the situation was known (pp. 88-89 - 'Use of synonyms').

(c) Thirdly if that word was not known, they would be told what the word was (pp. 88-89 - 'Use of synonyms').

(d) If they already knew a different word eg. leak, they would just be told a preferred word eg. 'squirt' without dismissing the other word (p. 88-89 - 'Use of synonyms').

While different strategies were used by different teachers, these were two teachers for whom a logical sequence in their strategies could be identified and thus be used to form models.

It can be noted that the first model used instances of the word's application while the second model uses only theoretical explanations. Further in the first model, words with opposite meanings to the word being addressed would be used while the second model, only synonyms would be used.

4.5.3 A summary of the teachers' strategies

Not all strategies could fit into a model. However, there were many different strategies.

The teachers were generally aware of language difficulties and had their own language strategies to try to cope with the situation.

Many different language strategies were used by teachers, depending on the situation. In all cases where the children are second language learners, vocabulary emerged as a problem. Words such as 'leak', 'squirt', 'enclose' and 'compress' were new to the children.

Teachers of different language groupings were aware of language problems and made an effort to address them. However there were instances were language was not sufficiently well addressed, for example in one second language situation, the children could not explain the meaning of the word 'transmit' but the teacher went on to use the word without explaining its meaning.

Although there were differences and similarities in the strategies used by different teachers, it has not been possible to link competency in language strategies to language groupings. However it would appear that in a multilingual situation, it is advantageous to be able to speak the learners' vernacular. This gives the teachers an additional language strategy, i.e. 'the use of the vernacular'. Differences and similarities in language strategies observed can be summarised in figure 4.3.

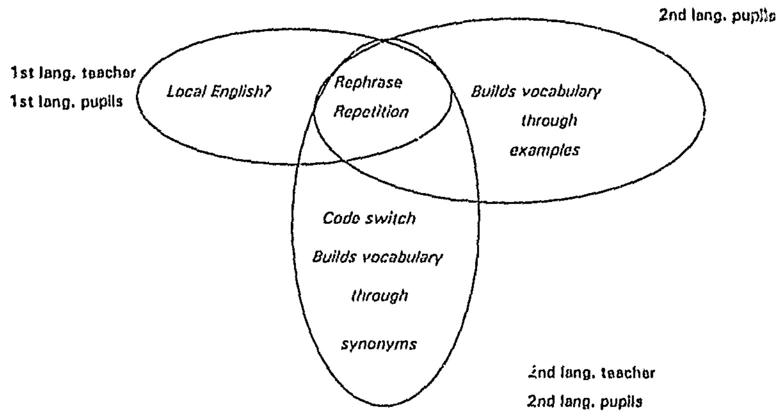


Figure 4.3: Strategies used in different language groupings

It has emerged that specific language strategies are both necessary and used in all language groupings - the extent of need being determined by both language and concept competence. One needs, therefore, to be aware of difficulties which might be peculiar to a particular learning situation. There is however a connection between the language strategies used and the difficulties encountered by pupils across different language groupings.

4.6 Interviews with students

Interviews were conducted to

(a) confirm initial misconceptions identified using paper and pencil tests

(b) uncover further misconceptions and/or

(c) language difficulties.

(d) validate experiments for use in materials/teaching package.

4.6.1 Rationale

The interviews were considered important because:

(a) teachers did most of the talking during the lessons and pupils' answers were often very short, for example either 'yes' or 'no'.

(b) it was anticipated that some pupils may not answer a conceptual test with sufficient detail to reveal their misconceptions while in other cases it might be difficult to understand their written responses because of their poor English.

(c) in interviews an interviewer may use different strategies to probe the pupils' answers to his/her satisfaction and give children a greater chance of asking questions when they do not understand.

4.6.2 Description of the interviewees

All the students had been or still were attending schools in Lebowa. One had a PTD (Primary Teachers's Diploma)

The following groupings of pupils were interviewed

Table 4.1: Information about the interviewees

Name	Age	Educ	SES	Home	Gender
A	13	std7	3	u	m
B	12	std7	3	u	m
C	12	std7	2	u	m
D*	27	std9	6	r	m
E*	20	std8	6	r	m
F*	16	std7	6	r	m
G	22	PTD	3	r	m
H**	12	std6	3	u	f
I**	13	std6	4	u	f
J**	14	std7	4	u	m
K**	15	std8	4	u	m
T***	17	std7	5	u	m
U***	15	std7	4	u	m
V***	15	std7	4	u	m

u - urban

r - rural

m - male

f - female

* - Interviewed together in a combination individual and group interview

** - Interviewed together in a group interview

*** - Interviewed together in a group interview

SES - Socio economic status: the smaller the number, the higher the socio economic status. Details of how SES was determined are discussed elsewhere (Nkopodi, 1989). SES ranges from 1 (highest) to 7 (lowest) - see appendix E.

PTD - primary teachers' diploma: A post school teachers' diploma in which the academic content (at the time of this research) was not higher than that offered at primary schools where the graduates were going to teach.

Table 4.1 shows that the majority of the interviewees were under the age of 16. The inclusion of older interviewees was not inappropriate because there is evidence that misconceptions transcend age, for example misconceptions on hydrostatic pressure were identified with post school students (section 5.3).

4.6.3 Circumstances under which the interviews were conducted

As the majority of the interviewees were minors, permission to carry out the interviews was granted by their parents.

All interviews were carried out in the interviewees homes. It was considered that the home environment would be more relaxing than the school environment.

It has been reported that the use of the school language may evoke anxieties encountered at school (Kamara and Easley, 1977). The interviewees were therefore given the choice of using English, their vernacular or a mixture of the two. The mixture was the most often used. Where language difficulties were identified, these were addressed by the interviewer to enhance mutual understanding (section 4.6.5).

Although reservations about having the interviewer and interviewee sharing the same culture have been reported elsewhere (Hewson, 1982), in this case the contrary was felt to be appropriate because the researcher was both a physicist and a second language speaker. He would therefore be in a position to look at the problem from both perspectives.

4.6.4 Different types of interview as data collecting techniques

Three methodologies of interviews were used namely:

(a) An individual interview involving only two people, the interviewer and the interviewee.

(b) A group interview where several interviewees are involved. The interviewer directs a question at the group and anyone of them is free to answer.

(c) a combination of individual and group interviews.
This starts with an interview of one child in the absence of others. A second interviewee is then invited and interviewed in the presence of the first interviewee. He/She is then informed of the first interviewee's response. The two interviewees would then be asked to comment on each other's responses. The process was then repeated for the chosen number of interviewees. This was found useful to uncover uncertainties in the answers given since the interviewees were allowed to change their minds if they thought one interviewee had given a better explanation than their own.

Methodology 'c' of interviewing has not been encountered in the literature or from any other source. The researcher felt that this approach would overcome the shortcomings of the other two techniques. Unlike in an individual interview, an idea mentioned by one interviewee would serve to invoke ideas in the next interviewee. The interviewees get an opportunity to give their original answers as is the case in an individual interview and also an opportunity of shaping their opinions from other interviewee's responses as is the case in a group interview.

It is also possible that methodology 'b' may be particularly problematic with interviewees who are aware that there is large difference in their abilities. The weaker interviewee will be inclined to change his or her view in the presence of the more gifted interviewees. In that case, methodology 'c' could offer a better alternative.

The interviewees were happy to participate in all three types of interviews across age and standard (standards 6 to 8 and age 12 to 27) contrary to Rollnick (1988) who found that students were unwilling to speak as individuals. Her study was done in Swaziland, a neighbouring country with a similar culture. This variation may possibly be attributed to the fact that the Swazi interviewees were adults and concerned about their pride in the event of incorrect answers. In addition, the interviews were not carried out in their homes.

4.6.5 How the interviews were conducted

The interviews centred around a practical activity. This included looking at the distances at which the water jets hit the floor and considered

(a) the effects of the width (cross sectional area), and shape of a container, and the depth and total volume of water.
(b) the effect of additional pressure (Pascal's principle).

The following protocol was used in the interviews.

(a) Equipment or apparatus (i.e. container with water) would be produced.
(b) The interviewee would be told what experiment was going to be done.
(c) The interviewee would be asked to predict what would happen and why.
(d) The experiment would be done.
(e) The interviewee would then be questioned about any discrepancy (ies) between their predictions and observations.

Although at the time of these interviews the writings of White and Gunstone (1994) had not been encountered, it turned out that the POE (Predict, Observe and Explain) strategy they used was similar to the strategy described above. An advantage of a prediction is the fact that contrary to conventional questioning where interviewees are only required to explain observed phenomena, POE requires the interviewees to predict outcomes of an experiment which makes it more likely that the interviewee will apply what he or she considers both important and relevant to explain the prediction (White and Gunstone, op. cit.). It is therefore clear that this strategy has merits which benefitted this study.

The interviews are reported according to concepts being investigated. The conceptual difficulties are discussed first and then the language difficulties.

<u>The relationship between the pressure and depth</u>

In this experiment a container with two holes, one above the other was used. Water was poured into the container and the interviewee was asked to predict the distance at which the water jets hit the floor.

This interview was carried out first with a twelve year old boy (A) and then a thirteen year old boy (B).

<u>*The prediction phase*</u>

This child (A) thought the water jet from a hole which is at a higher position will hit the floor further from the container than the water jet from a hole which is at a lower position. This is shown in the following extract from the interview.

1 *I: Now, which one will hit the floor further than the other?* (pause) *I mean if you*
2 *look at the distances from the container at which the water hits the floor ...*
3 *P: hmm.*
4 *I: ... and you measure the distances. Distance from the hole at the bottom and the*
5 *distance from the hole at the top. Which distance will be longer?*
6 *P: The top one.*

7 *I: The distance by err, the hole at the top?*

8 *P: hmm.*

9 *I: Why?*

10 *P: ... because it is high.*

11 *I: What do you think the reason is?*

12 *P: err, the height of the holes.*

13 *I: Okay. So in other words you say the water from this hole* (I points at the bottom
14 hole*) will hit the ground further.*

15 *P: No, at the top.*

16 *I: Oh, sorry at the top, yah. Okay, let us fill this with water and see what happens.* (I fills the container with water*).*

<u>The 'proving' phase</u>

The experiment was performed and the misconception suggested by the prediction was illustrated to the child as shown in the transcript below.

18 *I: Look carefully and see what happens. So what happens?* (pause*). Which one hits*
19 *the floor further than the other?*

20 *P:* (surprised) *Hmm the lower one.*

21 *I: Now can you see that what you said earlier was not true?*
P: Yes.

<u>Explanation of the observation</u>

Once the prediction was proved incorrect, the child explained that he had neglected the effect of air in the water. This is shown in the transcript below.

23 *I: ... so what do you think the reason is?*

24 *P: ... another force.*

I: another force in which one?

P: The lower one.

I: Okay, force by what? (pause*) What causes that force?*

P: Hmm..., air particles.

I: Air particles? Okay where are the air particles?

P: ... in the bubbles.

I: Are the air bubbles having greater force at the top or are they having greater force at the bottom?

P: At the bottom.

I: Why?

P: ... the water at the bottom hits further than the water at the top.

The child attributed his incorrect prediction to the height of the holes. The rationale was that the higher the position of the hole, the further its water jet would go. However when the experiment proved otherwise, a completely different line of reasoning was followed, i.e air particles in the water affects the pressure.

The second interviewee (B) of about the same age also attributed the pressure to the air, but only the air outside the water as the following transcript shows. This child had introduced the word 'pressure', hence that word could be used.

I: Okay. What is pressure?

P: Pressure is the unit per err..., force per unit area.

I: force per unit area. Okay, now if you have water in here where do you get the force from?

P: If you ...?

I: If you have water in here what is it that provides the force.

P: The pressure provides the force.

I: I mean the pressure of what? (pause*) You say the pressure is force per unit area is n't it?*

10 *P: Yes.*

11 *I: Now what is the force. Where do you get the force? That force.* (pause*) if you*
12 *have water in here.*

13 *P: There is pressure which exists upwards and again downwards.*

14 *I: Is n't it that you said pressure is force per unit area. Now, what is that force.*
15 *Where do you get the force from*

16 *P: ... from the air.*

17 *I: ... from the air? Err.., how does the air give us that force?*

18 *P:* (No response*)*

1[illegible] *: Okay you have water in here. Are you talking about the air that is in the water*
20 *or are you talking about the air that is outside the water?*

21 *P: The air that exists around here.*

22 *I: Is it in the water that air?*

23 *P: Not inside the water but outside.*

This child had already been taught about the concept of pressure and was therefore attempting to relate the air to hydrostatic pressure. It seems that the child ignored hydrostatic pressure and only attributed the pressure effects to external air pressure (lines 21-22).

The *language used*

The language used in these interviews was very explicit especially when difficulties with communications were recognised.

Communication between the interviewer and the interviewees (A and B) in lines 1-5 suggest some misunderstanding of the question. This is resolved by rephrasing the question in line 5 for interviewee (A). The child could then answer the question with understanding in line 6.

When it seems the subject (A) could not understand because of the word 'further' (line 1), it was explained by describing how one could determine if one water jet hit the floor further than the other.

It can also be seen that the child (A) correctly used the word 'top' (line 6), the interviewer double checked this with the child (A) (line 7) to find out if they were referring to the same thing.

In the case of interviewee (B) the interviewer tried to resolve the problem by rephrasing the question in the form of direct translation from the vernacular (line 6). When this strategy also did not work, further rephrasing of the question were done in lines 8, 11-12 and 14-15.

Another child (C) had a similar prediction but a different explanation of the observed phenomenon as shown below.

I: Now if I make another hole above this one, which one will have water hitting the ground further?
P: This one (pointing at the top hole).
I: Why do you think so?
P: ... because this one is higher than that.
I: Let us pour in some water to see what happens. (I poured the water as the pupil watches).
What do you think now?
P: (Scratches his head)

Explaining the discrepancy

In explaining the discrepancy, the child implicitly attributed the observation made to the weight of the water at the top. The transcript below shows that.

I: Can you think of a reason why the water did not come out the way you thought?
P: The water is being squeezed here at the bottom.
I: What is squeezing the water?
P: The water at the top is squeezing the water at the bottom.

The child's answer was not entirely incorrect. It would appear that he had some idea of the concept of the effect of weight due to the water at the top, however the child may have a different interpretation, for example that water is compressible. This can be inferred from the word 'squeeze'.

Lastly the connection between the pressure and depth was investigated in a group interview.

A correct answer is given although it can not be directly translated into a physics concept by the interviewees. (The interviewees, P1, P2, and P3 can be identified from table 4.1 as T, U and V respectively). In this interview the children's vernacular was chosen by consensus as the language to be used.

I: Okay, let us do this: I have a tin here, it has two holes, one is above and the other is below. Now if I pour water in here, which of the holes will throw water further from the tin than the other?
P1: The bottom one.
P2: The bottom one.
P3: The top one.
I: Okay, you say the top one and you say the bottom one.

Why do you say it is the top one?

P3: It is because this one is lower. It will only pour out water near.

I: What is it that makes the water to hit the floor near (the container)

P1: Isn't that the water get there quickly and gets out quickly.

I: Okay, what do you say?

P2: I say the water at the top pushes the water at the bottom and that is why the water hits the floor far.

I: Okay, you say the water above pushes the water below.

P1: Yes.

I: Alright. Let us see. (I performs the experiment)

Which hole?

P1: The bottom hole.

P3: The bottom hole.

I: The bottom hole throws the water further.

P2: In my opinion they are the same.

I: Okay, let me pour again. How do you see it now?

P1, P2 & P3: The bottom one.

I: Now is there a science concept you can use to explain this?

(No response)

I: What have you done in science so far?

P2 & P3: We have not started with science yet.

I: So what do you say?

P1: The water at the top pushes down on the water below?

It can be seen that while P2 could explain the observed phenomenon correctly (line 13), he could not recognise that as a science concept. On the other hand, P1 could predict the observed phenomena although his explanations seemed incorrect. It should however be noted that this child, although speaking in the vernacular, may have had difficulties trying to explain that the water jet leaves the hole with greater velocity (line 11). His answer, literally taken, seems to suggest that this water jet is the first to leave the hole. However he too changes to a more correct answer (line 30).

P3 having initially suggested that the water jet from the top hole would go further from the container than the bottom jet, possibly found it difficult to accept defeat, unless if he had difficulty with visual observations.

The discussion above shows that the interviewer should be ready to handle situations where the interviewees have a different interpretations of instructions and observed phenomena to their own (interviewers).

<u>The relationship between the pressure and the size of the hole</u>

This is an example of a situation where the interviewee 's attention was not focused on what was being investigated but on a completely different aspect. In this case the focus was on the size of the holes rather than the levels at which the holes were made. This however was found informative as well. The child was asked to predict the hole from which the water jet would go furthest from the container

<u>Prediction</u>

Asked to compare the distances from the water jets made at the same level in a narrow and a wide container, the interviewee (A) said that would depend on the size of the holes. This line of thinking is shown in the transcript which follows.

I: I have a tin here with two holes (The tin is V shaped). *The holes are on the same level.* (I fill this container with water). *Which hole do you think will have water hitting the ground further than the other or do you think they hit the ground at the same distance from the tin?*
P: They will hit the ground at the same distance from the tin.
I: What do you think is the reason?

P: ..because they (the holes*) are on the same level and also they are the same size.*

I: In other words the size of the holes will make difference.

P: Yes

I: Which would hit the ground further if their size were different?

P: The smaller hole?

I: Why?

P: ... because the water would be forcing its way out of the thin hole.

The effect of the size of the hole on the distance at which the water jets hit the floor was not discussed because the relationship between the pressure and the size of the hole was considered to be beyond the scope of this research. However the emergence of this idea served to inform the researcher of this problem. As a result in the field work the children were told explicitly that in all the experiments the holes should be the same size.

The relationship between the pressure and the cross sectional area

Two containers, with different width were presented to the interviewee with the same water level, h, and holes made at the same height as in figure 4.4.

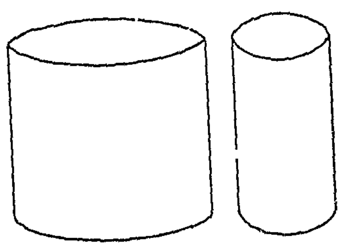


Figure 4.4: Different width containers

Prediction

The interviewee (B) predicted that the water jet from the wider container will hit the floor further from the container than the water jet from the narrow container. This is shown in the transcript below.

I: Okay, let us say now I take two containers like this and I make holes at exactly the same level. I take one big container and one small container. I then make a hole on each container and I make sure that the holes are on the same level, one hole on the big container and another hole on the small container.

P: hmm.

I: Now if I make sure that the water is also on the same level in the two containers. Which one will have water hitting the ground further than the other?

P: ...in the two containers?

I: Yah.

P: Water at the same level?

I: Yah, water at the same level but one container is narrow and the other container is wide.

P: Yah, and the water is at the same level?

I: Yah, you have one hole here on the small container and then the other hole here on the large container. You see they are on the same level.

P: Yes.

I: ... and then we add water also to the same level in the two containers. Now which hole will have water hitting the ground further than the other. Will it be the hole in the large container or will it be the hole in the small container?

P: ... in the large container.

I: ... in the large container. Why?

P: ... because there is bigger space.

This was one of the interviewees who thought that since there was a larger volume of water in a wide container, the water in a wide container will exert greater pressure than the water in a narrow container. This is equivalent to saying 'the pressure is directly proportional to the cross sectional area'.

Exposed to the same situation, other children had completely different predictions, i.e the water jet from a narrow container will hit the floor further from the container than the water jet from a wide container.

I: If we have two containers (both v shaped) *we make holes at the same level and add water to the same height* (I shows what he means by the words 'level' and 'height'). Which one will hit the ground further?

S: narrower one.

I: Why?

S: There is not enough space in the narrow one, so the water will try to get out.

In some cases some pupils (eg. C) would change their minds as they are exposed to different forms of the experiment. This was noticed when first two containers and then a kettle were used. The main difference between the previous and the following situation is the fact that with the kettle, the wide and the narrow parts are connected while this is not the case with separate containers.

I: Now let us look at this kettle. If I make a hole on the spout and another one on the side (I show the positions). *Which one will throw the water further?*

S: The hole on the side.

I: Don't you think the one on the spout will throw the water further because it is narrower?

S: No, there will not be enough water in the spout to throw the water far.

What has emerged from the above transcripts is that two completely opposite interpretations to the same experiments can be made by different interviewees.

Having encountered the kettle, the interviewee changed his mind when the discussion went back to the two containers.

I: Let us go back to this container. We have a wide container and a narrow container. Now if I fill this containers with water to the same level and also make holes in the two containers at the same height, which container will throw water further away than the other?
S: The bigger container will throw the water further away.
I: Earlier you said that a narrower container will throw the water further away than a wider container. Are you changing your mind now?
S: Yes.

The above transcript shows the importance of prior exposure in the answers given. The change of mind was a consequence of having been exposed to a kettle. Without that this change of mind (although still incorrect) was unlikely to have occurred. Although in this case the change of mind was not useful, the change itself means that in some circumstances (not all) prior exposure can be used to effect a useful change of mind eg. conceptual change.

Explaining the discrepancy

This interviewee was one of a few who admitted they did not know the correct answer when the experiment disproved their predictions. This is shown in the discussion below.

I: Let us prove it. I add water to the same level. I am going to make holes. Note where the water hits the ground.) (I makes a hole in the wide container and ask the subject to put an object where the water hits the ground)
(I makes another hole in the narrow container and ask the subject to put an object where the water hits the ground)

I: Now which one hits the floor further than the other?

S: Same distance.

I: Why?

S: I do not know.

The following are two points of view regarding the relationship between the pressure and the cross sectional area that have emerged:

(a) Narrow container means greater pressure.

This point of view assumes that water is compressible and that the smaller the room for water the greater the pressure.

(b) wide container means greater pressure.

This point of view concentrates on the weight of the water only and ignores other variables.

<u>Relationship between age, standard, science level and the answers given</u>

While misconceptions exist at all levels, anomalies were found when younger children out of intuition obtained correct answers outperforming their seniors who have been taught the concepts. It would seem that age, standard or even science background do not necessarily give an advantage when it comes to explaining observed phenomena

The following is an extract of an interview with two standard 6 girls aged 13 (P1 and P2) and two boys in standards 7 and 8 aged 16 and 20 (P3 and P4). The standard 8 boy had been taught about pressure the previous year while the standard 7 boy claimed not to have been taught about pressure yet but only about forces. The standard 6 children (P1 and P2) were last taught physical science when they were in standard 5 (the previous year)

Prediction

The transcript below shows that the younger children (both girls) made correct predictions which the older children (both boys) could not make. The interviewees P1, P2, P3 and P4 can be identified in table 4.1 as H, L, J and K respectively.

I: If I take this one and add water in here'. Say I fill this with water, you can see this part is wide and this part is narrow. If I pour water up to this level, where will the level be in this narrow part?

P4: That means you add water up to this level (points the level) .

I: Yah. Then on this side will it (the water level) *be higher, lower or the same (level)?*

P4: It will be lower (points at the wide side)

I: Okay. (N.S) ***What do you say?***

P3: It will be lower on this side (points at the wide side)

I: and what do you think?

P1 & P2: They (the levels*) will be equal.*

I: What makes them equal?

P2: The cause is (the fact that*)* ***in here it*** (the water in the wide part*)* ***can not reach here*** (this level*)* ***before this*** (the water in the narrow part*)* ***starts rising.***

I: What do you say (think*)?*

P4: I think the water on this side will be a bit higher, it will be a bit higher than the water on this side.

I: What makes it (the water*)* ***do that?***

P4: It is because this part is small and this part is large. Now if you pour water in here, there must also be water in here (the other side*)*. ***Isn't that it is not possible for this side to be full with water while there is nothing this side*** (empty*)*.

I: What do you say (think*)?*

P3: I also say it will be lower?

I: What makes it do that?

P3: ... because this side is larger than this side.

I: Now if it is larger what makes the other side to be lower?

P3: This side does not have enough space.

Observation

When the experiment was performed, the prediction given by the older children was disproved as shown in the transcript below.

I: Okay, let us pour in the water and see what happens.

(I pours in the water)

P1 and P2: (spontaneously) *They are equal.*

I: What do you say?

P3 & P4: (silent while P1 and P2 laugh)

P3 & P4: They are equal.

Explanation

After the observation one of the older children went on to give an incorrect explanation of the observation, while the other remained silent in surprise. The younger children were satisfied with their prediction and subsequent explanation.

I: What makes them equal.

P2: It is because we did not close here (the opening that connects the narrow and the wide tube). *If this was closed, then maybe it would rise in this side and when it gets say here, start going to the other side.*

An element of surprise in this transcript is the fact that both children who had not been taught about pressure realised that the water had to rise up to the same level in parts of a container which are connected. This could not be explained but was seen by them as common sense. However the children who had been taught about pressure could not obtain correct answers even when this was only a modified form of what is referred to as 'hydrostatic paradox' in their books. In a show of insight, P2 uses 'common sense' to explain why the levels are the same.

The relationship between the pressure and the shape of a container

Prediction

Interviewee (C) predicted that water jets from holes at the same depth of water in containers with different shapes will hit the floor at different distances from the containers.

I: This is another container (rectangular juice container*) I am going to make holes which will be at the same level as the holes we had in the other container (V shaped).* (I and P decided together where to make the holes and made them*). Now tell me, if we fill water in this two containers to the same level* (I points the level*) in which container do you think the water will hit the ground further?*

P: In this one (points at the V shaped container*)*

I: Why?

P: I think so because this one is four cornered and this one is round.

I: Why do you think the shape will make the difference?

P: I just feel that way because this one is four cornered and this one is round.

Observation and explanation

(I does the experiment*)*

I: Why is it not happening the way you said?

P: I do not know.

In cases where the shape is not regular, the relationship between the pressure and the cross sectional area of a container can not always be completely separated from the relationship between the pressure and the shape of a container. This is because often as the shape changes, so does the cross sectional area and vice versa. This is illustrated in the following transcript.

I: Let us go back to this one (the V shaped*). Here you said the water at the bottom hits the ground further because it is squeezing itself, now here you say the water is squeezing this water below. Can you explain?*

P: In this one (V shaped*) the water below is squeezing itself and also it is being squeezed by the water above.*

I: Now let us look at other containers. (I brings a 2 L coke bottle and a 340 ml coke can). *If I make holes on this two containers at the same level and fill water to the same height, which container will have water hitting the ground further than the other?*

P: This one (the can*).*

I Why?

P: ... because it is narrow so the water inside will be squeezed.

I: Now can you compare the distance at which the water from this (V shaped*) will hit the ground with the distance at which the water from this* (coke can*) will hit the ground from the same level?*

P: Water from this (V shaped) *will hit the ground further.*

I: Why?

P: ..because in this one the water is being squeezed at the bottom and also by the water above.

The discussion above suggests that the child thought that the pressure would be the greatest at the bottom of v shaped container, followed by the narrower container and then the wider container. This point of view can be seen as an extension of the previous one. The reverse order of the relative magnitude of pressure in the containers can be expected from those who thought pressure to be greater in a wider container.

Pascal's principle

This principle is possibly one of the most confusing aspects of hydrostatic pressure. This is seen from the fact that pupils, a student teacher and also teachers had difficulties with this principle. This problem is also highlighted by the frequency with which a child changes his or her mind in the interview.

The misconceptions displayed as the child changed his mind will be discussed in turn.

- The pressure transmitted decreases with depth

Some children knew the correct answers but were not sure that they are correct. The following is an extract from an interview with such a child. The child changed from an incorrect answer to a correct answer and then to an incorrect answer again when being questioned.

Prediction

This child (A) thought, if pressure is applied to water in an enclosed container with water, the water jets near the point where the pressure is applied will go further from the container than the water jets further from that point. This is shown below.

I: Now let us say I take a container, a plastic container, I fill it with water. Let us say. I take this one. Say I fill it with water, right? (pause) *... then I make holes all over. What is going to happen?*
P: Water will go out.
I: Okay. If I squeeze it what will happen?

P: The water will go further.

I: Why?

P: ... because you exert much pressure with the hand.

I: Okay. Let us say for instance some holes are at the top and others are at the bottom, right? Which ones will go a lot further than the others?

P: The water from the holes below.

I: The water from the holes below. Okay. What I am saying is we have a container here, some holes are at the top others are here and we know the water will come out like this, right (I draws on a piece of paper)*?*

P: Yes.

I: Now if I squeeze the top, will this... you see this is the distance from the bottom hole to the place where the water hits the ground, this is the distance from the hole to the place where the water from the top hole hits the ground (points these on the piece of paper). *Which distance will increase more than the other if I squeeze the top? Will they increase in the same way or will one hole increase* (the distance*) more than the other? Will the distance by one hole increase a lot more than the other?.*

P: The top one will increase more

This answer (line 23), could suggest a misconception that the pressure transmitted decreases with depth. This seems intuitive in the sense that experience often suggests that many things eg. light intensity tend to diminish with distance from the source.

The following excerpt discusses the connection between pressure on an object and the action of squeezing:

I: Can you think of a reason?

P: The pressure.

I: If I squeeze like that am I increasing the pressure?

P: No.

27 *I: I am not increasing the pressure?*

28 *P: Yes.*

29 *I: I mean by squeezing like this I am not increasing the pressure*

30 *P: No, you are not increasing the pressure.*

31 *I: Now what is it that causes the water to go further?*

P: Sorry, you are increasing the pressure.

Here the pupil changed from an incorrect answer to a correct answer. In this case the change was from pressure not being increased to the pressure being increased. It would appear that the question asked by the interviewer in line 31 induced a conflict which resulted in a change of mind. The question was posed as a check to see whether the interviewee understood what was meant by increasing the pressure. Following the successful connection of the act of pressing and an increase in pressure, lines 23-30, it was decided to use the word 'pressure' in the question which followed.

The following section shows a misconception when the interviewee thought the pressure transmitted decreases with depth followed by a change of mind.

<u>*Prediction*</u>

33 *I: Okay. I am increasing the pressure. Now if I increase the pressure, am I*
34 *increasing the pressure at the top hole more than I am increasing the pressure at*
35 *the bottom hole or am I increasing the pressure more at the bottom hole than at the*
36 *top?*

37 *P: You increase the pressure more at the top.*

38 *I: So, the top one gets an extra... more additional pressure than the hole at the*
39 *bottom. Is it what you are saying?*

Yes.

The connection between the act of squeezing and the distance at which the water jets hit the floor was made in lines 1-22. The connection between the act of squeezing and the pressure was made in lines 23-30. The connection between the magnitude of pressure and the position of the hole was done in lines 33-39. From these arguments, one can now infer that there is a misconception about the relationship between the pressure transmitted and the distance from the point where the pressure was exerted.

Explanation of the prediction

40 *I: Why do you say that?*
41 *P: ... because the areas of this are equal and the pressure exerts/exists (pronounced 'exests') much on the top hole.*

Surprisingly when the same question was asked again below, the child changed his answer and said the pressure will not decrease. It might be that merely repeating the question suggested that there might be something wrong with the answer given.

Change of mind

43 *I: Are you saying that the pressure will become less as it goes to the bottom?*
44 *P: No, it won't be less.*
45 *I: I mean the new pressure that I am adding.*
46 *P: No, it will go down it will become much than the pressure exerted at the top.*
47
48 *I: Hmm. Look I am not talking about the weight of the water inside. I am talking*
49 *about the new pressure that I am exerting. Will this new pressure be greater at the*
50 *top or will it be greater at the bottom or will I add the same pressure at the top and*
51 *at the bottom?*
52 *P: It can be greater at the bottom.*
53 *I: ... at the bottom. Why?*
54 *P: ... because more pressure will be 'existing' downwards.*

I: Okay. More pressure will be existing downwards but then what about the new one that I am adding? You see I just want to know about the new one that I am adding, whether the new one that I am adding ... I will add the same pressure at the top and at the bottom. (pause) (Sepedi) ***'What I mean is: isn't that there is pressure in here, then we add new pressure. This new pressure that I add, will it be added equally at the bottom and at the top, or am I going to add a large pressure at the top and only little at the bottom'?***

P: (N.S) ***It is going to be greater pressure at the bottom*** *but when it finds greater pressure at the bottom it becomes greater.*

I: (N.S) ***'What makes it do that'?***

P: (N.S) ***'It is the other pressure'****, the new pressure that is added.*

The *language used*

The interviewee had problems in understanding a question which related to the relative increase in distance from the container by water jets from different holes. Since the word 'relative' (which could possibly have condensed the question) was possibly not known at this stage (std 7), a somewhat clumsy language was used to explain this which resulted in a long sentence (line 9-10). Even this was not clear to the child. As a result the interviewer resolved the problem by drawing on paper to illustrate the question. This strategy was successful and also enabled the interviewer to refer to the paper in further questions (line 17-21).

In some cases the interviewee's answer would be so (line 24) short that the interviewer had to 'fill in ' to try and understand what the interviewee was trying to say (line 25). When the response to this was even shorter ('no'), it was necessary to double check by rephrasing the question as in line 27.

An attempt to use familiar words can be seen in lines 38 when the word 'extra' is used and immediately followed by the words 'more additional'. While this statement (line

38) may sound clumsy, the rational behind it was to make it clear that there is additional pressure for the water jets but that their relative magnitudes were required in that question

Problems can also be noticed with pronunciation. The interviewee kept on using the word 'exest' which could have been either 'exert' or exist (line 41). However the context in which it is used suggests that it means that the pressure is exerted.

4.6.6 Discussion

The above discussion suggests that the child (G) had difficulty in separating the pressure at a point (due to the weight of the liquid column) from the additional pressure transmitted. This view was noticed even from a student teacher as shown in the extract below.

I: Here is another one (plastic juice container). *Let us say I make holes all over the container. Now if I hold the top part and squeeze* (I illustrates), *which hole will have the water hit the floor further from the containers than others?*
S: (Seems not to understand)
I: (I make drawings of the jets of water before squeezing). *This is how the jets look like before squeezing. How will the jets of water look like after squeezing?*
S: The bottom ones will increase more.
I: Why?
S: The water above will be pushing down on the water below.
I: Thank you very much.

It would also appear that the student's reasoning behind the idea that the pressure transmitted increases with depth is that the pressure transmitted adds to pressure which has always been there.

In the discussion below the child again suggests that the pressure transmitted will increase with depth.

I: So the new pressure (N.S) ***'which I exert, how is it going to change as it goes to the bottom'?***

P: hmm ... (thinking).

*I: ...**as it goes down, will it increase or decrease?***

P: ***It will increase.***

I: Will it be bigger than when it was at the top?

P: Yes.

I: Are you sure?

P: No.

Again when the child was questioned further he said a correct answer. However he admitted that he was not sure of the answer.

I: Okay. So the new pressure (N.S) ***'which I add,*** *will it not* ***get to the bottom or will it?'***

P: (N.S) ***'It will arrive*** (at the bottom)*'*

I: (N.S) ***'When it gets there will it be less than it was or will it still be the same as when I added it.'***

P: (N.S) ***'It will be'*** *the same because it will be pressing the water and then the water will be pressing* (inaudible)

I: So you say that the pressure I add here will be transmitted to the bottom?

P: Yes.

I: Okay. ... and that additional pressure will be the same at the top and at the bottom?

P: Yes

I: Are you sure?

P: No.

Questioned further the child revealed why he was not sure and came with an answer that reconciled with the answer just given namely that

(a) the pressure transmitted will be the same and

(b) the answer given earlier namely that the pressure transmitted will be greater at the top hole.

The new explanation was that the pressure was initially greater at the top hole because it arrived there first. The pressure then moved to the bottom hole and became greater there.

The discussion is shown below.

P: (N.S*) **This** (at the bottom) will increase its distance. This at the top will increase until the pressure gets to the bottom and this also'....*

I: ...(N.S*) **'this will also increase?'***

P: ...then the water it will have passed the top hole arrived at the bottom.

I: ...then this will also increase?

*P: **'It will have been'** more the distance will have been more by the time the water* (level*) gets low.*

The line of thinking was previously picked up from those (relating the pressure to the depth of water) who thought the pressure was greater at the top than the bottom hole.

In the following transcript Pascal's principle was referred to directly by name.

I: Okay. Have you studied Pascal's principle?

P: Yes.

I: What does it say?

P: Pressure in a container exests (either exist or exert, the child pronounced it as 'exest') *in all directions.*

I: Okay, it says pressure in a liquid is transmitted equally in all directions throughout the liquid.

P: Yes.

I: What does it mean? Can you tell me what it says in Sotho.

P: It says that the pressure that is in the liquid, it exerts/exist (pronounced: exests*) in all the sides so that if we have the water inside the container the pressure that is going up will be equal to the pressure that goes down and in all the sides.*

This child preferred to answer the question in English even when invited to do so in the vernacular.

It can be seen that the child makes no mention of transmitted pressure. Even when the word transmit had just been used the child does not use the word. The reason for this may be either in the understanding of the concept or the word itself. Certainly from the child's phrasing of the principle it can be seen that the principle was not understood. What is not known is whether there is a link between not understanding the principle and not understanding the word 'transmit' which is so often used when the principle is stated.

There are some cultural experiences which also seem to add to the misunderstanding of Pascal's principle as noticed from a twenty seven year old. These are shown in the extract below.

I: Now let us say I have a plastic bag. Say I punch holes all over the bag. If I pour water in it the water will come out. Isn't it?

LMN: Yes.

I: Now if I squeeze the top part of the bag, which holes will have water from them increase distances at which they hit the ground more than others? Will it be holes at the top or will it be the holes at the bottom or will the distances be the same?

L: The bottom ones will increase their distances more.

I: N, What do you say?

N: I agree with him. The bottom water will increase their distances more.

I: What do you think, M?

M: I agree with them. It is like when you have 'morogo' (an indigenous mixture of vegetables which looks like spinach*) in a pot. If you start hitting the 'morogo' repeatedly at the top, the bottom one will be more disintegrated than the top one.*

The example given by 'M' in the last three lines referred to a manner of cooking 'wild' vegetables which involves hitting the vegetables repeatedly. The word 'wild' is used because these vegetables are not planted in the home garden but grow on their own in certain seasons. Asked about Pascal's principle the interviewee said that the pressure transmitted increases with depth. As an example he said this could be clearly seen in the process of cooking these vegetables. He claimed that when the top vegetables are repeatedly hit, vegetables at the bottom become more disintegrated than those at the top.

Although the example given by M does not reflect the correct situation of Pascal's principle in that the 'morogo' is not enclosed, his explanation is significant in that it reflects some kind of cultural problem with which the interviewer must be familiar with, to understand the explanation. In this case M's daily experience serves as an obstacle towards understanding the principle.

It should be noted that in the example mentioned by M, it is not only the pressure which is involved but also the heat involved when cooking. This observation may be true because when cooking, the vegetables at the bottom are at a higher temperature than the vegetables at the top. However that would not mean that the vegetables at the bottom have received more additional pressure (due to the process of hitting the vegetables) than the vegetables at the top.

Misconceptions were identified in most of the interviews.

4.6.7 A summary of difficulties identified during the interviews

The following are conceptual difficulties that emerged from the interviews. In all cases when the pressure was compared using two containers, the water in the two containers was kept at the same level.

(a) incorrect predictions

These were situations where the child could not predict the result of an experiment.

As an example some pupils would say that in a container with two holes one above the other, the water jet from the top hole will hit the floor further than the water jet from the bottom hole. That means the focus is on the height of a container and not the depth of water.

A second example is that water jets from holes at the same level in containers with different cross sectional areas will hit the floor at different distances. One point of view was that water in a container with a small cross sectional area will hit the floor further than water in a container with a large cross sectional area. A second point of view was the reverse of this.

(b) incorrect reasons were given to explain the predictions.

In this case the child would not necessarily give an incorrect prediction but would fail to give a scientifically acceptable explanation.

The following are examples of the reasons given.

(i) Water is getting squeezed in a narrow container and this increases the pressure at the bottom.

(ii) There is a large space in a wide container and this increases the pressure.

(iii) There is air inside the water which increases the pressure.

(iv) There is air outside the water which increases the pressure.

(v) There is also a feeling that the shape of a container would affect the pressure, for example the width in a section of a container would either increase or decrease the pressure. In this way if a container has portions that are narrower than other parts of the container, the pressure will be greater at the narrow parts or vice versa. This appears to combine (i) and (ii) above.

If the narrow part is near the bottom, the pressure here will be due to the water being squeezed and the weight of the water above. This appears to combine (i) above with effects of the weight of water.

(c) Misinterpretation of questions asked

Where holes are made at different levels in one container, one pupil said the bottom hole would shoot the water further (which is correct). The reason given was the fact that as the water level gets lower, they would be no more water coming out of the top hole whereas water will keep coming out of the bottom hole. This shows that a correct answer was obtained by misinterpreting the question.

The children interviewed had differences in age, socio economic status and in some cases the level of science background. However, the answers given did not appear to show any connection with any of the variables.

4.7 Chapter summary

Conceptual and language difficulties have been uncovered by the analysis of recorded lessons and interviews.

The following misconceptions were uncovered from pupils::

(a) Pressure in liquids is affected by (i) size of an object on which the pressure acts

(ii) shape of a container holding the liquid

(iii) air (in or out of the liquid)

(iv) cross sectional area of a container

(b) Transmitted pressure is affected by point of interest. That is transmitted pressure

(i) increase or decrease from the point of interest

(ii) is equal only at the same level in a liquid.

The age, gender and socio economic status and home region (i.e urban or rural) did not appear to be important in affecting the type of answers given.

Misconception (b) was a result of misinterpretation of the words used in Pascal's principle. This research therefore has shown that language problems go beyond just understanding the meanings of words. There is also a problem with understanding the interrelationship between the words even when individual words appear to be understood. In both interviews and lesson transcripts there were incidents where knowledge of the learner's language and culture were important to interpret answers given. Different combinations of individual and group interviews were used. However the findings did not appear to differ greatly although possibly a truer picture emerged from the mixture.

Despite the language difficulties, many teachers had their own language strategies. The strategies identified were:

(a) code switching
(b) familiar examples
(c) rephrasing
(d) demonstrations of what was being done
(e) the use of synonyms as well as explanation of the meanings of the words used and
(e) contrasting meanings of words with meanings of their antonyms.

By combining some of tne strategies above in different orders, two different models have been deduced from some of the recorded lessons. Of the two models the first one is preferred for the following reasons:

(a) It is constructivist in that first one needs to find out how pupils understood a particular word, then identify instances and non instances of the word, thereafter bring out the meaning by contrasting the instances with the non instances.
(b) The second language teacher's model may also be useful when the teacher is working under the constraint of time.

It appears that the first model requires many more ideas from children than the second model. This makes it easier for practitioners to identify and remedied misconceptions. The next chapter explains the design of a teaching package on the topic of pressure. This was to a large extent directed by the problems identified and strategies uncovered in the investigations described in this chapter.

5.0 CHAPTER FIVE - Development of test instruments

5.1 Introduction

A flexible approach was, of necessity, followed in this research. As circumstances changed, the research design was modified to accommodate the changes. It is therefore impossible to separate materials and designs for different tests from the pilot process.

When the words 'teaching package' and 'teacher's guide' are used, the former will refer to materials used by teachers and pupils while the latter will refer only to materials used by teachers. The word 'diagnostic test' will refer to either the conceptual test or the language tests or a test that contains both conceptual and language questions.

5.2 Development of conceptual test

The diagnostic test for conceptual difficulties was piloted many more times than the teaching package. This is because in addition to finding out if the questions could be easily understood, the diagnostic test was also used to identify misconceptions, which later directed interview questions, which in turn directed what was to be included in the teaching package. The process of piloting the diagnostic tests therefore also included the construction of questions which tested misconceptions uncovered during the pilot process.

In addition, only one diagnostic test was used to test conceptual problems on hydrostatic pressure while four variations on another test were adapted from Johnstone and Cassels (1985) designed to test language problems.

Although one diagnostic test to four variations of a language tests seems maybe an excessive ratio, this was not the case since the language tests were using the same words in different contexts. In addition, the total number of students who wrote all the four language tests was the same as the number of students who wrote the conceptual test. Figure 5.1 illustrates the development of the tests.

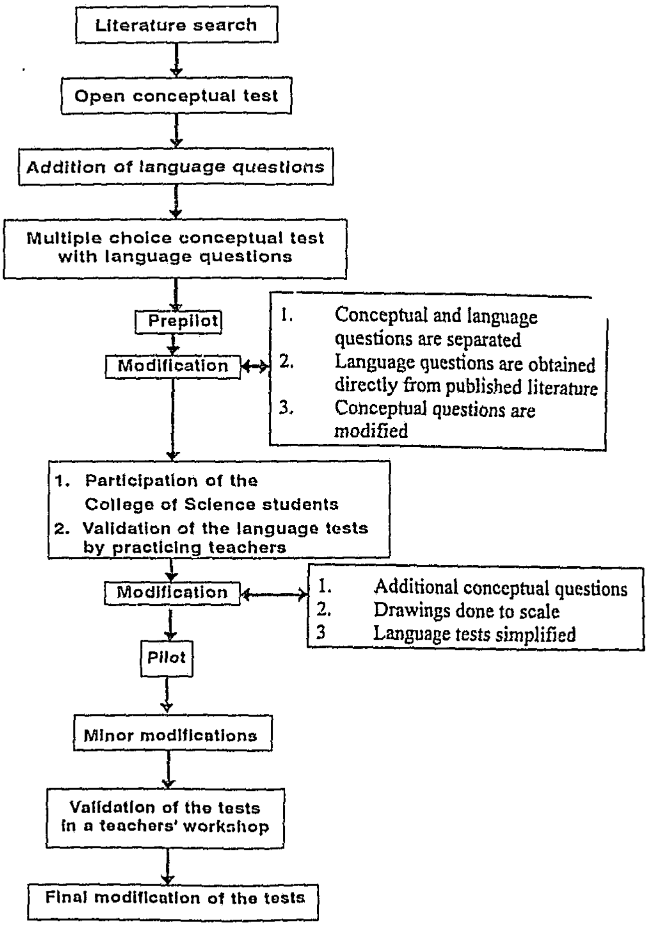


Figure 5.1: Development of the tests

5.2.1 Design of the conceptual test

The conceptual test investigated conceptions of hydrostatic pressure in the following areas:

(a) the effect of depth of liquid on the pressure

(b) direction of pressure on an object immersed in a fluid

(c) Pascal's principle

This conceptual test was developed along the line of MacGuire and Johnstone (1987) (section 2.7.3). Although all efforts were made to follow their guidelines in setting the diagnostic test, it should be noted that it is virtually impossible to find instances where pressure is not being exerted in everyday life following their suggestion that instances and non-instances of a concept should be identified . This element was therefore missing from the conceptual test.

Initially the conceptual test contained only open ended questions (appendix B) and was based on the standard 7 (aged approximately 14 years) physical science syllabus. The open conceptual test was used to identify ideas about pressure in liquids from postgraduate student teachers. These student teachers were used to develop the test as a convenience sample because of the educational disturbances in schools at the time of this research. All the students teachers had credit in at least first year physics. Since there is documented evidence that misconceptions can be found even among graduate teachers (Osborne and Wittrock, 1983), it was not considered inappropriate to use postgraduate students as they were an easily accessible sample. Indeed these postgraduate students displayed misconceptions similar to those later identified from the College of Science (university access course) students (section 5.3) and standard 7 children.

Since mostly young children who were not yet conversant with writing descriptions in a second language were the sample, the next step was to convert the open conceptual test into a multiple choice test using the misconceptions displayed by the postgraduate students as distracters. Only one question, that is, question 9 had to be open because it was not possible to include all possible answers in the distracters. This was a diagram of a fish in water where respondents were requested to draw the directions in which they thought the pressure acted on the fish. The computer facilities available for analysis made it possible to perform an efficient analysis despite the many different answers given by the pupils. This resulted in eighteen different answers.

When the conversion of the open conceptual test into a multiple choice form was complete, language questions were added. The language questions were based on the statement of Pascal's principle as stated in one of the most commonly used textbooks in South African schools. The principle was stated and then multiple choice questions asked to find out the meanings of key words used in the statement. These words were 'applied', 'enclosed', 'transmitted equally'.

5.2.2 The pre-pilot of the multiple choice conceptual test with language questions

The first draft of the multiple choice conceptual test was given to standard 7 and 8 children at an 'alternative' school (see chapter 1). As the standard 8 children had already encountered Pascal's principle when in standard 7, it was of interest to find out whether they would have the same difficulties as standard 7 children with the language used in the wording of Pascal's principle.

The students were told to ask questions if anything on the test was not clear. They were particularly encouraged to seek assistance when they did not understand a word or a phrase. In addition they were requested to underline such words and phrases.

From questions the pupils asked, it was found that the main problem with the test was the language used. The word 'cross-sectional area' was new for the standard 7 children and was not understood by the standard 8 children either. In addition, the sentences were long. The sentences were made longer by the fact that words rather than pictures or diagrams were used to explain a situation. An example of such a question would be

' *A boy swimming in a dam goes from position N to position S as shown in the diagram. He is swimming with his back upwards and stomach downwards'*

1. How will the pressure on his back when he is at position S compare with that pressure when he was at position N?

A typical distractor will then be

' *The pressure on his back when he is at position S will be lower than the pressure on his back when he was at position N'.*

As the example above shows, the questions were long. The length of the questions made it difficult for the children to understand and thus they took a long time on only a few questions. It was therefore impossible for the majority of the children to attempt questions based on Pascal 's principle as they were at the end of the test. Little can therefore be said about those language questions. However from concern related to language and the length of the test which came to light, it was clear that the language questions related to Pascal's principle would pose difficulties as well.

The standard 8 children were no better than the standard 7 children in understanding the language used in the diagnostic test. The reason why this diagnostic test was administered was partly because the researcher initially believed simple enough language could be used to express the questions unambiguously for the children, that is, initially language difficulties were underestimated.

5.2.3 Modification of the multiple choice conceptual test with language questions

Because of the difficulties mentioned in section 5.2.2 (such as length of sentences and vocabulary), modifications were made to the multiple choice conceptual test with language questions. Conceptual questions in the diagnostic test were shortened by using two questions in Engel and Driver (1981) as an example of short questions which probed conceptual difficulties and written in accessible language. The rest were original questions formulated by the researcher using the same format. The format entailed replacing the word 'boy(s)' in the original test by fish with names. The use of names made it unnecessary to distinguish the fish by describing their positions, thus resulting in shorter questions.

The language in the conceptual test was simplified by replacing unfamiliar words with more familiar words. In this way words such as 'cross-sectional area' were replaced by 'narrowness' or 'width'. The language questions were removed from the multiple choice conceptual test with language questions (because of the difficulties mentioned) leaving the multiple choice conceptual test as it stood before. The language section of the diagnostic test was replaced by questions taken from a test that was used previously with English first language speakers in Scotland by Cassels and Johnstone (1985). The original 45 words used were carefully chosen to include words considered difficult in school physics (Cassels and Johnstone, op. cit.). There were four language tests using the same words. Each test however tested the words in a different format:

The words were tested in the following formats

(a) one word synonym without context
(b) the word appears in four everyday situations only one of which is correct.
(c) the word appears in a science context stem.

(d) the word appears in a non-science context stem.

Cassels and Johnstone (op. cit.) used a mixture of the four formats in each test and each word was tested only once.

In this study it was considered that the pupils would be confused if the contexts were changed since a child is likely to get an incorrect answer simply because the context in which a particular word is used differs from the context in which the previous question was set. Similar problems have been reported elsewhere (Cassels and Johnstone, 1983) namely that it requires more interpretive steps to move from one context to another. The purpose of this research was not to test how well children can interpret a new context but only to find out if they understood the words. This made it unnecessary to put the children in a situation where they had to move between contexts.

In the study, each child wrote only one test consisting of questions which were all in one context. This means each language test was written by a quarter of the class chosen at random. Only words considered most likely to be encountered in the topic of pressure were chosen. These were, percentage, tabulate, average, effect, influence, illustrate, exert, external, evacuate, immerse, excess, standard, displace, efficient.

As the original test was designed primarily for first language speakers with experience and culture different from those of our sample, it was considered important to modify it by putting words in parenthesis where it was considered that the original words would be too difficult for an average standard 7 black child in South Africa since usually they only speak English at school, (Rollnick, 1988). The words in parenthesis did not necessarily have the same meaning as the original words, for example the word 'tarmacadan' was replaced by the words 'soft soil'. Because the word 'tarmacadan' was not being tested in the sentence, it could be replaced without changing the meaning of the word that was being tested, which was 'immerse'.

When the modification of the tests was complete, they were given to three English second language speaking standard 7 English and two standard 7 science teachers for their comments and validation. The teachers were also requested to answer the questions themselves to see whether the teachers would agree on the answers to the questions. Only the language teachers returned the tests with suggestions to put additional words in parenthesis (see section 5.5 for all words which were put in parenthesis).

The language tests, having been modified from published questions which had been used with a large sample, were considered not to need as many pilot implementations as the conceptual test. The next stage was therefore to pilot only the conceptual test with College of Science students, a second convenience sample.

5.3 Misconceptions from the College of Science students.

The total number of students were 100, aged about 18. They were first year students on a special academic programme for the educationally disadvantaged.

Thirty completed questionnaires were picked at random for analysis of misconceptions so that these could be used as a guide for further development of the materials. The misconceptions identified from this analysis are listed in table 5.1.

Table 5.1: Misconceptions by the College of Science Students

Concept	Misconception	Reason(s) given
Pressure increases with depth	The pressure is not affected by the depth of the liquid	
Pressure does not depend on the total volume of a liquid	Pressure increases with the volume of a liquid. Pressure decreases with the volume of a liquid.	Large weight of water increases the pressure In a narrow container, the liquid is being squeezed and this increases the pressure. Pressure is inversely proportional to volume (as in gas laws)
Pressure does not depend on the surface area, for a liquid	(a) Pressure increases with the surface area of the fish (b) Pressure decreases with the surface area of the fish	Large weight of water on the fish increases the pressure Small area of the fish increases the pressure
Liquid pressure acts in all directions	Pressure acts only in certain directions eg. upwards downwards upwards and downwards away from the direction of motion	The fish is being supported by the water. The weight of the fish is downwards. The fish is in equilibrium
Pressure increases with an increase in density	No misconception They all knew that pressure increases with increase in density	
Pascal's principle: Applied pressure is transmitted equally in all directions.	In a hydraulic press, the pressure transmitted depends on the relative size of the piston In the volume of an enclosed liquid, pressure change increases/decreases with depth. Change in pressure does not stay the same as applied pressure, it depends on the area (of the fish).	

The misconception relating the pressure to the size of the fish probably originated from the fact that the fish, being hand drawn, were not exactly the same size. Some students realised that some fish were bigger than others and this affected their answers.

5.4 Final modification of the conceptual test

All misconceptions displayed by the College of Science students were then included in the conceptual test for use by school pupils with the exception of those which were considered to be a consequence of the standard 10 syllabus - i.e relating pressure to volume which is a characteristic of gas laws.

The idea that the size of the fish affected pressure was in itself of interest. It was therefore decided to test this conception. A question was added where one fish was deliberately made smaller than the other. The backs of the fish were drawn at the same level and the students were asked to compare the pressure on the back of each fish. The sizes of the fish were varied by either enlarging or reducing the sizes using the photocopier, thus maintaining the shape of the fish. In addition, where applicable, the drawings of the fish were made exactly the same size by photocopying. The test was then piloted at a rural school.

5.5 Pilot study at a rural school

The school was situated in Lebowa, one of the previous South African 'homelands'. It was one of the schools built with financial contributions from the villagers (section 1.2).

5.5.1 Information about the teacher and the school

The choice of the school and the teacher was made by a physical science subject advisor, an active and enthusiastic teacher who knew the teachers who worked under him well.

The school was chosen because:

(a) it was one of the most orderly in the area. The children still went to and left school on time and generally cooperated with their teachers. Cooperation was therefore expected from the children.

(b) the standard 7 teacher had shown a keen interest in working with somebody involved in research.

(c) academically and professionally she had received education similar to the majority of teachers who experienced lots of problems with the methodology of teaching as well as the subject content. She had received her high school education under the D. E. T. (Department of Education and Training). She had therefore experienced the same problems, to a lesser or greater extent as the children. She studied for a University Diploma in Education (U.D.E) with the University of Bophuthatswana and had been teaching for one year.

(c) the teacher was also known to be one of the most hard working teachers in the area. It was therefore thought that she would not be threatened when faced with a new material but would rather be keen to learn something new.

Taking these factors into consideration, the school and the teacher were therefore considered to be a good choice.

5.5.2 A preliminary discussion with the pilot teacher

It was considered important to encourage the teacher to be open. She was therefore encouraged to respect herself as an expert whose knowledge according to her exposure was not inferior to that of the researcher. Her contact with school children, for example, made her more conversant with their learning difficulties than the researcher.

It was also pointed out to her that from research experience, some sections were written for cultures other than her own which could make it difficult for her to understand. As she and the researcher shared the same culture it was important for them to identify culturally biased sections and get a way of making them clearer.

5.5.3 Administration of the tests

Both the language and conceptual tests were administered to 53 standard 7 pupils, and 90 standard 6 pupils. Since it was almost at the end of the year, standard 6 children would give a fair idea of typical problems that may be expected from standard 7 children before being taught about pressure.

The multiple choice conceptual test was administered on the first day and on the second day the language tests were written. The four language tests were divided at random among the standard 6 and 7 children. The children were not given any time limit when answering the tests. However they took about forty five minutes to answer the conceptual test and about twenty minutes to answer the language tests.

5.5.4 Test difficulties and final modification

In order to identify further difficulties with the tests, the children were requested to cross out words which did not make sense to them, either those in brackets or those outside the brackets or to underline words they did not know when there were no additional words in brackets. They were further encouraged to ask questions when they did not understand.

Following the modification of the conceptual tests after piloting it with the College of Science students, no further misunderstandings with words and phrases were identified. However there were still difficulties with everyday English used in the language tests. The children were not familiar even with words that described their personal information such as 'gender', 'occupation', 'urban' and 'rural'. Fortunately this was realised and those words were also explained. In the language questions themselves the following words were crossed out, indicating that they were not familiar:

Editor, journalist, squirrel, tarmacadan, dinosaurs, rhomboid, boulder and thicket.

All the words crossed out were the words used in the original language tests by Johnstone and Cassels (1985). None of the words included during modifications was crossed out.

Notably, except the word 'rhomboid' (which the children had not encountered yet) none of the words was science specific. The problem arose because these words are rarely used in the children's everyday life.

The final modification of the language tests was done by removing words which had been crossed out and replacing them with those shown in brackets below:

Editor (principal), journalist (teacher), squirrel (cat), tarmacadan (soft soil), dinosaurs (hottentotts), rhomboid (rectangle), boulder (stone) and thicket (house).

As it can be seen, these words are not synonyms. The only factors considered was that the questions should still test the words they were supposed to test and that other words used should be familiar.

The final version of all the tests is given in appendix B.

5.6 Validation of the instruments and choosing schools

It was difficult to get comments from practising teachers on what they thought about the tests. One science teacher (an unqualified teacher with only a pass in standard 10 physical science) simply answered the questions and did not comment. A second science teacher (A P.T.D. graduate) said she had written the comments and on three occasions claimed to have forgotten the tests at home. When an attempt was made to reach her for the fourth time it was found she had left the school and nobody knew where she went to. The third teacher (said to be an MSc graduate from a foreign country) only said the tests were perfect. All attempts to get her to write down her comments failed until the school was closed down and she could not be traced any more. All these difficulties occurred at an 'alternative' school (not the one used in the pre-pilot). 'Alternative' schools have been described in section 1.2.

Finally it was decided to make use of a group of teachers in one circuit in the then homeland of Lebowa. All standard 7 science teachers in the circuit were invited to a workshop, to which 15 turned up. The workshop was held at a school near the circuit office where the tests were validated by several teachers together.

The workshop had a two fold function, namely, to get grass root involvement of teachers in the tests and to identify teachers and schools which could be involved in the last phase of the field work, i.e implementation of the final tests and the teaching package. The teaching package is described in chapter 6.

The teachers were given the versions of the tests which had the familiar words in parenthesis and the difficult words in place. The purpose of this was to show the teachers the original words so that their ideas would not be limited by the modified words. On the other hand the idea was not to reinvent the wheel. The teachers were therefore only expected to suggest new words when they thought the words in brackets were still unsuitable.

The teachers were firstly asked to answer the questions as individuals, then to get into groups of four, discuss their answers and also write down group answers. None of the individuals and groups got all the answers correct.

Table 5.2 shows words which either a group or an individual could not get correct. The occurrence of an 'x' indicate the frequency of the incorrect response in a group.

Table 5.2: Words teachers could not get correct

Word	Science context	Word without context	Non-science context	Word used in sentences, only one of which is correct
Effect	xxx	xxx		xx
Standard	xxx			x
Efficient	xxx			
Exert		xxx		xx
Influence		x		x
Evacuate		xx	xxx	xxxt
External				x
Excess				x

Finally they were requested to report back on the suitability of using the tests with standard 7 children. They were informed that the children were not expected to get a 'pass' in the tests but that the questions should be understandable. Their reports confirmed that the words identified previously by the researcher and the language teachers as problematic were indeed so and that the words put in brackets as possible substitutes could be used (5.2.3).

In order to select teachers who might participate in this project, questionnaires (appendix C) were completed to indicate whether they

(a) were definitely interested

(b) may be interested or

(c) were not interested.

If their response were either (a) or (b) they were requested to leave addresses and telephone numbers where they could be contacted. All except one teacher indicated interest in getting involved in the research. These teachers were then chosen on the basis of their teaching experience and qualifications.

A list of schools which did not participate in the workshop was obtained from the subject advisor. Individual teachers from these schools were then contacted to find out who would be prepared to be included in the control schools. This was done by phoning the school to find out who the science teacher was. A discussion was held with the teacher to find out about his/her background such as teaching experience, and academic qualifications. The teacher's background was then matched with that of the experimental teachers chosen from the workshop.

Once suitable potential control teachers had been identified in this way, they were phoned again and invited to participate in the project. When the teachers had agreed their principals were approached to obtain their permission for the use of their schools. In this way three control schools were chosen from schools which did not participate in the workshop. This criteria of choosing 'suitable' teachers however, later proved not to have been as suitable as it was hoped, for example 'teaching experience' did not necessarily coincide with experience in teaching science. A discussion of these problems and how they were solved is in section 3.4.

On the basis of the experience acquired during the field work plans for the implementation of the material were made.

5.7 Plans for using the tests in the major field work

It was realised from responses given by pupils when they gave reasons for their answers on their worksheets that they had problems with English. The problem was so serious that at times it was not possible to understand their intended meaning.

In the light of the above problem, it was decided to give the pupils permission to use a language of their choice when giving reasons for their answers in the major field work. The children could use English, their vernacular, or a mixture of the two. It should be realised that giving reasons for their answers was particularly difficult for them as they had to give answers that had not been rote learnt. However only a small number chose to use the vernacular.

5.8 Chapter summary

This chapter has discussed the development of the diagnostic tests. The diagnostic tests were piloted several times and each time an improvement made. Some additional conceptual difficulties were identified in the process of developing the multiple choice conceptual test. The conceptual difficulties identified were then incorporated in the test. Finally the tests were validated in a teachers' workshop. Based on the workshop experience plans were made for the use of the tests in the major field work. The process of development of the tests has shown the importance of grass-root involvement in a project which aims to help the grass-root practitioners, for example the identification of conceptual difficulties which informed the development of the test.

6.0 CHAPTER SIX - design of the materials

6.1 Introduction

The literature (chapter two) has shown that traditional teaching is not effective in bringing about conceptual change in learners. Misconceptions remain resistant to change even when the misconceptions are addressed directly.

The literature goes on to show that the use of conflict strategies may help to remediate misconceptions. However one needs to know the misconceptions before conflict strategies can be used.

In this research, pupil and teacher misconceptions, were identified from transcripts of lessons (Chapter 4) and piloting of diagnostic and language tests (chapter 5) so that these could be used in the design of the teaching package - that is teacher support materials comprising a teacher's guide and pupil worksheets. In addition, knowledge of teacher misconceptions would enable the researcher to know where to help the teachers to overcome their own difficulties so that they could efficiently remediate pupil misconceptions.

Both pupil and teacher misconceptions informed the development of the teaching package. This is illustrated in figure 6.1

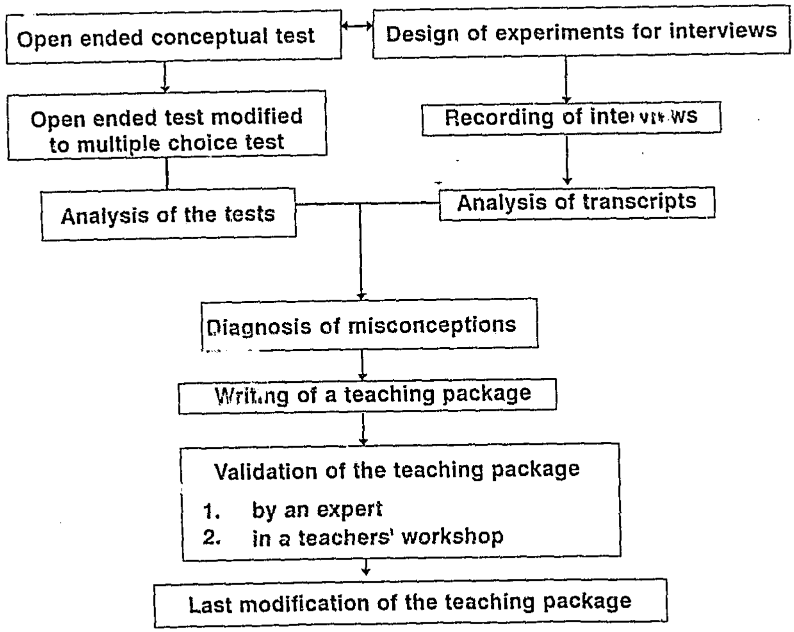


Figure 6.1: Development of the teaching package.

6.2 Overview of the teaching package

The teaching package was aimed at remediating the misconceptions using conflict strategies.

Written alongside the diagnostic tests, the development of the teaching package was informed by pupil and teacher interviews, and lessons on hydrostatic pressure by practising teachers.

The components of the teaching package, i.e. a teacher's guide and pupil worksheets are each described in turn and given in full in appendix A.

6.2.1 The teacher's guide

The rational for the writing of the teacher's guide was the fact that, in general, teachers in the society at which this research is aimed have a weak science background and few resources (section 1.2).

The teacher's guide was therefore written for a teacher who does not necessarily have a pass in standard 10 (grade 12) physical science nor experience in teaching the subject. For these reasons few assumptions of the teacher's content knowledge and ability to improvise were made.

The process of development of the teacher's guide is shown in figure 6.2.

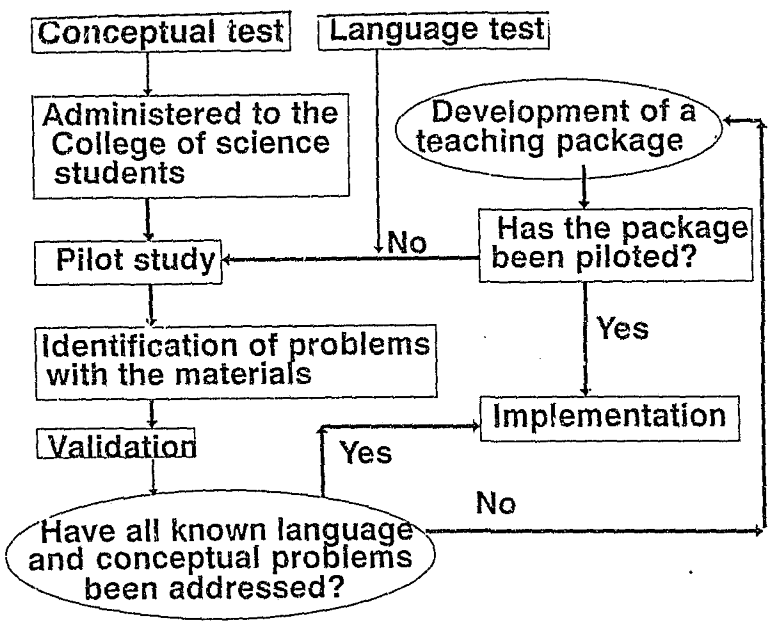


Figure 6.2: Development of the teacher's guide.

In developing the material, the following were included

(a) language modifications to address pupil difficulties

(b) teaching strategies

(c) culturally or regionally biased examples

(d) conceptual difficulties

Input into the first three areas was obtained from the teachers only, while the last one was obtained from the pupils as well. The teacher's guide contained the following sections:

(a) background information for teachers

This gave the teacher extra support which was not found in the pupil worksheets and school text books.

(b) preknowledge for pupils

Concepts which pupils were assumed to know before a new topic was introduced were stated. This helped the teacher to find out if those assumptions were valid for the children. Otherwise the presentation as suggested would not be successful.

(c) objectives for the topic.

What the pupils were expected to know at the end of the topic was stated.

(d) pupil difficulties.

These were the difficulties that pupils were known to hold about hydrostatic pressure or their ideas about the topic before receiving tuition.

(e) hints on performing the experiments and improvisation of equipment.

Since these were mostly novel experiments, it was unlikely that the teachers had tried them before. Difficulties with some activities were thus expected. The hints were some suggestions on how to overcome difficulties which had already been identified during the design of the package.

Some of the difficulties identified were possible errors in performing the experiments which might have gone unnoticed but resulted in incorrect conclusions.

(f) pupil worksheets.

These were designed to give the pupils instructions on how to make the simple equipment and do the experiments.

(g) suggestions on how new words in the pupil worksheets should be addressed.

Since most children involved in this study were English second language learners, it was felt that words which were likely to be new for them should be identified and addressed.

(h) Answers to questions posed in the worksheet.

Since after piloting the first version and discussion with some teachers revealed that they too have some misconceptions, it was decided to include the answers in the teachers' guide.

Finally the teacher was encouraged to take his/her own initiative where the guide failed to address a certain problem and to communicate that kind of initiative to the researcher. A possible use of conflict strategies even if a new problem should arise was also mentioned.

6.2.2 The pupil worksheets

The pupil worksheets were divided into two sections, (1) solid pressure and (2) liquid pressure.

Although the final analyses of results was only for hydrostatic pressure, it was decided to write worksheets on solid pressure as well as a service to teachers and pupils.

The worksheets consisted of several units which varied in length. The number of units which could be covered in a lesson was at the discretion of the teacher involved. It was decided not to indicate to teachers the time which should be spent on the units as this might have seemed too prescriptive. In as much as they took different times to complete the syllabus using conventional teaching, so were they expected to when using this package. Only pupil ability and progress determined the pace of teaching.

The worksheets gave step by step instructions to pupils. They also had diagrams and explanations of possibly difficult vocabulary.

6.2.2.1 The pupil worksheets on solid pressure

There were five units on solid pressure to help children with their understanding of concepts.

Conceptual difficulties

Often the pupils attributed the effects of pressure to either force or area and seldom combined the two. The worksheets were therefore designed to present a situation where the

(a) same force was applied while the cross sectional area was varied.

(b) force as well as the cross sectional area were varied in the same proportion.

The pupils were asked to explain how the pressure was affected in (a) and (b).

In these worksheets, use was made of objects which are pointed on one end and flat on the other end such as a ball point pen.

Remediating the conceptual difficulties

The misconceptions were remediated by making use of cognitive conflict as suggested in Hewson (1981). The general procedure was based on the following sequence of steps.

The starting point of the remediation process was stating a problem. For example the pupils were asked to find out why one end of an object (such as a pen) hurts more than the other when each end in turn was pushed against a child's hand. They then had to explain what they thought affected the pain. Their explanations often revealed the misconceptions.

Cognitive conflict was induced by showing the children that it is possible to have the pointed end of the object touching without any pain and that it is possible to have a large applied force with very little or no pain when the surface area is large.

With the help of the teacher a solution was found namely that neither the area nor the force applied can be looked at in isolation. The definition of pressure as force/unit area was introduced after the cognitive conflict activity. The pupils were then helped through questions in the worksheets to realise that both an increase in the force applied and a decrease in the area of contact increased the pressure .

The understanding of the conditions under which the pressure increased and decreased solved the original problem of finding out what affected the degree of pain when an object was pushed against one's hand.

Similar strategies were followed with worksheets on hydrostatic pressure, except that group work was emphasised because of problems incurred when an individual does the experiments such as handling several pieces of apparatus at a time.

Each child in a group of three was given a name and a role which was described in the worksheets. In the choice of names care was taken to use only names that are applicable to both boys and girls. It was hoped that the worksheets would not be seen to have a gender bias by the pupils while the idea of giving roles would ensure that each pupil became active. In addition the children chose for themselves who they wanted to be.

6.2.2.2 The pupil worksheets on liquid pressure

The following misconceptions were identified in interviews and tests:

(a) It was thought that the pressure of water in a container depends on the

(i) total amount of water in a container

(ii) width of the container

(iii) shape of the container

(b) It was further thought that the pressure exerted on one point of a liquid in a closed system will vary and either be diminished or increased as it is transmitted to different points of the liquid.

The worksheets were therefore designed to help both in identifying and remediating these misconceptions.

The worksheets were divided into nine units and addressed several misconceptions. Each unit concentrated on only one of the identified misconceptions.

<u>Conceptual difficulties</u>

Different ways of identifying the misconceptions were used in different units. In units 1-4 the pupils were asked to predict the distance (s) at which a water jet (water jets) from a hole in a container will hit the floor taking the depth of water into consideration. They were then asked to explain their observation once the experiment was performed.

The equipment consisted of fruit juice and milk containers of different shapes and sizes. The liquid used was water and in one case when the effect of density on pressure was compared, paraffin was also used. The following activities were described step by step in the pupils worksheets:

A hole is made in the container and the hole closed with prestik. The container is then filled with water. One pupil opens the hole while another pupil keeps on adding water to ensure that the container is always full. The children are requested to note the positions where the water hits the floor. They then choose the reason why the water jet hits the floor at the given distance. The units then look at the reasons (one at a time). The following are some of the reasons the units look at.

(a) The quantity of water in the container.

(b) The width of the container.

(c) The shape of the container.

(d) The depth of water above the hole.

(e) The pressure in the water.

The misconceptions were then investigated in turn in respective units to show that the reason chosen was incorrect. The remaining units looked at properties of hydrostatic pressure such as its direction, its relationship with the density of a liquid and Pascal's principle.

In these units, the children were asked to:

(a) make a prediction of water levels in two joined parts (of different width) of one container (hydrostatic paradox).

(b) predict and explain the directions of pressure when holes were punched in a plastic bag filled with water and the bag squeezed.

(c) compare effects of density on the pressure by comparing levels of water and paraffin respectively in a manometer arm when the other arm was put in water and paraffin to the same depth.

(d) predict and explain Pascal's principle by comparing the relative increase in the levels of water in the arms of a manometer made for this purpose with simple apparatus.

Remediating the misconceptions

The remediation process was as in section 6.2.2.1. The sequencing of units and activities is shown in figure 6.3.

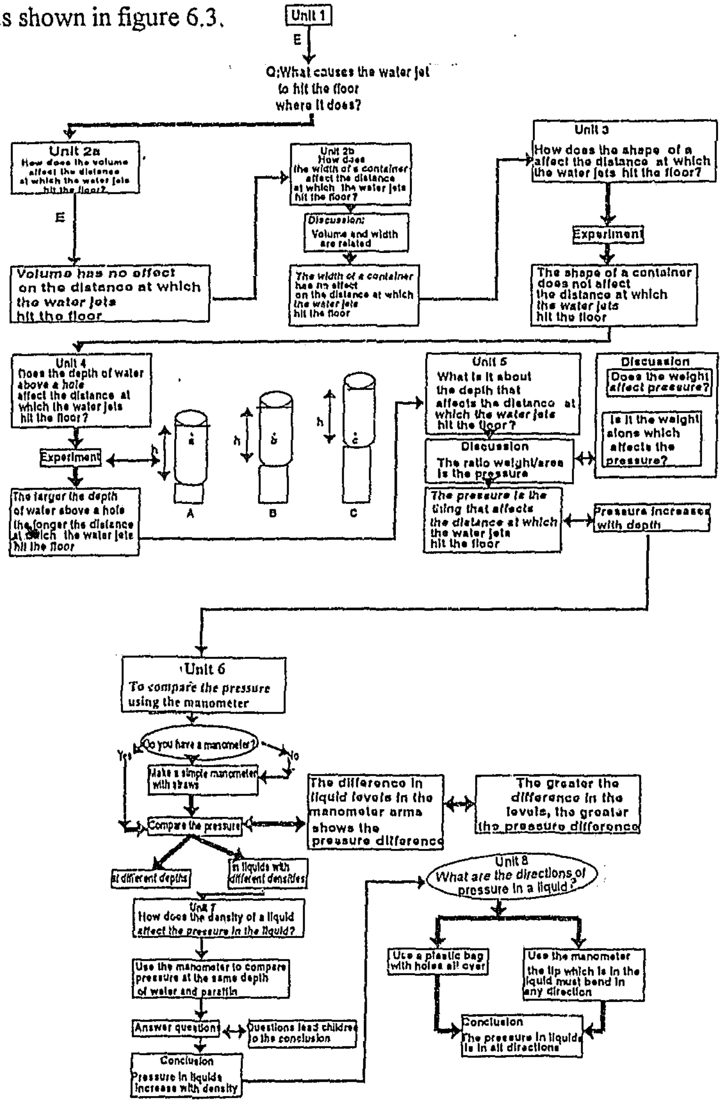


Figure 6.3: Units and activities relating to hydrostatic pressure.

6.2.2.3 Equipment used

Simple equipment was used such as ball point pens, drawing pins, juice containers, and straws which could be found locally. The following were some of the advantages of low cost equipment:

(a) the material for making the equipment was readily available.

(b) the children themselves could make the apparatus. As a result performance of an experiment was not restricted to the classroom but could be done at home as well. This may show the children that school experiments are not a fake and that the principles are not only applicable in a school laboratory but also in everyday situations.

(c) because of the low cost and simplicity, many sets of apparatus could be made, giving all children a chance to perform the experiments. It was considered that in the short to medium term the problem (of shortage of facilities) can to some extent be addressed by low cost equipment.

(d) low cost equipment is cost effective and therefore easy to replace. Once standard apparatus is damaged it might take a long time before being replaced. As a result teaching suffers until the apparatus is replaced. Because of this some teachers do not let the children do the experiments themselves for fear of breakages.

The low cost equipment was modelled on apparatus available in the physics department of the University of the Witwatersrand and on that used in school text books.

The first step in making a piece of apparatus was to find out what apparatus was available for demonstrating a certain concept. It would then be checked whether the apparatus explicitly addressed a known misconception. If it did, the last step would be the construction of similar equipment using low cost material.

In some cases equipment which adequately addressed a misconception could not be found, for example Pascal's principle. An example of the application of Pascal's principle usually found in school books is a hydraulic lift. The problem with this was the fact that while it can be seen that pressure is transmitted, there was nothing to convince the children that the pressure exerted on one end got through to the other side unchanged.

A new piece of apparatus had to be invented to illustrate Pascal's principle. Its construction involved using straws and a juice bottle. The straws with a coloured liquid are dipped to different depths in the container full of water. When the pressure was exerted on the bottle, the level of the coloured liquid in the straws would rise by the same amount. For details see unit 9, appendix A.

6.2.2.4 Language

As far as possible simple language was used in the worksheets although this often resulted in long sentences. The sentences were mostly in the first person in line with everyday communication (for easy reading).

New words were identified at the beginning of each unit and addressed before the pupils started working on the units. This was done by first finding out if the pupils knew the words. If they did not (or gave no response) the teacher would explain the word. In some cases it was suggested that different objects be shown to illustrate the meaning of a word and its opposite. In addition a glossary appeared at the end of the worksheets. Despite this, there was still a need for the teacher to address the new words to ensure that the children had understood.

6.3 Piloting of the teaching package

The materials were piloted together with the tests (section 5.5) at a school in Lebowa. Conceptual difficulties which were not addressed in the teaching guide were identified. In addition the use of the strategies suggested was monitored.

6.3.1 Conceptual difficulties

The pilot teacher in the rural school was asked to answer the diagnostic tests given to pupils ('if she did not mind'). It was put to her that the reason was to determine the extent to which 'we as teachers' agree on the correctness of the answers. This was a polite way to find out the extent to which the concepts and language were problematic. Secondly the knowledge of what the teacher did not know enabled the researcher to offer appropriate extra support to the teacher and to include this in the package.

She did not answer the diagnostic questions. It was decided not to insist on this but instead to hold a discussion on the units with her.

In the discussion, language and conceptual difficulties were uncovered.

(a) She did not know the word 'wedge' which was used in the teacher's guide.

(b) She thought that if a portion of a liquid was in the form of a cube, then the downward force on the top of the cube was equal but opposite to the upward force on the bottom of the cube. It emerged that she had read this incorrect explanation in her textbook. The fact that the weight of the cube adds to the force acting on the top of the cube to balance out the force at the bottom of the cube was ignored.

(c) A third difficulty related to Pascal's principle. The principle was stated in the book as 'If pressure is applied to an enclosed liquid, the pressure is transmitted equally to all parts of the liquid'. The teacher had the view that when an additional pressure is exerted on an enclosed liquid, that pressure is divided equally to all points that were being looked at in the liquid. She said the words 'transmitted equally' used in the textbook gave her that impression. Asked what would happen if the number of such points were increased, the teacher said she realised that she had a misconception because as the number of such points increases, ultimately there would be 'no pressure left to be transmitted'.

(d) Lastly the formula P = F/A used for solids could not be related to hydrostatic pressure at all. However it emerged that, in one of the textbooks used, this relation was made although incorrectly so. The textbook gave the impression that this could be used for all shapes of containers (which is not the case)

6.3.2 Feedback from the teacher and pupils about the materials

The teacher was good at following teaching suggestions mentioned in the teacher's guide and said she was pleased with the way the children were kept active when using the material.

She also said that she found the guide more readable than the textbooks she had seen. Asked to complete an evaluation form about the teacher's guide she wrote that it was, 'exciting and stimulating'.

The children had problems mainly because they had never used worksheets before. They were only used to typical lessons where 'teacher talk' dominates. It was difficult for them to read and follow instructions, particularly in English. The teacher therefore resorted to reading each step of an experiment and explaining this to the pupils so that they could understand. In many cases the explanations were translations of English instructions into the children's vernacular. Added to this was the fact that words rather than drawings were used in most of the instructions. This demanded a lot of interpretation from the children. As a result the units took one and half times longer than was originally planned.

6.4 Modifications to the teaching package

It was decided that the word 'wedge' be replaced by the word 'cube' (which was familiar). It was further realised that the use of a wedge will be difficult to both teachers and pupils as it would involve resolving the force acting on one side into components. Since the wedge was only introduced to illustrate a condition under which the upward and the downward forces would be equal, it was felt that a cube would be at least as efficient because of its familiarity.

Having realised that the teacher had problems with some of the concepts, it was decided to include answers to the questions in the teacher support material. Additional notes were also included in the teaching package to show

(a) the connection between the formula P = F/A in solids with that in liquids.

(b) that the downwards force on the top of the cube is not equal to the upwards force acting on the bottom of the cube.

Since the children also had problems in understanding the worksheets, additional diagrams were included. Having modified the teaching package, it became necessary to validate it before its final implementation.

6.5 Validation of the teaching package

Validation of the teaching package was done by an academic and practising teachers.

The academic was an experienced teacher who had taught science at a college of education before becoming a lecturer at the University of the Witwatersrand. After a discussion some modifications were made.

The final validation of the materials was done in a teachers' workshop (section 5.6) together with validation of the tests. The suitability of the worksheets regarding the everyday words used, the availability of the apparatus used, clarity of instructions and practical problems expected when teaching the units was done in groups of four.

A report back was then given by a representative member of each group. On this basis the teachers could decide whether or not they would be happy to use the package. They were happy with the material, both in content and presentation.

6.6 Plans following the design of the materials

During the process of the design and validation of the materials, it was found that the teachers experienced difficulties with some aspects of hydrostatic pressure. Although there was consensus from the teachers involved during the validation of the materials about the suitability of the content and approach suggested in the materials, it was realised that the approach was novel to them and they were not always confident of their knowledge of the subject content. It was therefore decided that the researcher should be available to assist the teachers if necessary during the final field work (chapter 7).

6.7 Chapter summary

As mentioned in section 5.1, the development of materials could not be separated from test development. Through interviews, lesson transcripts and pencil and paper tests conceptual and language difficulties were identified from teachers and students. Knowledge of these difficulties was not only used to develop diagnostic tests (chapter 5) but also to write materials which aimed at addressing these difficulties. These materials were piloted at a rural school in the presence of the researcher. Finally the materials were validated at a teachers' workshop. It was found that although the teachers were happy with the materials, they needed some support in the use thereof. The researcher therefore planned to be available to support the teachers if necessary during the final field work (chapter 7).

7.0 CHAPTER SEVEN - Evaluation and implementation of the teaching package

7.1 Introduction

This chapter discusses the activities in the teaching package and their modification(s) during the final field work.

Although both the experimental (E1 and E2) and the control (C1, C2 and C3) classes are discussed, this chapter focuses mainly on the experimental schools since they used novel materials, strategies and were most likely to experience unusual problems. The problems might be in the form of questions from pupils or difficulties with the use of the materials.

7.1.1 Overview of the final field work

Figure 7.1 summarises the activities which took place during the implementation of the teaching package.

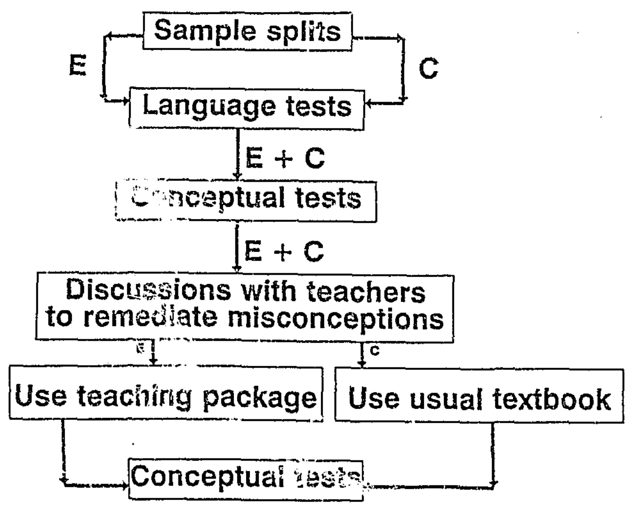


Figure 7.1: Activities during the final field work

The main difference between the two groups was the fact that the experimental schools were given the teaching package to use while this was not done with the control schools. The researcher was available to the experimental groups particularly for the following:

(a) to show the teachers how to use the equipment. The apparatus used was described in the teaching package for the experimental groups and in school books for the control groups. Finally the researcher was available to discuss any other initiative from either the experimental or the control groups.

(b) direct observation to observe the teaching strategies. This entailed looking at how the innovative strategies were used in the case of experimental groups and how traditional strategies and the teacher's initiative were employed in the case of the control groups.

Finally the researcher was available to all groups so that the teachers could be directly assisted with strategies or content where necessary and thus build their confidence. For the experimental groups in particular the assistance was required in the case of the strategies used while it was important mainly to observe the strategies used in the case of the control groups. In both the experimental and the control groups, teachers were assisted with the subject content when they needed it.

At the experimental school the researcher checked the suitability of laboratory, its availability, and the arrangement of classroom buildings in order to decide how best and where the teaching activities could be done as conveniently as possible without interrupting the normal running of the school. It was found that logistics at the school was a problem and therefore the researcher needed to make plans around the logistics. This was followed by the teaching phase. The final activity was to ask the teachers and pupils in the experimental classes to complete an evaluation form for the worksheets and teacher's guide respectively.

7.1.2 Logistical preparations

The researcher requested to be taken to the laboratory to see what facilities were available and the extent to which they were used. It was found that as expected the laboratory was ill equipped and seldom used. In fact standard 7 children never used the laboratory at all as it was always used by a standard 6 class (because they were too many to fit in any other class) during their science classes.

It was realised that since the laboratory was not going to be used and the activities involved water, it would be necessary for the children to bring their own bowls from home. On the other hand, larger classes than originally anticipated were found (160 in one classroom). In order to get as many pupils as possible to participate in the experiments, the pupils had to be divided into larger groups than originally planned. Their classrooms were therefore considered unsuitable. It was then decided that the experiments would be done outside the classrooms. This was discussed with the teachers who agreed with the suggestion.

7.1.3 Initial support for the teachers

Discussions were held with the teachers to help them with subject content and experiments as well as making low cost equipment (see sections 3.3.8 and 3.3.9 - statements of assumptions and limitations of the study).

Facilities were not a difficult issue to address because the teachers readily admitted that they have received poor or no training in the use and making of low cost equipment. However from anecdotal evidence many teachers are reluctant to admit their poor knowledge of the subject content. The latter was thus approached with care.

This was done by discussing known misconceptions on hydrostatic pressure with the teachers and followed by discussions on how these could be remediated. It was decided not to ask for their answers to conceptual problems directly as for some people it could be embarrassing to obtain an incorrect answer.

In order to make the teachers comfortable, they were told something like 'This is what some people think about this concepts, this is not correct, the correct answer should be this. Did you also think like they did or did you know the correct answer?' They often admitted that they did not know the correct answer. In some cases the answers they would have given could be found indirectly, when the teachers asked for further explanation of the concept in question.

7.2 Test administration

Whilst it is acknowledged that it is impossible to totally control administration in different situations, efforts were made to minimise any difference in the administration of the tests.

All six classes at the five schools wrote the same tests. The conceptual tests were always administered first and then the language tests for the sake of consistency.

Both pretest and post-test were given under the supervision of the teachers after a briefing where the teachers were requested to

(a) explain all instructions regarding the test.

(b) explain all terms used in the instructions such as occupation and gender.

(c) help children in deciding what their parents' occupations were if the children could describe what their parents did, but could not name the job or occupation. In addition, they were required to help children who had difficulties with the vocabulary used in the biographical questionnaire.

When the tests had been administered, local preparation for implementation was done with the teachers. This took the logistics of the school into consideration.

7.3 The teaching phase

The two teachers for the experimental groups were given copies of the teaching package.

Because otherwise it could be disruptive to the children's schooling, whole classes were used in all the schools. In addition, this meant that a relatively large number of children from different categories such as home and socio economic status could be found in the sample.

7.3.1 Modifications to the original teaching activities

The two experimental classes did not always take place at the same time. It was therefore often possible to pass an idea discovered in one class (when a child asked a question) to the other class. Some ideas were therefore often passed from one class to the other.

Because of shortage of facilities and large numbers, it was not possible to follow the original design which was that all children should have hands-on experiment action in groups of three. The following modifications were therefore made.

One experiment was done collectively by all children involved in a group. A smaller group of three children would do the experiment while the rest of the children were watching and telling them what to do. In order to keep them active, they were encouraged to make observations, say what they observed and what should be done. In this way all the children had an opportunity to make some kind of contribution.

The children were asked by the teacher to explain new terms or illustrate with the use of the equipment what the words meant. Where necessary the children would be guided with questions to discover the meaning of the word.

Unexpected good points from the teachers could also be observed such as consciousness of language difficulties. For example on starting with the concept of hydrostatic pressure, the question was asked by one of the teachers 'what does the word 'exert' mean?' to which a pupil replied 'apply'.

Units 1 to 3 were done in groups of about 10 outside the classrooms.

Because of the pressure of time, it was decided that from units 4 to 9 demonstrations should be done in class rather than groups of pupils doing the experiments outside the classroom. The demonstrations were however still done by a small groups of children while others participated by shouting the instructions and giving their observations where applicable.

7.3.2 Some difficulties experienced in the implementation of the teaching package

Although the teaching package was discussed with the teachers, they were often unable to handle new questions from pupils possibly because of their academic and professional training (see section 1.3). In addition they often lacked confidence when an experiment went wrong.

There were times when the teachers did not understand what was expected from them. As a result some sections were not treated as expected. As an example, instead of requesting the children to come with their ideas to explain why a water jet hits the floor at a certain distance from a container, teacher E2 treated this as a multiple choice question. The options were only those provided in worksheets. When the children had attempted to answer the questions, the teacher finally provided the correct answer. She however, advised the children that experiments were going to be performed to see whether alternatives were correct or not. While this may achieve the same results as the conceptual change strategies explained in the teaching package, it lacks the element of surprise inherent to the strategies. In addition this restricts the children's answers to the alternatives given in the teaching package.

There were difficulties with unit 8 (directions of pressure using a bag of water) because for some readers the diagrams were not very clear. Some assumptions were made such as that it would be clear to the reader that the tip of the manometer should be either bent in different directions or that it should be removed and replaced by one facing in a different direction since the investigation was about the existence of pressure in different directions. Since bending was easier than removing, the tip was simply bent in different directions. Although this was not a problem in teacher E1 's class, it was not clear to teacher E2.

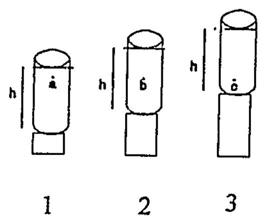
Both teachers were briefed about the options of removing or bending the straws although the worksheets only stated the option of removing. Teacher E2 only followed the option of replacing the straws. This resulted in a considerable loss of her time when this experiment was done because after inserting another straw, the hole had to be resealed to avoid water leakage.

Additional problems emerged in unit 8b (directions of pressure using the manometer). One was that in one diagram only the straw that goes into the liquid was shown, the rest of the manometer was not shown. Although teacher E2 had received prior briefing on this, she appeared confused by the diagram when the experiment was done. Another problem was the drawing of four containers each with the tip of the manometer pointing in a different direction. This was meant to clarify the position at which the tip should be put. However this was interpreted to mean that four containers were required. Identical containers were used, therefore this did not induce any error. Although she followed this instruction as she understood it, she later mentioned that she thought four containers were not necessary and suggested at most two.

The following were the last two problems coming from children:

(a) A dot was used to indicate the position where the manometer tip needed to be placed. Since the dot was similar to that used to indicate the point at which a hole should be made in the container, the children thought that again they needed to make a hole at that spot. The teacher realised this when the children performing the experiment were just about to make the holes and advised them accordingly.

(b) The last problem related to the following diagram.



The containers above are identical and have the same level of water.

The children thought the shorter line in container 3 above (to indicate the water level) would affect the answers. This was not a problem for the teachers although it was for the children.

As teacher E1's class was ahead of teacher E2's class in the work covered, it was possible to warn teacher E2 of some responses that may come out due to the errors, while teacher E1's problems could immediately be addressed with the help of the researcher. A possible way of addressing this problem is suggested in chapter 9.

As far as possible, the control lessons were also monitored.

7.3.3 The control lessons

All three teachers had at least one textbook used for reference purposes in addition to the prescribed book which was also used by the pupils. The control teachers were allowed to use any resources and teaching strategies they had access to.

The control teachers were given any form of support including lesson preparations when it was so required. This involved how to introduce a topic and what teaching aids were necessary. This kind of assistance was requested by only one teacher. Often this was done at her home in the afternoon.

The researcher sat in some of the control lessons and took full notes. A constraint in visiting these classes was the fact that it was not always possible to drive from one school and arrive in time for the next period at another school. In such cases it was necessary to rely on feedback from the teachers.

7.4 chapter summary

The final field work has shown that although advance planning of the field work was essential, the researcher should be ready to handle the unknown. It is thus important to adopt a flexible approach so that one can adapt to the unexpected and changing circumstances.

It is also important to the researcher to be available during the field work to see the extent to which the teachers adhered to plans. Events during the final field work have shown that the success of the planned activities can be affected by the competence of the teachers involved. In addition, as it turned out in this particular case, the researcher had an opportunity to see how the materials could be used in large classes.

8.0 CHAPTER EIGHT0 - Results and Analysis

8.1 Introduction

The analysis of the data has both quantitative and qualitative components.

The quantitative analyses were:

(a) comparison of the pretest scores for each group (section 8.2.2, tables 8.3 and 8.4) using descriptive statistics and t-tests respectively.

(b) comparison of the pre-, post-test and change in scores of the experimenta' and the control groups separately (section 8.2.4, table 8.7) using descriptive statistics.

(c) analysis of covariance for all groups - this looked at the following independent variables with preknowledge as a covariate (section 8.2.4, tables 8.8 and 8.9):

   (i) type of intervention (i.e experimental or traditional materials and teacher effects)
   (ii) gender
   (iii) age and
   (iv) socio economic status.

   The analysis of covariance was done separately for
   (a) the answers on the conceptual test only and
   (b) the reasons given for the correct answers.

(d) analysis by concept of the multiple choice test results (section 8.3.3).

(e) the attitudes of pupils towards the experimental materials (section 8.3.5).

The qualitative analysis illuminated some of the quantitative results in terms of teaching styles and language strategies in the classrooms. This was investigated using

(a) observations

(b) field notes

(c) lesson transcripts.

In the analyses of this data, the following factors should be taken into consideration:

(a) The teachers in the control groups received as much physics content support as those in the experimental groups (for ethical reasons).

(b) The teachers in the control groups were not discouraged from using their own language strategies. As a result some of them used strategies which, in places, were very similar to those specifically designed to be used with the experimental groups.

8.2 Quantitative analyses - general

The data collection will be discussed first and then the discrimination and difficulty indices of the test items. These will be followed by the analyses of results.

8.2.1 Data collection

Data were collected in both the pilot study and the main field work as described in chapters 4 and 5. The total data collected are summarised in tables 8.1 and 8.2.

Table 8.1: Data collected in the pilot study

Initial investigations		
Groups	Activities	N
Preliminary investigations		
Standard 7	lesson tapes	10
Teachers	interviews	4
Pupils	interviews	10
Student teachers	open test	20
The pilot process		
Alternative school	multiple choice test	40
College of Science	multiple choice test	100
Rural school	multiple choice test	30

Table 8.2: Data collected in the main field work

Main field work		
Groups	N*	Activities
E1 E2	134 126	Conceptual test - pre- and post-test and Biographical questionnaire Language tests Intervention Field notes - six lessons Attitude questionnaire (1 teachers and 100 pupils)
C1 C2 C3	55 53 64	Conceptual test - pre and post-test Biographical questionnaire Language tests Field notes (6 lessons)

* - total number of pupils who wrote both the pre- and the post-test

The biographical questionnaires obtained information about age, gender, and the socio economic status of both the father and the mother, not just of one parent as was the case in a previous study (Nkopodi, 1990).

8.2.2 Initial comparison of the groups

Following the problems encountered in the field work (section 3.3), involving a change of part of the sample, it became necessary to check whether meaningful deductions could be made from the data obtained. The means and standard deviations for each test were calculated. These are shown in table 8.3. In addition, a univariate normal plot was done to compare distribution of scores on the pretest.

Table 8.3: Pretest means on conceptual test by group

Group	N*	Mean	Std dev
E	[illegible]	3,39	1,32
E1	142	3,49	1,29
E2	148	3,28	1,34
C	234	309	1,45
C1	76	3,13	1,54
C2	67	2,56	1,58
C3	91	3,26	1,38

* - all pupils who wrote the pretest

Table 8.3 shows that the standard deviations in each case are similar indicating that the data are fairly symmetric. A univariate normal plot showed that the data was normally distributed. The t-test was then used to compare the pretest means between each pair of groups before teaching to compare scholastic performance between the groups. It is essential to know if their pretest scores (i.e. preknowledge) are comparable in the first instance (table 8.4). Since the extent to which learners acquire new knowledge meaningfully frequently depends on their prior knowledge.

Table 8.4: Comparison of pretest conceptual scores

Groups	t	df	p
E and C	2,35	476,4	x
E1 and E2	-1,35	288,0	ns
E1 and C1	-1,73	132,4	ns
E1 and C2	-3,20	119,5	xx
E1 and C3	-1,26	182,4	ns
E2 and C1	0,72	134,1	ns
E2 and C2	-2,17	121,1	x
E2 and C3	-0,[illegible]0	185,3	ns
C1 and C2	-1,19	140,7	ns
C2 and C3	-1,88	140,6	ns
C1 and C3	0,57	152,6	ns

ns - not significant

x - significant at 0,05 level

xx - significant at 0,01 level

Table 8.4 shows that most groups were not significantly different from each other. However, the combined experimental group, E was significantly better than the combined control group C. When individual groups were compared, it was noted that the only significant difference was that the control group C2's mean was lower than those of both the experimental groups. This suggests that it was the group C2 which made groups E and C significantly different.

It was considered important to protect the analysis against at least some of the type (i) and type (ii) errors. Type (i) error refers to a situation where a tested hypothesis is falsely rejected while type (ii) error refers to a situation where an error is made by not rejecting a hypothesis when it is false (Hays, 1994).

Ten independent tests needed to be done in this case (a comparison of two experimental groups with three control groups), $\alpha_w = \alpha_1 + \alpha_2, +...+ \alpha_{10},$ where 'α_w' is a family wise error rate and α_i is the probability of making type (i) error for test i (where i = 1, 2, ..., 10).

α_{pc} (α per comparison between any pair of groups) is then defined as $\alpha_{pc} = \alpha_w/10$. Since in educational research the probability of 0,05 is often the least significant acceptable, α_w can be chosen to be 0,05 for the purpose of this research. If α_w is defined as 0,05, then two groups can only be significantly different if $\alpha_{pc} = 0{,}005$ i.e. we choose a new level of significance. This therefore means that no groups were significantly different on pretest results.

The forgoing discussion has shown that despite the forced change in the sample, the final sample was suitable because the groups were comparable in terms of their preknowledge.

8.2.3 Suitability of the conceptual test for the sample

Discrimination indices were calculated for each item to test the extent to which each item discriminated between the students who achieved high marks on the total test and the students who achieved low marks on the total test (for the whole sample).

Facility indices were used to find if the test was at the level of an average standard 7 child in this sample. (Section 3.5.3 shows how the discrimination and facility indices were calculated).

The discrimination and facility indices for the different conceptual questions are shown in table 8.5.

Table 8.5: Discrimination and facility indices

	Discrimination indices		Facility indices	
Questions	Pretest	Post-test	Pretest	Post-test
*1	0,2	0,2	81,9	84,7
*2	0,4	0,4	36,8	40,8
3	0,5	0,5	37,5	42,8
4	0,2	0,2	24,4	22
*5	0,4	0,4	53,3	65,4
#6	0,3	0,4	20,8	23,5
*7	0,3	0,3	19	22
#8	0,2	0,2	26,1	17,4
9	0,01	0,1	0,95	2,72
#10	0,4	0,4	24,8	25,6

* = questions testing effects of depth on pressure

= questions testing Pascal's principle

A discrimination index of around 0,3 is regarded as acceptable (Crocker, 1974). Table 8.5 therefore shows that most questions discriminated well. In all cases there were no negative discrimination indices, suggesting that no question could be rejected outright as totally inappropriate (Crocker, op. cit., p. 76).

The table further shows that the facility indices also varied across questions. Crocker (op. cit.) states that a facility index of around 50, that is 50% of the class can obtain the correct answer, is generally accepted as average. Variations in the facility indices further show that the questions had different levels of difficulty.

The facility indices show that question 1 did not discriminate well because it was too easy while questions 4, 8 and 9 did not discriminate well because they were too difficult. The remaining questions discriminated well despite being difficult.

The table shows that with the exceptions of questions 4 and 8 the facility index rose in the post-test (although some remained below 50) suggesting that the questions were becoming easier after teaching, which was hoped for.

8.3 Quantitative results

Pre- and post-test means were used to investigate the performance of different groups. The groups were compared in the following ways.

(a) connection between the conceptual and the language tests
(b) intact experimental and control groups
(c) experimental versus control groups by
(i) socio economic status
(ii) gender
(iii) age

8.3.1 The language tests

The language tests were colour coded green, blue, yellow and pink following Johnstone and Cassels (1985) as explained below.

Green - word synonym without context
Blue - the word is used in a science context
Yellow - the word is used in a non-science context
Pink- the word is used in four everyday situations only one of which is correct.

The language tests were first administered as part of their validation to teachers in a workshop. The majority of these teachers had a poor performance (table 5.2).

For the pupils the language tests were administered before they were taught about hydrostatic pressure. Their scores (table 8.6) were therefore influenced by prior knowledge and not teaching during the period of this research.

The mean score for each test was calculated. In addition, Pearson's product moment correlation coefficients was used to investigate the relationship between the conceptual test and language tests.

Table 8.6: Percentage scores obtained in the language tests

Group	N	Yellc		Blue		Green		Pink	
		%	std	%	std	%	std	%	std
E1	35	5,6	1,7	4,5	1,8	5	2,1	4,9	2,1
E2	37	5,6	1,7	4	1,7	4,5	1,6	4,7	1,5
C1	19	3,6	1,9	3	1,4	3,8	1,6	3,6	1,5
C2	17	5	1,9	3	1,6	3,8	1,5	3,6	1,3
C3	23	5	2,0	4,3	1,6	3,5	1,5	3,8	1,4

Table 8.6 shows that the scores obtained were very low for all groups in all the language tests. The experimental groups performed better than the control groups in the 'pink' and the 'green' tests. In addition, the experimental groups performed better than group C1 in all tests and better than group C2 in the 'blue', 'green' and 'pink' tests. These differences were however, not significant.

Looking at table 8.6 from another perspective, we find that for all groups apart from C1, performance in the yellow test was best. In general (except groups E1 and C3) this was followed by the pink test. This suggests that words were better understood in a non-scientific (everyday) situation.

Pearson's correlation coefficients did not show any correlation between scores obtained in the language tests and scores obtained in the conceptual tests. This may be explained by the possibility that the language tests were difficult to the point where the majority of the children were guessing their answers.

8.3.2 Relative performance between different groups on the conceptual test

Table 8.7 shows pretest and post-test mean scores for each group both for correct answers and correct reasons for the correct answer.

Table 8.7: Pre- and post-test means for answers and reasons

Answers								Reasons for the correct answer						
Group	N1	Pre-Mean	Rank	Post-Mean	Rank	Change	Std	N2	Pre	Rank	Post	R	Change	Std
E	260	3,32		3,54		0,22		100	1,06		1,67		0,61	
E1	134	3,49	1	3,59	1	0,10	1,48	64	1,31	1	2,15	1	0,78	1,41
E2	126	3,28	2	3,53	3	0,25	1,39	36	0,80	3	1,12	2	0,40	1,20
C	172	3,09		3,39		0,3		33	0,64		0,66		0,02	
C1	5*	3,13	4	3,29	4	0,16	1,87	6	0,33	5	0,27	5	-0,10	0,76
C2	53	2,56	5	2,84	5	0,28	1,70	7	0,37	4	0,67	4	0,26	1,00
C3	64	3,26	3	3,55	2	0,29	1,73	20	1,08	2	1,00	3	-0,03	1,32

E - the experimental groups combined

C - the control groups combined

N1 - all pupils who wrote the tests

N2 - all pupils who obtained the correct answers in the conceptual tests

The ranks, 'R' show relative performance of different groups for the answers and reasons given for the correct answer based on either the pre- or the post-test score.

Table 8.7 shows that all pupils performed very badly with means around 35% - that is only 3 to 4 questions out of 10 were answered correctly, and even of these on average, only 1 or 2 questions included the correct reason for the correct answer. For the intact group E for example, the average number of correct answers in the pretest was 3,32 and of these, only an average of 1,06 correct reasons were given. This means on average a student would get a correct answer and a correct reason for only one question. However, there were pupils who obtained scores as high as 7 out of a total of 10, although they were a minority.

As table 8.7 shows, although there are differences, the students performed badly in all groups both in the pretest and the post-test. This holds both for the conceptual answers and the reasons given for the correct answers.

Within the overall poor performance (ranging in scores from 0 to 7 out of 10), for the intact groups E and C in table 8.7 we can see that the experimental groups performed better in the pre- and the post-tests for both the conceptual answers and the reasons given for the correct answers. However the control groups improved more than the experimental groups in the conceptual answers while the reverse was true for the reasons given for the correct answers. The scores were also investigated for individual groups.

For the conceptual test, group C2 had the lowest mean scores in both the pre and post-tests. The remaining groups were comparable in the pre- and post-test scores on the conceptual test.

In the case of conceptual answers, improvement was higher for the control than for the experimental groups. The improvement in scores from the pretests to the post-tests show that the control groups C2 and C3 have benefitted most (giving the correct answers).

Improvements for the conceptual answers were low in groups E1 and C1 while they were comparable in the remaining groups. The group which improved least on the conceptual answers (E1) was the group which improved most on their ability to give the correct reasons for their answers. This group, E1, also had the highest test scores on both the pretest and the post-test. It is therefore not surprising that improvement was low since the pretest score was higher as well. Improvement was only significant at the 0,05 level for the experimental groups and only so for the reasons given for the correct answers.

Since each group had a different teacher, it could be that different aspects of the content were emphasized resulting in the achievement of different objectives. It appears from the table that the children in the experimental groups could explain their answers better (they had higher scores on the reasons given) than the children in the control groups, while the children in the control groups improved better at giving the correct answer - something which could be achieved even by rote learning.

Ranking different groups by the mean of their scores reveals results which are far too general for effects of different variables to be understood. Covariate analysis is thus necessary to try and understand effects of different variables.

8.3.3 Effects of individual variables

The effects of intervention (type), gender, age, socio economic status and preknowledge (pretot), were looked at for both experimental and control groups with the preknowledge as a covariate and the post-test score as a dependant variable. The equation used was the following:

*post-test = type type*variable1*variable2 type*variable1 type*variable2 variable1 variable2 pretot.*

'*' indicates interaction between variables. 'Variable' stands for any variable being investigated such as gender or age, etc. This equation was used both for the correct answer and for reasons given for the correct answer. The computer was programmed to calculate the relevant score in each case.

All variables were initially used in the equation. Then the number of variables was gradually reduced to identify variables which affected the post-test score significantly.

The pupils were categorised into age groups so that the number of pupils in each age group was large enough for quantitative analysis to be used.

1. under 16, N = 222
2. 16 to 19, N = 189
3. above 19, N = 20

8.3.3.1 Intervention, gender, age and preknowledge

Table 8.8 shows the results of the covariate analysis for all groups on the conceptual answers.

Table 8.8: All groups on the conceptual answers.

N = 431

Source	With interaction			Without interaction		
	df	f value	p	df	f value	p
Type	4	1,69	ns	4	0,94	ns
Gender	1	0,04	ns	1	3,44	ns
Age	2	0,90	ns	2	0,68	ns
Gender*Age	2	0,78	ns			
Type*Age	6	1,27	ns			
Pretot	1	31,48	xx	1	33,29	xx

ns - not significant

xx - significant at 0,01 level

Table 8.8 shows that only the covariate (preknowledge) was significantly related to the post-test score.

Table 8.9: All groups on reasons given for the correct answer. N = 113

Source	With interaction			Without interaction		
	df	f value	p	df	f value	p
Type	4	7,78	xx	4	15,98	xx
Gender	1	0,05	ns	1	1,11	ns
Age	2	0,72	ns	2	1,22	ns
Gender*Age	2	0,59	ns			
Type*Age	6	0,65	ns			
Pretot	1	106,67	xx	1	111,97	xx

ns - not significant

xx - significant at the 0,01 level

Table 8.9 shows that when the reasons for the correct answer are considered then intervention as well as the preknowledge made a significant difference. It would appear that teaching styles and the materials used in the experimental groups helped the pupils to understand the concepts.

8.3.3.2 Parental socio economic status

In South Africa particularly in the rural areas because of the migrant labour system, men often work in the large cities far away from home and only come home during weekends or when they are on leave. Even that depends on the availability and affordability of transport. Since it is possible that the two parents had different influences on their children 's studies, the effect of the socio economic status of each parent was therefore looked at separately.

Table 8.10: Effects of the parental socio economic status on the conceptual test score.

Source	With interaction			Without interaction		
	df	f value	p	df	f value	p
Type	4	0,73	ns	4	1,13	ns
Age	2	0,63	ns	2	0,71	ns
Father	6	0,65	ns	6	1,27	ns
Type*Father	18	0,77	ns			
Age*Father	7	1,76	ns			
Type*Age*Father	9	2,05	ns			
Pretot	1	27,24	xx	1	30,05	xx
Type	4	0,46	ns	4	0,88	ns
Age	2	0,24	ns	2	0,66	ns
Mother	6	0,88	ns	6	1,04	ns
Type*Mother	16	0,95	ns			
Age*Mother	6	0,33	ns			
Type*Age*Mother	9	0,58	ns			
Pretot	1	18,83	xx	1	23,97	xx

ns - not significant

xx - significant at the 0,01 level

Table 8.10 shows that neither the mother's nor the father's socio economic status had any effect on the post-test score in the conceptual test, once again only the pretest score was related to post-test achievement.

Table 8.11: Effects of the parental socio economic status on the reasons given for the correct answer

Source	With interaction			Without interaction		
	df	f value	p	df	f value	p
Type	4	3,32	xx	4	9,04	xx
Age	2	3,30	x	2	1,67	ns
Father	6	0,80	ns	6	1,43	ns
Type*Father	18	1,43	ns			
Age*Father	7	2,01	x			
Type*Age*Father	9	1,23	ns			
Pretot	1	85,32	xx	1	83,69	xx
Type	4	6,41	xx	df	10,41	xx
Age	2	2,79	ns	2	0,80	ns
Mother	6	1,48	ns	6	1,99	ns
Type*Mother	16	1,42	ns			
Age*Mother	6	1,62	ns			
Type*Age*Mother	9	0,59	ns			
Pretot	1	82,81	xx	1	99,52	xx

ns - not significant

x - significant at 0,05 level

xx - significant at 0,01 level

When the reasons given for the correct answer were considered (table 8.11), the socio economic status of the father became more important. For example intervention, age, and age*father were significant, contrary to 'intervention' only for the mother. The mother's socio economic status might be expected to be more important than that of the father because of the fact that she stays longer at home with the children. However it appeared that the socio economic status of the father (who is almost certainly the head of the family) was more important. The father was possibly in many cases more instrumental than the mother in determining what facilities are available and the general life style of the family.

On the whole it appeared that the preknowledge of the pupil was the most important factor determining the post-test score. All other variables were not consistently significant across the groups.

8.3.3.3 A comparison of individual groups

Since all groups were involved in the above analysis of covariance it is possible to have significance in one or more pair wise comparison which then become negligible when other groups (which do not show this significance) are involved. It was therefore decided to use an ancova to do a pair wise comparison of all possible combinations of the experimental and the control groups to see whether some pairs of groups showed such a significant effect.

The variables used were type (whether experimental or control), age, type*age, type*gender and pretot (pretest score). However only those variables which proved to be significant in at least one pairwise comparison will be reported.

Tables 8.12 and 8.13 show variables which had significant effects.

Table 8.12: Significant variables for the correct answers

Groups	Age	df	f value	Gender	df	f value	df	f value	pretot
E1 and E2	ns	2	0,57	ns	1	1,47	1	29,74	xx
C1, C2, C3	ns	2	0,79	x	1	1,12	1	6,79	xx
E1 and C1	xx	2	5,29	ns	1	1,47	1	23,34	xx
E2 and C1	x	2	3,04	ns	1	0,79	1	12,06	xx
E1 and C2	ns	2	2,15	ns	1	1,64	1	21,41	xx
E2 and C2	ns	2	0,85	ns	1	1,00	1	9,96	xx
E1 and C3	ns	2	0,89	xx	1	12,27	1	23,53	xx
E2 and C3	ns	2	1,83	xx	1	9,24	1	13,10	xx

ns - not significant　　　　　xx - significant at the 0,01 level

x - significant at the 0,05 level

Table 8.12 shows that the experimental groups were not significantly different from each other. On the other hand, for the control groups gender had a significant effect on the post-test score. When the experimental groups were compared with group C3, each experimental group performed better than group C3, gender being significant. Within each group boys performed better than girls. Age became significant when the experimental groups were each compared with group C1. In both cases the experimental groups were younger on average and performed better than the students in group C1. It is possible that group C1 had more repeaters (who might be older and less motivated) than the experimental groups. The number of repeaters in each group was not investigated. The pretest score remained significant in all comparisons.

Table 8.13: Significant variables for the reasons given for the correct answer

Groups	type	f value	df	pretot	f value	df
E1 and E2	xx	21,36	1	xx	88,74	1
C1,C2,C3	ns	2,01	2	xx	33,10	2
E1 and C1	xx	21,89	1	xx	63,24	1
E2 and C1	x	4,10	1	xx	34,54	1
E1 and C2	xx	12,95	1	xx	62,32	1
E2 and C2	ns	1,12	1	xx	35,31	1
E1 and C3	xx	9,95	1	xx	61,22	1
E2 and C3	ns	0,17	1	xx	37,54	1

ns - not significant

x - significant at the 0,05 level

xx - significant at the 0,01 level

Table 8.13 shows that on overall there was significant difference between the experimental groups on the post-test score (type is significant). Since the pretest scores of the experimental groups did not differ significantly, this difference may suggest that teachers in the experimental groups had different abilities in using the experimental materials. This may mean that one of them (E1) was quicker than the other (E2) to acquire skills required to use the resources effectively. The fact that the control groups were not significantly different may suggest that over time the teachers got used to using certain examples in a similar manner to the point where they achieved a comparable level of competence in the use thereof. In addition they received the same kind of training at the teachers' colleges of education.

Table 8.13 shows that when the groups were compared in pairs, group E1 was significantly better with respect to each of the groups while group E2 was significantly better only with respect to group C1. This suggests that the teacher in group E1 was most efficient in the strategies used. The teacher E2 even when equipped with identical resources to the teacher in group E1 did not achieve comparable results. Therefore resources alone are not enough to effect conceptual change but a combination of resources with good strategies is more effective.

Tables 8.12 and 8.13 show that only the pretest score was significantly related to the post-test score both for the correct answers and for the correct reasons given for the correct answers. Other variables were not consistently so and depended on groups which were being compared.

The fact that the pretest score always had a significant effect shows the importance of the pupils' preknowledge. Intervention also was significant (to a lesser extent) for the reasons given for the correct answer. It can therefore be said that scholastic achievement was largely affected by the combined effects of intervention and the pupils' preknowledge. Age and gender were significant only in certain cases. The variables intervention, age and gender are therefore not reliable to predict scholastic achievement to the same extent as the preknowledge.

3.3.4 Analysis by concept

The global results can only indicate trends. In this case poor understanding of pressure concepts. Each question targeted a specific idea and must therefore be considered separately. However the following discussion must be seen in light of the overall poor performance of all standards.

This part of the analysis will focus on children who

(a) obtained the correct answer and gave various reasons for the correct answer.
(b) consistently obtained correct answers in both the pre- and the-post-test
(c) in addition to being consistently correct in their answers are consistently correct in the reasons given as well
(d) changed from an incorrect answer to the correct answer
(e) changed from an incorrect answer to both the correct answer and the correct reason
(f) changed from the correct answer to an incorrect answer.
(g) changed from the correct answer and correct reason to an incorrect answer.

Children who benefited most from instructions are those in category (e).

A t-test of proportions of students who obtained the correct answer for each question in the pre and the post-test to the total number of students who wrote the test (section 3.5) was used to check if post-test scores were significantly better or worse than the pretest scores for each question.

In the conceptual test some of the questions may be grouped together since they address the same concept. These groups are questions 1, 2, 5 and 7 which all look at the relationship between the pressure and depth and questions 6, 8 and 10 which all look at Pascal's principle. Other concepts are each looked at in only one question. For this reason the analysis is subdivided into 5 concepts namely

(a) the relationship between the pressure and depth (questions 1, 2, 5 and 7)

(b) the relationship between the pressure and the volume of a liquid (question 3).

(c) the relationship between the pressure and the density of a liquid (question 4).

(d) Pascal's principle (questions 6, 8 and 10).

(e) Direction in which pressure is exerted (question 9).

In each case the incorrect answers were combined unless a point of interest emerged, for example if a large number of pupils gave one incorrect reason for a correct answer. The reasons given for the correct answers are coded and put in parenthesis next to the reason. For some questions the number of pupils obtaining the correct answer was so small that it is not represented in a figure.

All improvements in the discussions referred to as 'significant' are significant at the 0,05 level.

<u>The relationship between pressure and depth.</u>

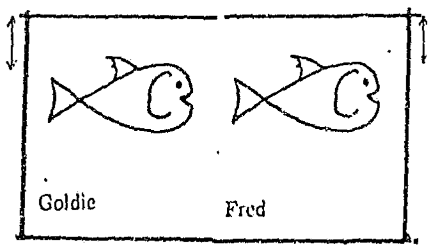
This concept is looked at in questions 1, 2, 5 and 7. Each question looks at the same problem from a different perspective.

Questions 1 and 2 were similar (in terms of distracters) but the diagrams were slightly different.

Question 1:

Pressure at the same level.

The stem of the question was stated as: 'The diagram shows two fish, Goldie and Fred in a tank of water.

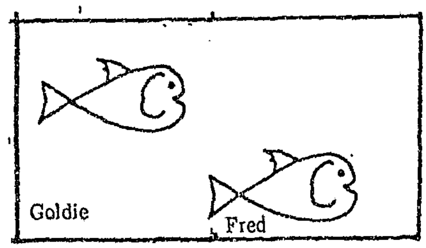


Compare the pressure on the two fish

Question 2:

Pressure at different levels.

The stem of the question was stated as: 'Fred has now moved deeper in the tank



Compare the pressure on the two fish

The alternative answers for both questions are shown in the table below.

Answer	**Description of the answer**
a	The pressure on Goldie is greater than the pressure on Fred
b	The pressure on Goldie is the same as the pressure on Fred (correct for question 1)
c	The pressure on Goldie is lower than the pressure on Fred (correct for question 2)
d	I do not know

Different reasons were given for the correct answer but it was found that these could be grouped into a total of 8 categories.

The numbers on the left below show how the reasons for question 1 were coded and those on the right relate to question 2.

Goldie and Fred are at the same level (1).
The size of the fish is the same (2).
One fish is bigger or deeper (Inability to read a diagram) (3)
The fish are at the same level and facing the same direction (Level and direction) (4)
The fish are the same size and face the same direction (Size and direction) (5)
Language difficulty (6)
The fish are in the same tank (7)

Fred is deeper in the water than Goldie (1)
The size of the fish is the same (2)
One fish is bigger (Inability to read a diagram) (3)
Pressure decreases with depth (4)
Pupils read more into diagrams than is there (i.e. movement) (8)
Language: difficult to interpret (6)

The reasons can be summarised as follows:

Reasons 1 and 4 in both questions relate to the depth.

Reasons 2, 3 and 5 in question 1 and reasons 2 and 3 in question 2 refer to the size of the fish. The fact that the children referred to the size of fish as reason for the correct answer may suggest that the children confused characteristics of hydrostatic pressure with those of solid pressure, in this case it was the connection between hydrostatic pressure and area (size of the fish or the surface area of the fish).

Reasons 8 in question 2 referred to movement while no reason for question 1 related to movement. Reason 8 read more into the diagram than was actually the case. The fact that reasons 8 for question 2 referred to movement may have to do with the fact that the fish had changed position and the respondents failed to understand that the question refers to the situation where both fish are stationary. Reason 6 in both questions implies language difficulties.

The fact that some of these reasons can be grouped under one concept difficulty such as depth, shows that different pupils can have different difficulties around the same concept by looking at it from different points of view.

The pre - and post-test results for questions 1 and 2 are discussed below and shown respectively in figures 8.1 to 8.6.

Figure 8.1: Pretest and post-test answers

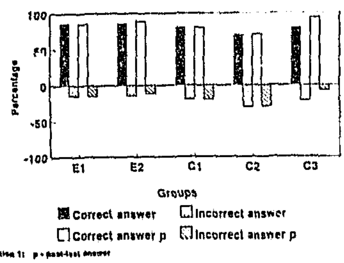
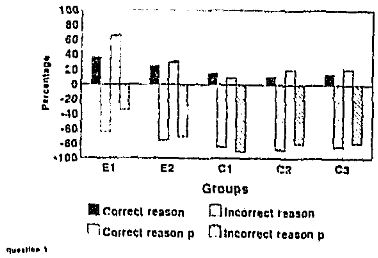


Figure 8.2: Reasons for the correct annswer



For question 1, figure 8.1 shows that for all groups at least 70% of all children obtained the correct answer. This suggests that the children did in fact know something about hydrostatic pressure, that is, the idea that hydrostatic pressure is the same at any two points at the same level is well established.

However, looking at question 2 (figs 8.3 and 8.4 below) which was a variation of question 1, i.e the pressure was compared at points that are at <u>different</u> levels the initial feeling with question 1 was not confirmed.

Figure 8.3: Pretest and post-test answers

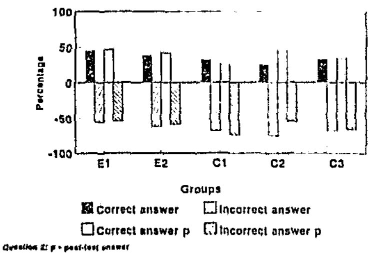
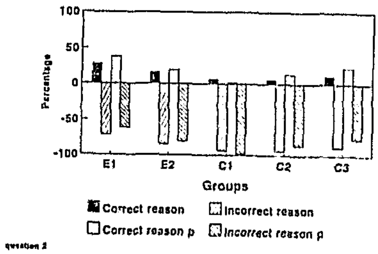


Figure 8.4: Reasons for the correct answer



We find that overall performance in question 2 was not as good as in question 1 neither for the answers to the conceptual questions nor reasons given for the correct answer. Thus an initial feeling that pupils know that hydrostatic pressure increases with depth was not totally supported. Pupils knowledge and understanding of this concept is fragile.

Considering reasons given for the correct answer (figures 8.2 and 8.4), all groups except C1 improved on the post-test in both questions but this was only significant in groups E1 and C2 for question 1 while for question 2 it was groups E1, C2 and C3 which made significant improvements - all at the 0,05 level.

Students' performance in these questions can also be seen in terms of movement to and from the correct responses.

Figure 8.5: Changed and consistent responses

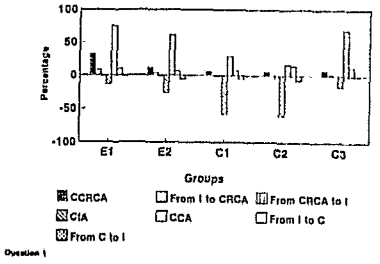


Figure 8.6: Changed and consistent responses

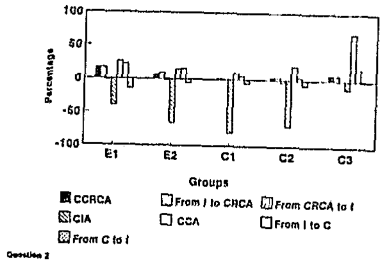


Figure 8.5 shows that for question 1 the experimental groups and group C3 had a higher percentage of pupils than the remaining groups consistently obtaining the correct answer in both the pre- and the post-test. For question 2 (figure 8.6) group C3 had the highest percentage of such pupils.

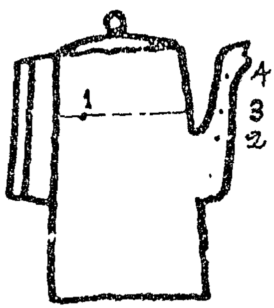
The experimental groups proved to be better than other groups when the reasons were looked at. For example figure 8.5 shows the experimental groups had a higher percentage of pupils consistently obtaining the correct reason for the correct answer (CCRCA) than the remaining groups while the control groups were comparable.

When performance is looked in terms of those who benefitted from intervention, figures 8.5 and 8.6 show that although the number of children turning to the correct answer was small, for question 1 it was group C2 and C3 which had the highest percentages. For question 2 it was the experimental groups and group C3 which had the highest percentage. It therefore appears from figures 8.5 and 8.6 that group C3 benefitted most in this particular question. In what can be regarded as a sign of better understanding than other groups, in question 1 it was only the experimental groups and group C3 had children turning to the correct reason for the correct answer although the perrentages were all small.

The above discussion, shows that in these questions, the experimental groups and group C3 had a comparable performance which was better than that of the remaining two groups.

Because of the need to investigate understanding from different perspectives, the relationship between hydrostatic pressure and depth was tested in a different way in question 5. Question 5 indirectly asks the question, 'what happens if an attempt is made to make the pressure different at two points which are at the same level by adding water at one of the points? i.e. water is added onto one point (increase of pressure) and observation made to see what happens at the other point.

Question 5: 'The hydrostatic paradox': The question was: Water is poured into the kettle below until it reaches level 1.



Where would the level be in the spout?

(a) 2
(b) 3
(c) 4
(d) I do not know

The following are the reasons given in responses to this question

The water level must rise until the pressure at the bottom is the same (1)

Magnitude of number (such as 'c' because 4 is a big number) (2)

Personal (eg. otherwise water can flow to the table) (3)

This is how it should be (4)

The level depends on the width of the container (5)

Parts of the kettle have different sizes (6)

The pre - and post-test results for question 5 are discussed below and shown in figures 8.7 to 8.9.

Figure 8.7: Pretest and post-test answers

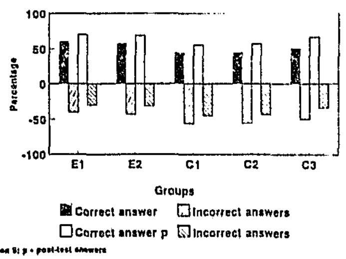
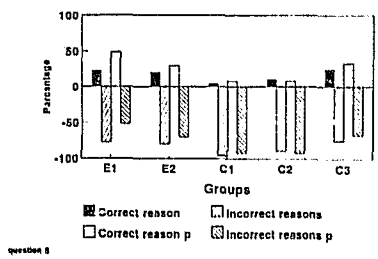


Figure 8.8: Reasons for the correct answer



Figures 8.7 and 8.8 show that once again there was poor understanding even though for the conceptual answers overall performance in this question was better than in question 2 however it remained weaker than in question 1.

Figure 8.7 shows that for the conceptual answers all groups showed an improvement although in no cases was the improvement statistically significant. When the reasons given for the correct answer were looked at (fig 8.8), improvement on the-post-test was significant in group E1 only. In the other groups failure to explain their answers could be because the hydrostatic 'paradox' was not explained (as mentioned in section

8.1, the researcher sat in the lessons and made this observation - section 8.4).

The effect of the teaching can further be seen in terms of movement to and from the correct answers in this concept. The movement is illustrated in figure 8.9.

Figure 8.9: Changed and consistent responses

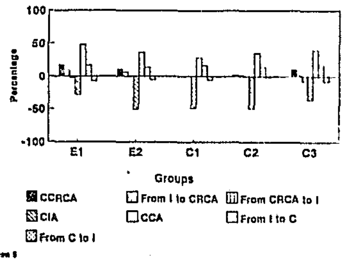
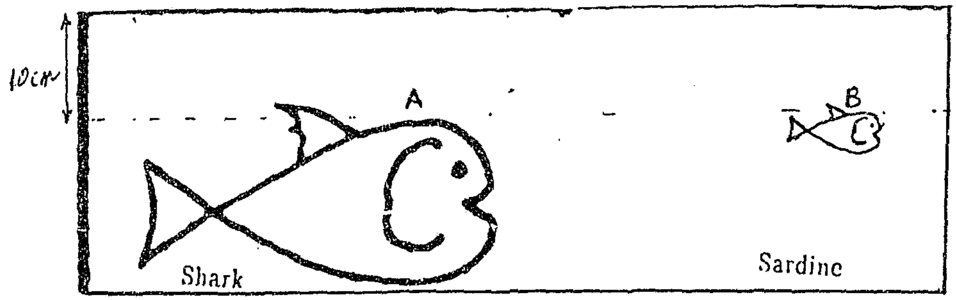


Figure 8.9 shows that there is a fair percentage of pupils consistently obtaining the correct answer (CCA) in all groups. The number of those turning to the correct answer (I to C), although a smaller percentage is comparable in all groups. When the reasons given for the correct answer (CCRCA) are looked at, once again the experimental groups and group C3 had higher percentages of those giving a correct response than the remaining groups. Although small, the experimental groups had higher percentages of children turning to the correct answer and correct reason than the control groups. It appears that while performance in all the groups was fairly comparable, groups C1 and C2 had difficulties in getting the children to be consistently correct in their responses. As in figures 8.7 and 8.9, this may show that the question of the 'hydrostatic paradox' was not (adequately) addressed in groups C1 and C2 although the other groups do appear to benefitted much better than these two because their advantage over groups C1 and C2 was only in the percentage of children who consistently gave the correct responses.

In question 7, the relationship between the pressure and the depth is looked at in a different context i.e the relationship between the pressure and the size of an object on which the pressure acts. It can therefore be seen as an extension of questions 1, 2 and 5.

Question 7: The effect of the cross sectional area on the pressure. The question was stated as 'Below is a large fish, Shark, and a small fish, Sardine in a tank of water.



Compare the pressure on the top of the two fish above.

(a) The pressure on Shark at A is greater than the pressure on Sardine at B.
(b) The pressure on Shark at A is the same as the pressure on Sardine at B.
(c) The pressure on Shark at A is lower than the pressure on Sardine at B.
(d) I do not know.

Reason for my answer.

These are the codes used for the reasons given in this question.

A and B on the fish are at the same level (1)
big fish implies big pressure (2)

small fish implies big pressure (3)

small fish swims faster (4)

The appearance of the fish affects the pressure (5)

shark is lower than sardine (6)

The fish are in one box (7)

Language difficulties (8)

Performance in this concept is shown in figures 8.10 and 8.11

Figure 8.10: Pretest and post-test answers

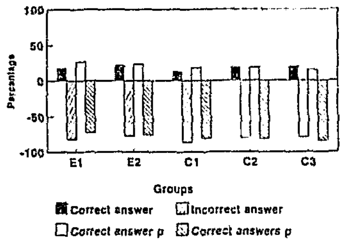
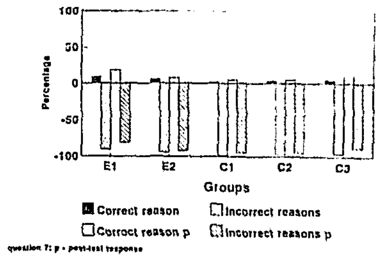


Figure 8.11: Reasons for the correct answer



Figures 8.10 and 8.11 show that overall performance in this question was poorer than in all the preceding questions with a minority of all pupils in all groups obtaining a correct answer .

The improvement in the percentage of children obtaining the correct answer was significant in group E1 only. It is therefore not surprising that few students gave a correct reason. The following reasons could have made this question more difficult than the preceding questions:

(a) pupils were referred to specific points where the pressure was to be compared. They previously looked at the whole fish.

(b) the fact that for one fish (Shark) the bottom part was deeper in the water than that of the other fish (Sardine). This may have distracted the children's attention from the points at which the pressure was compared.

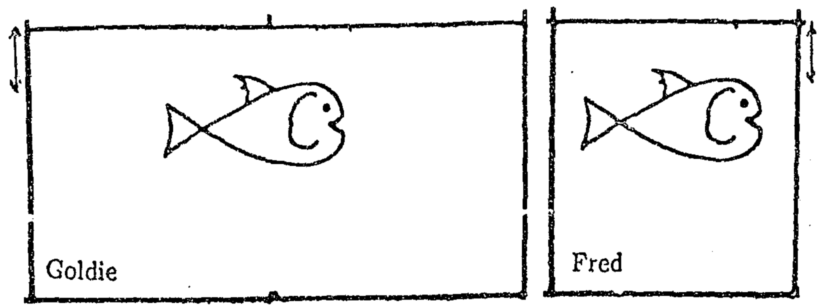
(c) they possibly did not have the vocabulary to say the 'fish were not the same size' (eg. reason 8), i.e the reason would be stated as 'the fish are not the same'. It was thus difficult to tell whether the students were referring to the looks (shape) or the size of the fish.

The discussion shows that performance in this concept varied from question to question. In questions 1 and 2, for example, performance was better than in questions 5 and 7. The understandings of this concept are therefore inconsistent and not supported in different contexts.

The relationship between the pressure and the volume of a liquid.

This concept is looked at in question 3 only.

Question 3: The stem of the question is: Goldie and Fred are now in different tanks



Compare the pressure on the two fish.

(a) The pressure on Goldie is greater than the pressure on Fred.

(b) The pressure on Goldie and Fred is the same.

(c) The pressure on Goldie is lower than the pressure on Fred.

(d) I do not know.

These are the codes used for the reasons given in question 3

Goldie and Fred are at the same level (1)
The size of the fish is the same (2)
Pressure increases with the volume of water (3)
Inability to read a diagram (The size of the fish is proportional to tank sizes) (4)
pressure decreases as the space for swimming increases (5)
The direction the fish is facing and the height of tanks (6)
The fish are in different tanks (7)

Responses in this question are illustrated in figure 8.12 and 8.13.

Figure 8.12: Pretest and post-test answers

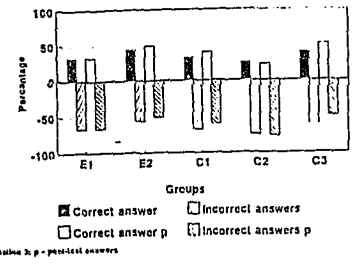
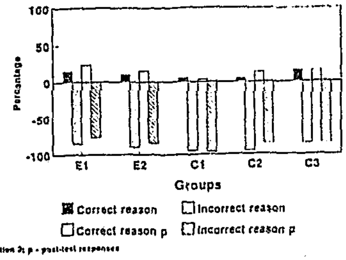


Figure 8.13: Reasons for the correct answer



Figures 8.12 and 8.13 show that overall performance in this question was weak. However, for the conceptual answers, it was better in groups E2 and C3 than in the rest of the groups. For the reasons given for the correct answers, performance was poor in all groups (figure 8.13). Within this poor overall performance, improvement was significantly better in groups E1 and C2 - although improvement in group E2 was close to that achieved by group E1. These groups (E1 and C2) however were the only two groups which did not show any improvement in the conceptual answers. Group C3 had similar performance to the two groups in both the pre- and the post-test scores.

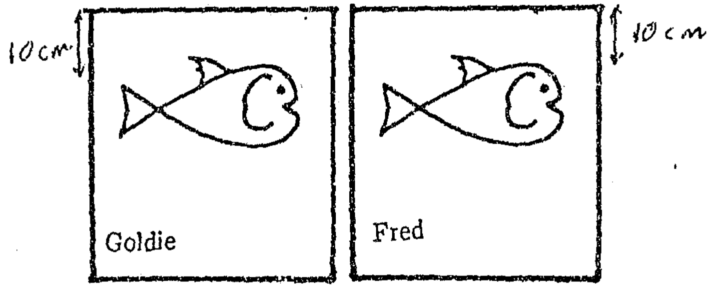
For the experimental groups, improvement may be attributed to the fact that the experimental materials directly addressed the misconception 'does the total volume of water affect the pressure?' In the case of group C2 this may be attributed to the fact that although the teacher did not have the experimental materials, she tried hard to explain what the children observed in her demonstrations (see section 8.4.1.2).

Reason 2, i.e. reference to the size of the fish can be isolated as interesting because it shows that some pupils attributed characteristics of solid pressure to hydrostatic pressure. It would appear that they connected the pressure with the size of the fish, pressure. It would appear that they connected the pressure with the size of the fish, i.e. they thought that the pressure was the same because the fish are the same size. However a decline (when individual incorrect reasons for the correct answers are given - not shown in the figures) in the percentage of pupils choosing this reason in the post-test suggested a measure of success in changing this idea. The success was highest in groups E1 and C2.

<u>The relationship between the pressure and the density of a liquid.</u>

This concept is looked at in question 4 only.

<u>Question 4</u>: The stem of the question is: 'The sketch below shows Goldie in fresh water and Fred in salt water. The density of salt water is greater than the density of fresh water.



Compare the pressure on the two fish.

(a) The pressure on Goldie is greater than the pressure on Fred.
(b) The pressure on Goldie and Fred is the same.
(c) The pressure on Goldie is lower than the pressure on Fred.
(d) I do not know.

The reasons for the answers in question 4 are given below with the code numbers used in the graphs.

Salt water has greater density than fresh water (1)
The size of the fish is the same (2)
language/Inability to read a diagram (Goldie is lower than Fred) (3)
the greater the density, the less the pressure (others: pure water increase the density/pressure (4)
Correct idea poorly expressed (eg. salt water has greater power than pure water, fresh water etc) (5)
The size of the containers is the same (6)
same height/level of liquid (7)
the two situations are the same in all respects (8)

Performance in this concept is illustrated in figures 8.14 and 8.15

Figure 8.14: Pretest and post-test answers

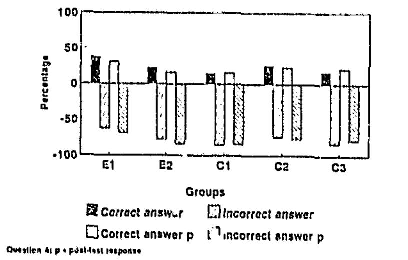
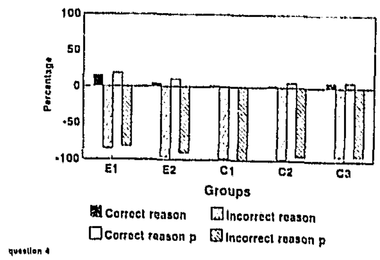


Figure 8.15: Reasons for the correct answer



Figures 8.14 and 8.15 show that performance in question 4 was poor both for the conceptual answers and the reasons given for the correct answers.

Figure 8.14 shows that except in groups C1 and C3, there was a decline in the percentage of children choosing the correct answer in the post-test. The decline in the correct answers given by some of the groups may suggest that the correct answer was obtained largely due to guess work, rote learning, misinterpretation of the word 'density' or a combination of these factors. Figure 8.15 shows that the performance in reasons given for the correct answer was much worse than performance in the case of the correct answer only. The extent to which these results were poor however suggests that the correct answers were possibly obtained by chance. However, groups E2 and C2 although previously showing decline in the number of pupils obtaining the correct answer had a significant improvement in those giving the correct reason for their answer although percentages were very small. This suggests that most children in these groups who obtained the correct reason on post-test were children who obtained the correct answer but not necessarily the correct reason for the correct answer in the pre-test.

Pascal's principle

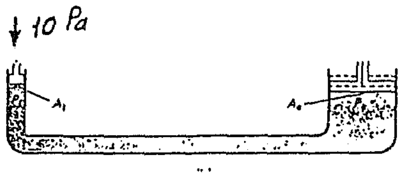
Students' understanding of Pascal's principle was looked at in questions 6, 8, and 10. Overall performance in all questions looking at Pascal's principle was very weak.

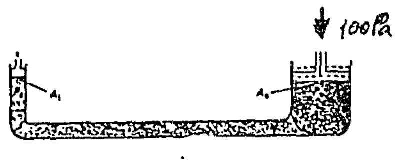
In question 8 pressure was being exerted on fish while in questions 6 and 10 it was being exerted on either end of a hydraulic lift.

The questions were the following:

<u>Question 6 and 10</u>: Below is a sketch of a hydraulic jack.

Question 6 | **Question 10**





A pressure of 10 Pa is applied on the narrow/wide end. The pressure on the wide/narrow end is

(a) greater than 10 Pa

(b) equal to 10 Pa

(c) less than 10 Pa

(d) I do not know

Reason for my answer.

Codes used for reasons given in this question are listed below.

the pressure must be transmitted without change since the liquid is enclosed (1)

wide implies greater pressure (2)

narrow implies greater pressure (3)

narrow and wide sides are on the same level (4)

narrow and wide sides are not on the same level (5)

Performance in this concept is shown in figures 8.16 to 8.17.

Figure 8.16: Pretest and post-test answers

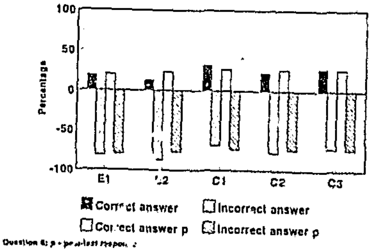
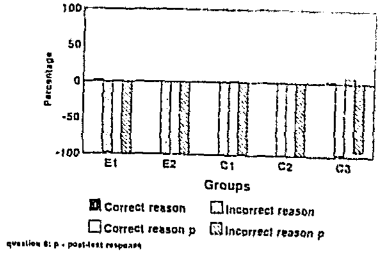


Figure 8.17: Reasons for the correct answer

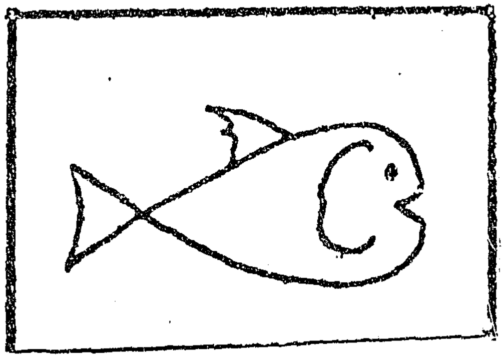


Figures 8.16 and 8.17 show that overall performance in question 6 was very poor, particularly in the case of the reasons given for the correct answers.

The results for questions 10 and 8 was just as poor as the results of question 6. The fact that the diagram used in question 6 was similar to that used in their textbooks did not appear to make it easier than questions 8 (a novel question) and 10. There was virtually no understanding of Pascal's principle before or after intervention.

Directions in which the pressure is acting

Question 9: The question was stated as 'Draw arrows to show direction(s) in which pressure is acting on the fish.



(f) I do not know

The answers were shown by drawing arrows towards/away from the fish on the chosen spot of the fish.

These are the codes given for the reasons given in this question.

Pressure in liquids acts in all directions (1)
The fish is swimming (pressure in the direction of motion including downwards) (2)
Air comes downwards from the open top (3)
Air comes from the mouth (4)
The size of the fish is big (5)
Inability to read a diagram (6)
The pressure is opposite to the direction of motion (7)
There is only one fish in the tank (8)

Question 9 was different from other questions in that it was open ended. As a result many different answers were given, each separately coded.

Once again only a small percentage of children in both the pre- and the post-test obtained the correct answer. However unlike any of the preceding questions, the most popular choice was 'I do not know'. The number of pupils choosing this alternative ranged from 22% to 68% and was an average of 40% per group. It appears that the open-ended nature of this question provided difficulties in that there was a smaller room to guess the correct answer than it was the case with the preceding questions.

8.3.5 Difficulties common in different questions

Whilst different misconceptions emerged in different questions, it appears that the following were the main difficulties

(a) attribution of characteristics of solid pressure to hydrostatic pressure. This is shown by the following:

(i) size of the fish (questions 1, 2, 3, 4, 7, 8 and 9), i.e. larger fish implies greater pressure or vice versa .
(ii) size of the part of the hydraulic lift where pressure is exerted (questions 6 and 10), similar to (i).
(iii) reference to the size of the spout (question 5).

(b) inability to read a diagram as shown by the following explanations:

The size of the fish is different (questions 1, 2 and 3).
One fish is lower than the other (question 4)
The fish look different (question 7).
The fish is moving (question 9)

(c) inability to read the essentials of a question (questions 7 and 8).

(i) In question 7 some pupils failed to understand that the question referred to pressure at specific points on the two fish. They therefore concentrated on the total size of the fish.

(ii) In question 8 pupils failed to understand that the question focused not only on the pressure, but on the change in pressure.

(d) Difficulties with language

For example, in question 7, reason 8 may suggest an inability to express one's self, i.e an attempt to state that the size of the fish is not the same. The reasons behind an incorrectly stated answer are thus a lot more complex than it appears at first glance.

It can be seen from the above that in all questions some pupils mentioned the size of the object on which the pressure acted as a reason for their answer. This finding shows that the majority of students may have related hydrostatic pressure to the cross sectional area as in solid pressure. The students could therefore not

(a) relate hydrostatic pressure with the depth of a liquid

(b) apply Pascal's principle.

It would appear from these results that the intervention had little effect. However classroom observation indicated that the approach using the teaching package was welcomed.

An attitude survey relating to the package was therefore administered to the experimental groups and their teachers.

8.3.6 Attitudes towards the teaching package

The instrument used was a Lickert type questionnaire (Appendix D) describing various feelings towards aspects of the intervention. The children were asked to state whether they (a) agree (b) are not sure (c) disagree with the feelings described. Table 8.14 shows the percentages choosing each response for various items.

Table 8.14: Percentages choosing each response for various items.
N = 140

	Agree	Not Sure	Disagree
A. The experiments were interesting	87,0	4,1	8,9
B. It was difficult to do the experiments	24,1	7,6	68,2
C. It was easy to follow the instructions from the worksheets	82,7	3,0	14,3
D. I needed the teacher's help in order to understand the worksheets	68,2	6,5	25,3
E. The teacher used a simpler language when using these worksheets than on other days	64,9	7,1	28,0
F. We regularly do experiments at our school.	70,1	4,2	25,7
G. We have done experiments on liquid pressure before	52,4	10,0	37,6
H. I understand liquid pressure better now	81,1	9,5	9,5

Table 8.14 shows that the children were generally happy with the way they were taught and that they found the experiments interesting.

Statements C and D may seem contradictory at first glance. However, taken together they may suggest that although the pupils could do most of the experiments, there were situations where the teacher's help was necessary.

Positive attitudes towards the materials were displayed by one of the experimental teachers (appendix D). The other experimental teacher failed to complete the questionnaire despite repeated requests and assurances that any kind of response would be welcome and that she did not have to write what she thought would please the researcher.

Although the majority of pupils and one of the teachers had a positive attitude towards the materials, the results were not very encouraging. This would seem to suggest that attitude although important, contributes little towards success. There are other contributing factors, for example prior knowledge which may outweigh positive attitudes.

8.3.7 Conclusion 1: Quantitative section

The quantitative results have shown that on overall the students had a very weak understanding of hydrostatic pressure.

For the covariate analysis most variables were not significant. However the pretest score always emerged as a significant variable. Intervention was also frequently significant when considering both the correct reasons and the correct answers.

When analysis by concept was done, there was often improvement on the post-test score although this was significant in only a few cases. The number of significant cases rose when a correct reason given for a correct answer was considered.

In both the experimental and the control groups there were cases where the percentage of pupils obtaining the correct answer in the post-test was lower than the corresponding percentage in the pretest. However for the correct reason given for the correct answer, this was the case for the control groups only. This suggests further that while the experimental groups were not better than the control groups in giving the correct conceptual answers, they were better in giving the correct reason for their answers.

Although generalisations can be made, there were differences between individual groups. Table 8.13 together with the mean score for the reasons given for the correct answers (table 8.7) also show that in the case of the reasons given for the correct answers, group E1 was significantly better than all the control groups. However group

E2 was only significantly better than group C1. This suggests that on the whole the pupils in group E1 had a greater level of understanding than the pupils in the other groups.

The finding with intervention and the fact that it was only significant with the reason for the correct answer rather than the correct answer only suggested that these results should be analysed qualitatively as well. Qualitative results may better explain why some variables are significant while others are not.

Quantitative analyses show that:

(a) overall performance in all the questions improved very little despite intervention.

(b) The preknowledge and intervention had effects on the results. However, quantitative analyses do not give us sufficient details of how each of the variables affected performance.

8.4 The qualitative analyses and results

In this section, teaching styles in the experimental groups are discussed, followed by teaching styles in the control groups and finally a comparison of teaching styles between the experimental and the control groups.

8.4.1 Comparison of teaching styles

The materials were designed to encourage the use of a constructivist approach and conflict strategies in the experimental groups. Each concept was addressed by looking at known misconceptions and those suggested by the children's answers. Experiments were done to support scientific ideas.

The teachers of the control groups were not given specific guidelines although they were given advice on request. The comparison between teachers is therefore made on the following basis:

(a) pupil experiments
(b) interaction between the teacher and the pupils.
(c) consideration of language difficulties
(d) link between the experiments and theory
(e) link between new work and work done previously

Because the experimental groups used identical resources and similar teaching strategies, they will be discussed together. This will be followed by a discussion of the control groups.

8.4.1.1 Compa[illegible] experimental groups

The comparison within the experimental groups is on the basis of the use and interpretation of ideas in the experimental materials as well as initiative on the part of the teacher when confronted with a new situation such as a new question. This comparison is done for each unit.

Unit 1: Introduction

This was an introductory unit which laid the basis for all the other units.

Teacher E1 treated this unit as planned by asking the children to come forward with their ideas about what affects the distance at which the water jets hit the floor. However teacher E2 treated this in a multiple choice fashion, using typical misconceptions given as alternative answers. The misconceptions here were thus limited to those listed in the worksheet. In addition teacher E1 addressed language problems but teacher E2 did not.

Unit 2: The effect of the width of a container and the total volume of water on hydrostatic pressure.

This unit was treated in a very similar fashion by both teachers. The children performed experiments following instructions from the worksheets. Deviation from the instructions was made only when a query arose. This was the case in other units as well. The following shows a discussion which followed a question from the experimental teacher asking to know why the water always rose to the same level in the containers despite their different shapes:

P: The height of the containers is the same.

T: What will happen if the height of the containers is not the same?

P: The water in the tall one will be higher.

T: Can we do an experiment to see if he is telling the truth?

Ps: Yes.

T: Come to the front to do the experiment (points at the boy who first raised the query).

(The boy comes to the front and with the help of the teacher sets up the equipment and performs the experiment).

T: Are you satisfied now?

P: Yes.

This unit could affect performance in question 3.

Unit 3: The effect of the shape of a container on hydrostatic pressure.

Both teachers used a few pupils to demonstrate the experiments while the rest of the children watched and participated in answering questions posed in the worksheets.

This unit could affect performance in question 5.

Unit 4: The effect of the depth of water above a hole on hydrostatic pressure.

Similar strategies were used by both teachers. These involved the use of three children to each hold a container against the wall at different heights while the rest watched the distances at which the water jets hit the floor. This unit could affect performance in questions 1 and 2.

Unit 5: This unit discusses the 'hydrostatic paradox' and shows that it is the depth of water which affects the pressure.

Similar strategies were used in both groups. However each group had a child who gave a novel response. As a result there were slightly different additional explanations given to each class each of which gave some insight into some aspect of hydrostatic pressure.

Unit 6: This unit shows the children how a manometer can be made and used.

Teacher E1 showed the children how to make the manometer but E2 did not. However her children did not seem to have any problem making the manometer following the instructions in the worksheets. This unit could affect performance in questions 6 and 10.

Unit 7: The effect of the density on hydrostatic pressure.

E1 and E2 went through this unit in a similar manner. This unit could affect performance in question 4.

Unit 8: This unit discuses the directions in which hydrostatic pressure is exerted.

E2 had difficulties in setting up the equipment (in unit 8a). As a result she lost some time. It is therefore possible that she did not have as much time for discussion as she would have liked. In addition E2 misread a diagram and an instruction (in unit 8b).

Some pupils in both groups thought a dot which was intended to show the position of a straw in a diagram was a hole. This was a result of having previously used dots to show positions of holes.

This unit could affect performance in question 9.

Unit 9: This unit discusses Pascal's principle.

The main difficulty in this unit for both E1 and E2 was to get the holes in the equipment properly sealed so that pressure could be transmitted without any water spilling. Prestik was used which was not a good adhesive once the equipment was wet (See figure 8.18 below -- a photo).

This unit could affect performance in questions 6, 8 and 10.

On the whole, the two experimental teachers followed the instructions in the teachers' manual and pupils' worksheets well. However it should be noted that for the two teachers, it was the first time they had used materials written differently from their usual text books. There was therefore still room left for improvement in the teachers' use of the materials, for example as discussed in chapter 9.

8.4.1.2 Comparison within the control groups

The control groups will be discussed in turn.

Group C1

Fewer experiments were done in this group compared to other groups. The following transcript shows a typical explanation given in this class.

T: We are going to explain pressure in liquids. Even liquids exert pressure. The pressure exerted by liquids is called hydrostatic pressure. Hydro - means liquid. Now we want to explain how these liquids exert pressure

(Writes on the board) Experiments on how liquids exert pressure.

If you want to see how liquids exert pressure, you can make holes, pour water to see how liquids exert pressure. We have two containers. One has holes at the bottom and the other in the sides. So we pour water in the container to see directions the water take. ***We agree with each other, is it not?*** *(She pours the water into the container) Which direction does the water take?*

Ps: Down

T: Downwards meaning the pressure is downwards. ***Is it not?***

Ps: Yes

T: Again we shall take a container with holes in its side. We want to see the direction of pressure. Which direction does our pressure take?

Ps: Downwards

T: Maybe tomorrow we shall see how water exert pressure downwards

The following are some distinctive features of this lesson.

The experiment was done immediately after the definition. No explanation was given of the nature of hydrostatic pressure.

No language strategies were observed in this lesson. Although code switching was used, it was done merely to confirm agreement rather than as a teaching strategy. It is also noted that in the teacher ignored an incorrect response.

The following transcript was taken when Pascal's principle was being taught:

T: I am going to explain the experiment because there are no apparatus
To demonstrate how pressure is transmitted, you take a plastic bag. ***You know a plastic bag, isn't it?***
P: Hmm
T:... fill it with water. Make a knot (showed them a plastic bag with a knot). Make small holes. Press it down.
The water will be transmitted equally from the hole
Observation: When pressure is exerted on a liquid, the water is transmitted equally.

(There were no questions from pupils. The teacher did not make any link between the pressure and the water jets).
T: Pascal's principle can be applied on car brakes and hydrostatic machines.
We shall do the experiment later so that you can understand.
I gave you home work last time.
Ps: No
T: Didn't I?

It is noticed that explanations in this session were inadequate. No mention of transmitted pressure was made, instead it was said that the water is transmitted. No link was made between the water jets and the pressure. This suggests that although the children gave 'correct' answers, it is likely that there was guesswork involved or they had rote learned the responses.

This was the weakest of the teachers both in the language strategies and other teaching strategies which is reflected in the pupil performance. There was nothing in common observed in teaching strategies used by this teacher and those used by any of the other teachers.

Teacher C2

Teacher C2 did lots of experiments. These were however done in the classroom in the form of teacher demonstrations. The following is an example of a transcript of teacher C2's lesson.

53 *T: We say force can be* ***applied*** *by anything. Anything that can apply force in*
54 *contact with any other thing can exert pressure.*

55 *Remember, there are states of matter. What are they?*
56 *Ps: Solid, liquid, gas*
57 *T: We have seen that solids exert pressure for example a brick on a sponge. If the*
58 *rain has rained, there is a lot of water inside the river. Is it easy for a person to*
59 *cross the river?*
60 *Ps: No*
61 *T: That person can be carried away by the water flowing. This shows that the water*
62 *exert what on the person?*
63 *P: Force.*
64 *T: But because the water is in contact with the person, we can talk of ...?*
65 *Ps: Pressure.*
66 *T: Pressure exerted by the liquid is known as ...?*

P: Hydrostatic pressure.

T: So now hydrostatic pressure is the pressure exerted by the liquid. We have shown that the liquid can exert force. Therefore it can also exert pressure. This pressure is known as hydrostatic pressure. Hydro means a liquid. With solid pressure, we have the learned that the direction of pressure is the same as the direction of the force applied.

What is the direction of the force of the brick on the sponge? I am talking about the example I gave you. When I have put a brick on a sponge, what is the direction of the force?

T: What is the direction of the force?

P: The direction of the force.

I: I want to know the direction of the force.

P: Downward.

T: Downwards. We are going to look at properties of pressure in liquids. In the case of solids, it depends on the direction of the force. When I open a door to this side, the pressure is in the same direction. Do you understand me? I say the direction of the pressure is the same as the direction of the force. Force can not go this way (points) and pressure that way.

I am going to demonstrate. At the end you are going to tell me what is the direction of pressure. Do you hear me?

Ps: Yes

T: Water has weight. Do we agree?

Ps: Yes.

T: It exerts pressvre (fills juice bottle with water). There are holes under this tin. If you fill it with water, the water squirts out (writes the word 'squirt' on the board) (Pours water in the tin). The water squirts out because it exerts pressure. That means it (the water) <u>exerts</u> pressure. If it were not exerting pressure, it would just stay inside (the container) even if there are holes. Do we agree? Here is another container with holes on the sides. If the pressure is only downwards, water will only go downwards. But look now which direction?

Ps: Sideways

T: The water exert pressure on the side of the container. The fact that it finds holes, makes it to squirt out.

There is another experiment where you force a stopper down into water with a stick. If you remove the stick, what happens to the stopper?

Take a stopper, immerse it. Will the stopper remain at the bottom?

P: It goes to the top.

T: It comes to the surface of the water. This shows that water exert pressure on the stopper. What do you think is the direction of the pressure?

P: Upward.

T: Upwards direction. That is why the stopper comes to the surface. ***Do you hear me?*** *It shows that even if there were no holes, water would exert pressure at the bottom (in a container that has holes at the bottom).*

What is the direction of pressure which makes the water to squirt out from holes in the side.

P: The direction will be sideward.

T: The direction will be sideways. In the case of the stopper, it moves to the stopper. We can come with a conclusion of the direction of pressure. What is the direction of hydrostatic pressure? Combine the three explanations and tell me what is the direction of hydrostatic pressure. In case of solids the direction is the same as that of an applied force. What can you conclude about the direction of hydrostatic pressure?

P: (after a long wait) All directions.

T: ***You people can't you combine these directions.*** *It was downwards, upwards and sideways (Everytime pointing the apparatus that was used).*

These holes cover all directions, *south, north, east, west. Therefore the direction of pressure is in all sides as long as the liquid is in contact with the container.* ***Do we agree?***

Ps: hmm.

T: ***It seems we do not agree.*** *(Writes on the board)* ***It does not matter where you***

make holes, (the) water will just come out. *Pressure is in all directions. In the case of solids, the direction is that of the applied force.*

The above transcript shows the following strategies:

(a) familiar examples (although the river was not an appropriate example in hydrostatics, it served to bring the message home, namely that water exerts pressure). This is comparable to the experimental teachers in the sense that low cost equipment made with materials familiar to pupils was used and hence familiar examples. This was the case in all units except that the experimental groups were introduced to a home made manometer in unit 9.

(b) code switching.

It is noted that the teacher discussed 'force' and showed how this translated into pressure (lines 9-13). She also contrasted solid pressure with liquid pressure to clarify the properties of hydrostatic pressure. At the end after some effort she managed to get the children to make deductions (lines 58-67).

She (teacher C2) also showed concern that the children should understand her as in the statement 'it seems we do not agree', followed by writing on the board and repetition (line 74).

The above strategies show that this was a very good teacher who in addition to explanations and language strategies, linked up various concepts.

Teacher C2 therefore compared very well with the teachers of the experimental groups although she was not supplied with the experimental teaching package. Her children may have benefited most on a section related to Pascal's principle because this section was taught twice. In her first attempt a conceptual error was picked up by the researcher who discussed it with the teacher. The teacher in turn deemed it fit to repeat the lesson where this error was corrected. However any possible advantage enjoyed over other groups due to the repetition was not reflected in the quantitative analysis. That is, while some pupils could have enjoyed this advantage, their number was not large enough to be reflected in the figures.

Teacher C3

The following were noticed in this teacher's class

(a) Language strategies were used.

(b) Lots of experiments were performed in much the same way as in the experimental groups. The experiments were performed outside the classroom with the use of simple equipment. These were often performed by the children under the teacher's supervision. While great deal of emphasis was put on getting the children to make the right observation, explanation of what was being observed was shallow.

The following transcript illustrates both the teaching and language strategies used:

*T: **These are the things we want to see:** (The) distance **at which the water hits the floor. Where water from this** (points to one hole in the container). **Where water from this** (points to another hole in the container). **Where water from this** (points to a third hole in the container).*

When I fill (the container) with water,** I am increasing the depth. **You must notice the distance at which the water goes.

*Is the distance the same? **I want to know from** which ... **You want me to explain*** *in Sesotho, don't you?*

Ps: Yes

T: Which water goes far away.

P: bottom hole.

T: Which one goes nearer? Now, when I fill up I increase (the) depth (fills the tin with water). Look is the distance still the same? Let us see. This (points at the water jet) squirt to this place. Now this (points at another water jet) squirt to that place. You have seen where the water jet squirts to. This decreases (shows that the distance decreases as the depth of water decreases). Now let us fill it with water. I increase the depth. Is n't it?

Ps: Yes.

T: Even when I close the holes, there is pressure. When I open, the water gets out because I have opened. We want to learn about pressure at all levels. All levels means near the top, in the middle and near the bottom. We fill up again. What about the pressure? It becomes big. When the water decreases, it (the water) goes nearer. That means (the) pressure is ...?

Ps: decreasing.

T: We know that it is decreasing because we see the water go nearer. Is the pressure the same.

Ps: No

T: At which level do you think the pressure is bigger?

Ps: Bottom.

T: What happens to the pressure when I increase the depth?

Ps: (No response)

T: Does it increase or decrease?

Ps: increase.

T: As the depth increases, the pressure increases. When we increase the depth, we increase the pressure by the liquid.'

It is possible that this teacher may have enjoyed an edge over the experimental teachers since for her, this was part of her routine rather than an activity which was only done for the first time after having been introduced by the researcher as was the case with the experimental teachers.

It can be seen that the relationship between the water jet distances and the depth of water was discussed (lines 5-17) as was the case with the experimental groups (unit 5). In addition, the relationship between the pressure and depth were discussed. What was not discussed in this lesson was why the depth of the water affects the pressure, i.e how the variation in the height of a liquid column affects its weight and hence the pressure (lines 28-35) contrary to the situation in the experimental groups (unit 5). The language strategies used were code switching and rephrasing.

The discussion shows that while this teacher gave good explanations, they stopped short of giving insight into why the water jets behaved as they did. Pupils from this class can therefore be expected to be good at giving correct answers and somewhat weak at giving correct reasons.

8.4.1.3 Synthesis of the strategies used in all groups

The control groups were found to deviate more from the written material (their prescribed textbooks) than the experimental groups. They could more easily give examples which were not in their books while the experimental teachers faced with new material were found to stick to what was in the material except when a question was asked. For instance the teacher C2 gave the example of a river which did not appear in her textbook without being requested to do so. An experimental teacher only deviated from the prepared material in answering a query regarding the 'hydrostatic paradox' (see section 8.4.1.1 - Unit 2).
When the teachers were individually compared, teacher C1 appeared to have been the weakest of all the teachers in the type of questions asked, the activities organised as well as with teaching strategies.

Teachers C2 and C3 were comparable in terms of the activities organised as well as teaching strategies. The main difference between teachers C2 and C3 was the fact that teacher C2 relied mainly on teacher demonstration while teacher C3 organised pupils to do the activities themselves as was the case with the experimental groups.

Teacher C2 seemed to have an edge over teacher C3 in terms of linking the work being taught with the previous work as was the case with the experimental groups. In this respect one can expect teacher C3's children to be at least as good as teacher C2's children as far as multiple choice questions were concerned and that teacher C2's children might benefit more than teacher C3's children when it came to explanations of various concepts as it was indeed the case (table 8.7).

The strategies used in different groups suggest that the experimental groups were likely to perform like group C3 in the conceptual answers and like group C2 in the reasons given for the correct answers.

Since the experimental groups combined the strategies used in the control groups, they may be expected to perform better than the control groups on average.

8.4.2 Conclusion 2: Qualitative section

Scholastic achievement was affected by various factors such as teaching strategies, materials used and the pupils' preknowledge.

The qualitative section has described the different strategies used by the teachers. The strategies contributed towards the difference in performance.

Individual control groups also had their own strategies which in some ways were similar and in other ways dissimilar to other control groups and the experimental groups. Some of these were efficient and their effectiveness can be confirmed by the results achieved. While innovative materials encouraged teachers to use new strategies, some teachers, on their own, used strategies which were effective even if traditional materials were being used.

8.5 Conclusion

Overall results were very low despite intervention. The following factors may have affected the results.

(a) resources used by both the experimental and the control groups
(b) teaching and language strategies used.

The experimental groups relied on the supplied resources while the control groups relied on the usual textbooks. The experimental groups therefore had to address misconceptions as well as language difficulties as these were built into the materials. This may have resulted in better performance by the experimental groups. However the control teachers were not prevented from using similar strategies if they had acquired the strategies on their own. Viewed from another perspective, it is possible that the experimental groups were not yet comfortable with the new teaching strategies. It could have been difficult for them to be as efficient in the use of these strategies as they normally would have been when their usual strategies were used. On the other hand the control groups were more likely to

(a) have used familiar strategies
(b) have tried harder knowing that research was in progress.

In addition, while most questions were new to all the students, the control groups had encountered two of the questions related to Pascal's principle in their textbooks. The experimental groups had not. However the control groups did not perform better than the experimental groups in this respect.

For the conceptual answers only, the experimental and the control groups were comparable . Within the overall poor performance, the experimental groups performed better than the control groups in giving the correct reasons for the correct answers. It can therefore be said that there were some advantages in the use of novel materials.

Finally, the preknowledge was the only variable significant on post-test in all cases whenever it was tested.. This was the case when the experimental groups were combined and the control groups combined as well as the individual experimental groups and the individual control groups were compared. This is in line with the constructivist view that what the children know is an important starting point for new knowledge. The variables intervention, gender and age were not consistently significant and are thus unreliable in predicting performance.

Qualitative analyses showed anecdotes which revealed some factors which may have affected performance. These were for example

(a) language and teaching strategies

(b) competence in the subject content.

By comparing strategies used by different teachers, it was possible to rate the teachers in terms of their competency. It would appear that expected performance by various groups based on the discussion of strategies used by the teachers is not in conflict with the overall ranking shown in table 8.7 i.e. quantitative and qualitative analysis agree to some extent.

9.0 CHAPTER NINE - Discussion, Conclusions and Suggestions

9.1 Discussion

The results of this research can be divided into two broad sections, i.e language and conceptual aspects. These were collected through quantitative and qualitative methods using the following instruments and strategies:

(a) a language test with 4 sub-tests which investigated pupils understanding of some relevant vocabulary. The tests were considered relevant as they were used elsewhere in the world for this purpose. They were however modified to suit the local population.

(b) pencil and paper conceptual test where students were asked to choose a correct answer and then give reasons for their answers. The conceptual test was administered in paper and pencil form to reach as many pupils as possible and to make quantitative analyses possible.

(c) interviews with students and teachers, lesson observations, audiotapes and field notes.

Recording teachers' lessons was a useful supplement to interviews since the opportunity of picking up misconceptions is created but at the same time reducing the chance of embarrassing the teacher to a minimum. The teacher does what he/she is supposed to know best - to teach. However it is likely that teachers would show many more misconceptions in an formal interview situation where probing is possible than in a lesson (as was the case with pupils). It would therefore be most useful if conceptual errors which emerged during the lessons could be probed further in interviews with teachers.

The initial investigations (lesson observations and open conceptual test) identified conceptual confusions in the chosen topic area - that of hydrostatic pressure. Novel materials were designed with the purpose of remediating these conceptual difficulties. These initial investigations were carried out as planned. As mentioned in section 3.4, the following circumstances made it impossible to carry out the original design of the final field work as planned:

(a) time delays - an impromptu teachers' workshop which coincided with this research was organised by an non-governmental organisation. This forced this research to be delayed for the duration of the workshop (a week).

(b) the sample had to be changed because of

(i) stay-aways - there were either teacher or pupil stay-aways at some schools

(ii) teacher sensibility -one teacher expected the researcher to do the teaching on her behalf on the grounds that her knowledge of physics was inadequate.

(iii) an unexpectedly large number of pupils were found in the experimental classes. It was therefore not possible to use small group activities to investigate phenomena (experimentally). Instead some pupils within the experimental groups carried out the activities as demonstrations. However, there is some evidence that scholastic achievement after demonstrations is in general not significantly different from what it would have been if the pupils themselves had performed the experiments (Yager et. al. 1969). This finding was confirmed by Garret and Roberts (1982) in a review of published literature comparing demonstration and experimental methods in studies done since the year 1900. Their findings showed that while results from studies done prior to 1946 varied, the findings between 1946 and 1960 all showed no significant difference when the effectiveness of the demonstration method was compared with that of the experimental method.

In all these reported studies done between 1946 and 1960 multiple regression was reportedly used to analyse the data collected as was partly the case in this study. These results were confirmed further in studies done after 1960. There were however isolated incidences, where the experimental method produced significantly superior results over the demonstration method, for example with certain population groups. However Garret and Roberts (op. cit.) acknowledge that such isolated incidences cannot be generalised.

The above findings suggest that the results of this study remain valid despite the fact that a demonstration rather than the original design of a laboratory method was used and the change in method should not be used to explain the findings.

9.2 Conclusions

The results obtained whether quantitatively or qualitatively or a combination thereof can be used to confirm or reject hypotheses (section 3.3.5).

Hypothesis a: There is no correlation between performance in language tests and performance in a science conceptual test on hydrostatic pressure.

To look at effects of language on scholastic achievement, Pearson's product moment was used to investigate the relationship between the results on the language tests and the results in the conceptual tests. No significant correlations were found, thus confirming the hypothesis. However the low percentage scores obtained suggested that the language tests were far too difficult for the learners with a mean score of 4,7% and a range of 3,5% to 5,6%. The reason why correlations between the language and conceptual tests were not obtained might therefore be because of the restricted range of marks. The difficulties pupils experienced with the subject specific words may well have contributed to the results on the conceptual test although no direct relationship was established.

Hypothesis b: Scholastic achievement for learners will not be significantly different whether or not language issues are addressed in teaching.
Hypothesis c: All teachers use the same language strategies in teaching science.

Results showed that pupils had language problems, for example language difficulties made it difficult for the learners to either understand the questions or to express themselves adequately or both. At times the reasons they gave for their answers could make sense when they were translated back into the vernacular language (the language in which they were possibly thinking). For example, the statement "the fish are the same" does not make sense, it should either be "the fish are the same size" or "the fish look similar". However when this statement is translated into Sepedi it can only mean the latter. In this study this statement was classified as a 'language problem' and these possibilities discussed when the results were analysed. In addition, observations have shown that difficulties with some words and phrases may lead to conceptual errors., for example misinterpretation of words 'transmitted equally' in Pascal's principle lead some teachers to think that the statement meant that the pressure was 'divided equally' between different points in a liquid. Therefore language and teaching strategies can be a hindrance or a facilitator of learning, depending on how effective they are in making a concept clearer. However, the fact that difficulties with concepts may lead to language difficulties, which is possible as shown by studies such as Inglis (1993), was not the subject of this study. The existence of language problems shows that there is a need to address language problems.

Observations have shown that different teachers had different language strategies although they were not equally good. In this research teachers were not prevented from using their own language strategies. There was therefore common ground as well as differences between the experimental and control groups. In addition there were differences within the control groups. It is not always possible to separate language strategies from teaching strategies nor their effects on conceptual understanding.

Although overall results showed that the preknowledge was an important factor in effecting conceptual change, when different aspects of hydrostatic pressure were looked at separately, it was found that the percentages of children obtaining the correct answers as well as those improving on the post-test were similar in the experimental groups and group C3.

Observation showed that teacher C3 was an example of a good teacher who on her own had acquired effective teaching and language strategies (section 8.3.4). The latter were often similar to those used in the experimental groups. This may explain why the results of experimental groups and group C3 were generally comparable although the experimental groups often performed better when different aspects of hydrostatic pressure were analysed quantitatively.

The discussion shows that although there were no significant correlations between the language and conceptual tests (hypothesis a), language effects emerged in places within the quantitative results. In addition the three groups which had similar language strategies also had similar results. Language strategies therefore have effects although they were not shown to be significant in this research. Single incidences have shown that language is important and failure to address it may lead to misconceptions.

Hypothesis d: Scholastic achievement for learners will not be different whether or not constructivist strategies are used in teaching.
Hypothesis e: Achievement in conceptual answers will not differ significantly between children using intervention materials and those using conventional materials.

These two hypothesis can not be separated because the groups using intervention materials also used conflict strategies.

Overall results were poor both for the experimental and the control groups. This may suggest that the strategies used (both traditional and conflict strategies) may not have been the most suitable for the pupils or the teachers or both. Understanding appeared to have been dependant on the context of the question: for example, some children would correctly say hydrostatic pressure is the same at two points that are at the same level, but would fail to give the correct answer when hydrostatic pressure is compared at two points that are at different levels. These two hypotheses were therefore confirmed. GLM analysis revealed that:

(a) the only variable which consistently affected the post-test score significantly was the students' preknowledge.

(b) there was barely any improvement on post-test score in respect of the correct answers.

(c) the materials and strategies used by the experimental groups brought significantly superior results compared to those of the control groups only with respect to the reasons given for the correct answer. The experimental groups seemed to have had greater increase in understanding than the control groups in the case of the reasons given for the correct answer only.

Hypotheses f, g and h: Pupil's gender, age and parental socio economic status will not significantly affect the children's performance in science concepts relating to hydrostatic pressure.

In general, gender and age did not have effects on overall performance of pupils. There were however incidences where each had an effect when individual groups were being compared, for example gender was significant when the experimental groups were compared with group C3 while age was only significant when the experimental group E2 was compared with control group C1. In these comparisons boys and pupils of a younger age performed better than girls and older children respectively. These findings regarding gender and age can however not be generalised. What made gender and age significant in this instance was not investigated

In general the socio economic status did not affect results significantly. However, different effects for the socio economic status of the mother and of the father were noticed indirectly, for example age was significant when the socio economic status of the father was considered but was not so when the socio economic status of the mother was considered. It might be that with age of children, the relationship between the children and the father change drastically compared with the mother's relationship with her children.

9.3 Further Discussions

The discussions have shown that it is not always possible to separate different hypotheses. This is because some variables such as language and teaching strategies are so intertwined that at times one teaching strategy may address language in a manner that is not always obvious.

Different teachers had different effects on scholastic achievement by pupils because of their differences in such variables as skills, personalities and attitudes towards the children and their work. It is therefore not possible to measure all variables accurately.

Overall, the conflict strategy of conceptual change did not produce encouraging results on the conceptual answers. Although this strategy appeared to be promising in the case of the reasons given for the correct answers where the experimental groups were significantly better on post-test results than the control groups . This suggests that while a conflict strategy shows that an idea is not correct, this strategy on its own is not sufficient to effect conceptual change. Failure of this strategy to effect conceptual change might arise from the fact that

(a) this strategy does not necessarily provide an anchor for the pupil on which a correct idea can be linked.

(b) the experimental groups were very large thus making it difficult for the teacher to identify misconceptions held by individual pupils.

There were however individual pupils who obtained an average score as high as 70% despite a mean overall of 33%. Results obtained when different aspects of hydrostatic pressure were looked at are the following:

(a) students failed to relate the hydrostatic pressure to the depth of a liquid. Some children connected hydrostatic pressure with the cross sectional area of the object on which the pressure acts. In question 1, for example pupils obtained high scores in general because the pressure was compared at two points which were at the same level. However this performance was not repeated in question 2 where the pressure was compared at points which were at different levels - suggesting that understanding of this concept was fragile. This feeling was confirmed when performance in questions 5 and 7 was even weaker. Performance in this concept thus depended on context.

(b) students failed to read diagrams properly. Some children read more into diagrams than there actually was. For example some students thought a fish which was ahead was moving or moving faster than the one behind while in fact both fish were stationary. This is similar to Trowbridge and McDermott's (1980) finding with first year physics students that some students tend to confuse position with speed (In this study graphs on the same system of axis showing two objects moving at different speeds were shown to the students. The students thought the objects were moving at the same speed at the point where the graphs crossed).

Qualitative results from interviews and lesson tapes (chapter 4) have shown that cultural background may lead to certain incorrect interpretations unique to people of that cultural experience. For example, a pupil incorrectly related Pascal's principle to his experience of the process used to cook vegetables (chapter 4). It also emerged both in interviews and pencil and paper conceptual test that it is important to understand the learner's vernacular language in order to interpret their statements correctly, for exampl: section 9.2 (conclusions regarding hypotheses b and c). Knowledge of a science learner's culture and vernacular language are therefore useful to identify some conceptual difficulties.

9.4 Suggestions

This study appears to agree with the constructivist view that what the learner knows is the most important fact in constructing meaning of the new situation, i.e. pretest score affected the post-test score significantly. It has also revealed that there are many factors which affect learning, such as competency in the language of instruction and the teacher's ability to recognise and address pupils' obstacles to learning. Each of these make some contribution. It is therefore possible that because of large classes, the preknowledge of different pupils could not be identified and was therefore not sufficiently addressed.

The fact that the preknowledge was consistently significant across different groups suggest that interventions should be planned with the preknowledge in mind. For example, the following questions should be considered when intervention is planned:

(a) What preknowledge and what level of competence should learners have before intervention on a certain topic is undertaken?

(b) When the objective is to improve student performance in a certain topic, should intervention start with that topic, with a topic before or with several topics before the target topic?

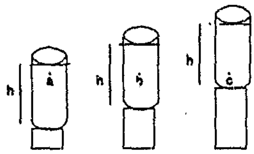
Qualitative analysis has revealed in single incidences that the children's preknowledge may be affected by language and culture. This suggested that teachers need to be trained in qualitative research so that they can identify similar difficulties in specific topics, i.e. the importance of a teacher as an action researcher can not be overemphasised. Although some teachers instinctively know how to identify and remedied these difficulties often acquiring these skills over a long time, others need to be trained to do so.

For teachers to use qualitative research efficiently they need to be made aware of the general areas in which difficulties are most likely to be encountered, for example the following:

(a) conceptual difficulties/misconceptions
(b) language difficulties in science
(c) cultural effects on pupils when learning science
(c) the importance of identifying the learners' prior knowledge before a new topic can be introduced.

Another area to be considered in order to improve the competency of teachers relates to the writing style and use of novel materials. For example:

(a) teachers need more training in the use of novel materials. This therefore emphasises the importance of inservice training for teachers in the use of new strategies before the materials can be tried.
(b) materials should be written in a clear unambiguous language. In these resources it emerged that a diagram and an instruction were not as clear as they should have been. The former is shown in the diagram overleaf.



The containers above are identical and have the same level of water. However the children thought the shorter horizontal line in the container on the right hand side above (to indicate the water level) would affect results of an experiment. Although for teachers this was not a problem, it shows that diagrams should be as clear as possible. Care should be taken that diagrams should not have anything which may confuse the readers while it is not part of the exercise.

Instructions need to be made clearer, for example in unit 8 (appendix A) four sketches are used to illustrate the different positions of a manometer. This was interpreted by one teacher to mean that four containers were required. Similar difficulties with instructions are described in section 7.3.2. Following these difficulties, an improved version of the package should include the following modifications:

(a) a new instruction to bend the tip of a straw in different directions rather than replace a straw with one that faces a different direction was given.

(b) only one diagram of a container needs to be used to illustrate an experiment where the pressure is compared in different directions at one point.

(c) In the activity mentioned in (b) above the dot used to indicate the position of the manometer tip, will be replaced by a stick with a mark to indicate the position.

If the suggestions above are not followed a lot of time can be wasted in attempting to interpret the instructions. Misinterpretation of the instructions can result in desired results not being obtained and the possibility of misconceptions being reinforced.

Since it is not possible to document all possible difficulties experienced by pupils and teachers, more qualitative research should be done to uncover as many as possible of such difficulties in single incidences. The difficulties should include the learners' prior knowledge and cultural factors because these may affect the acquisition of new concepts. In order to be as efficient as possible, a researcher conducting research under similar circumstances should bear the following factors in mind:

(a) never rely on the middleman for information regarding the school, no matter what his/her integrity. Always supplement information from the middleman by contacting schools directly. The unexpectedly large number of children at the experimental school came as a shock because a subject advisor suggested that at most eighty children could be expected in one class. In fact the numbers were double that.

(b) the role of the teacher, that of the researcher and whether there could be some flexibility in the roles should be said explicitly. It is possible that in this research this point was not stressed enough and that this may have led one teacher (who had agreed to participate in this research) to think that teaching could be done by the researcher on her behalf. This well intentioned teacher thought that for a change her pupils would receive 'expert' tuition from the researcher.

(c) sit in classes before the main field work to satisfy yourself as the researcher that the teachers you are going to involve are as comparable in terms of their teaching skills and knowledge of the subject content as you would accept. Information about teaching experience and academic and professional qualifications are misleading. Alternatively a research assistant should be sent with a clear criterion of comparing the teachers and preferably this should be accompanied by tape or video recording of the lessons which can be viewed by the researcher to backup the assistant's report.

In conclusion, this research has shown that

(a) large class size does not preclude practical activity.

(b) constructivist/conflict strategies are not always successful in remediating misconceptions.

(c) language difficulties can not be ignored.

(d) students' preknowledge is paramount in a learning situation.

(e) standard 7 (grade 9) students have great difficulties with the majority of concepts in hydrostatic pressure.

(f) there is a general awareness among teachers of the need to address language issues although they do not know what strategies to use.

(g) teachers need support both in science concepts and teaching strategies. Given a chance they can change and use novel strategies successfully.

(h) despite poor performance by the pupils, many school experiments can be done successfully with low cost equipment even with large classes.

(i) cultural effects can not be ignored although they were encountered in a single incidence in this research.

Finally, this study has shown that in a volatile situation research design should always be accompanied by contingency measures. However the contingency measures are not always enough to solve all problems which might arise. It is therefore important for the researcher to be willing to adapt his/her research approach to changing circumstances It has also emerged that where there is a willingness to rise to the circumstances valid results can be achieved despite the odds against the researcher.

10 CHAPTER TEN - Bibliography

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APPENDICES

APPENDIX A: TEACHING PACKAGE

(a) Teachers' guide
(b) Worksheets on solid pressure
(c) Worksheets on hydrostatic pressure
(d) Glossary

APPENDIX A

TEACHER SUPPORT MATERIAL

1. Introduction

This guide is for the teacher. In it there is

- Background information
- Descriptions of experiments
- A list of things students should know before you start
- A list of things students should be able to do when you finish.
- Hints on making simple equipment
- Hints on explaining difficult words
- Answers to questions in the pupil worksheets

You may need to use this information if your pupils have problems with some sections related to pressure eg. force and area. The pupil worksheets assume that the pupils have understood force and area when pressure is taught. However this package may serve as an aid if the pupils still have some problems. It also contains some suggestions you can use to give pupils extra support which they can not get from the worksheets or their textbooks.

1.1 Teaching Strategies

It is possible that the strategies for teaching which we use in this guide are different from those you use. However there are some people who have used these strategies in the past. These people have found that pupils benefit more from it than the usual way of teaching. We call this approach the 'conceptual change strategy'.

The basis of this approach is to first find out what the pupils think about a particular topic from their everyday experience. What they think often makes it difficult for them to acquire new knowledge. What they think is correct is often not the same as what we teachers think is correct. Once we know what they think, we try to show them why what they thought may not be correct. We then try to replace incorrect ideas with more scientific ideas. We call these incorrect ideas misconceptions.

We show them that their ideas are incorrect by showing them that those ideas do not always work. This creates confusion in their minds. During the confusion we show them that there is a different way of looking at the problem which removes the confusion.

We believe that when the pupils have gone through the confusion, they will understand better and rote learning will be minimised. The main disadvantage of this method is that it takes a longer time to complete a topic. It also needs patience from the teacher and the ability to create a comfortable atmosphere for the students so that they can freely communicate their ideas. We believe that the advantages of this method far outweigh the extra time and effort involved.

In the worksheets we have addressed the incorrect ideas which we know the students hold. The worksheets have been divided into units. Each unit addresses one idea. Some units will cover an entire lesson, while in some cases more than one unit may be done in a lesson.

We do not claim that all pupil misconceptions have been addressed. Only the known ones have been addressed. It is possible for you to come across new ones. We hope however that the misconceptions that have been addressed will provide you with strategies to remedied any new misconceptions you may discover.

The approaches we use in the teacher's guide and in the pupil worksheets to explain concepts are sometimes different. This is because we believe it is advantageous for the teacher to know different ways of explaining a concept. In many cases the explanation of concepts in the teacher's guide is not suitable for pupils but is given to help an inexperienced teacher or a teacher who has not taught the concept for a long time to fully understand the ideas.

1.2 The language used

We have attempted to use simple language as far as possible in this guide and in the pupil worksheets. Please make sure that the pupils can understand all words you used. If they have difficulties with words and phrases in the pupil worksheets, please explain to them.

Many strategies are useful, including the vernacular, to make sure that the pupils have understood the words and phrases.

There are many language strategies which teachers use. Some people use one and others use several different strategies. This depends on which strategy they think will work in a given situation.

The following are some of the strategies we found teachers using.

1. the use of synonyms (another word with the same or similar meaning).
2. locally based examples to show meaning.
3. the use of the vernacular in places.
4. rephrasing.
5. repetition.

The above are by no means the only language strategies available. You may have your own. We would appreciate it if you can let us know the language strategies that you have used.

2. Background information

2.1 What is a force?

A force is a push or a pull. If you push or pull an object, you apply a force to that object.

When objects touch, we say they are in contact. When there is a force between such objects, that force is called a contact force.

When you put object A on top of object B, a downwards force is exerted on object B. This force is the weight of object A. An equal and opposite force acts upwards on object A.

All objects have weight even when they do not feel heavy. A grain of rice does not feel heavy but a bag of rice does feel heavy. It has weight. However the weight of the bag is the total weight of all rice grains in the bag. This shows that even one rice grain has weight.

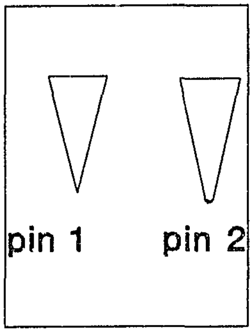
Objects made of different materials will have different weight even when they are the same size. When objects are the same size, it means they occupy the same volume. A stone will have greater weight than a feather when they occupy the same volume. That means if you put the stone and the feather on different surfaces with the same size of contact areas, the stone will exert greater force than the feather on that area.

When you use an example such as that of the feather and the stone above, you should explain to your pupils why we use the article 'the' in the second sentence instead of the article 'a'. This means we are referring to the same stone and feather as in the first sentence.

2.2 What does the sharpness mean?

What does the sharpness mean?

This word describes how thin or narrow the contact edge of the object is.



If you look at the drawing of the two pins, we say pin 1 is sharper than pin 2. Sharpness, pointedness or narrowness, flatness, bluntness or width are words we can use to describe the size of a surface. Scientists use the word 'area' to describe the narrowness or flatness. Pupils must also get used to this word and its meaning because they are the scientists of tomorrow.

In our study of pressure we are not usually interested in the total surface area of an object. We are only interested in the part of the area that touches you when you push the object against your body. We call this area the contact area. This means the area that touches.
When you push a brick against your body, you may use one of the small sides or one of the larger sides. When you calculate the area, you must make sure that you calculate the <u>contact</u> area.

Every object will have a contact area even if it is very small. A needle is very sharp, so its contact area is very small. It may therefore not be possible to measure the sharpness of the needle with the equipment you have in your school.

The pressure object A exerts on object B is affected by both the force and the contact area. This force may be the weight of object A if object A is put on top of object B.

The weight of an object is related to its density. The density of an object therefore indirectly affects the pressure the object exerts.

The next section looks at the density.

2.3 What does the density mean?

The density of a suostance is a measure of the mass of the substance for unit volume. A unit volume is a volume whose measure is 1 unit - 1 cm^3 or 1 m^3 for example.

If the volume is measured in m^3 then the mass should be measured in kg. We sometimes measure the volume in cm^3 because a m^3 is very large. When we use cm^3 as the unit for volume, we usually use the gram as the unit for mass.

Remember that when two substances occupy the same volume, the one with the greater density will have the greater mass. It is therefore not correct to say if one substance has greater density than the another, it will feel heavier to lift. This is only true when their volumes are the same. For example a truck load of feathers will have greater mass than a cup of mercury. However mercury has a greater density than feathers

The next section looks at the pressure due to a solid (solid pressure) and then the pressure in a stationary liquid (hydrostatic pressure).

Later we shall see how the density of a substance affects the pressure it exerts.

2.4 What is pressure?

The word pressure in everyday language often means 'force'. That means if you apply pressure on a person, you are forcing that person to do something. Also if you think about the word 'press' from which the word pressure is derived, you will realise that it also has to do with a push. This further suggests that pressure means the same thing as force. However in physics the two words have different meanings even though the ideas are connected.

The word pressure in science refers to the force a unit area. To find pressure we divide the force by the area on which the force acts i.e Force/area.

We can change the pressure by either changing the force or by changing the area. An increase in force results in an increase in pressure but an increase in the contact area results in a decrease in pressure. If we increase the force and the contact area in the same proportion (eg. by doubling both), the pressure does not change.

All forms of matter can exert pressure. In all cases we can calculate the pressure from the formula $P = F/A$. We sometimes call the pressure from a solid, 'solid pressure', and from a gas, ' gas pressure'. In the case of a liquid, or a gas we are only concerned with pressure when the liquid or gas is not moving.

There are certain things which the students should know before you can teach the concept of pressure.

2.5 What pupils should know before you start teaching pressure

Before you start this work you should make sure that the pupils can

- measure length
- calculate area for a regular and irregular shaped surface.
- state that a 'force' is a push or a pull
- state that weight is a force which acts downwards towards the Earth
- measure force in newton
- explain the difference between mass and weight.
- measure area in m^2, cm^2 etc.
- convert from m to km. (This will make it easy for them to convert from Pascals to Kilopascals).

2.6 What pupils should know after they have been taught pressure

After you have finished teaching about pressure the pupils should be able to:

- state the relationship between pressure, force and area.
- relate increase/decrease in force to increase/decrease in pressure (when the area is constant).
- relate decrease/increase in area to increase/decrease in pressure (when the force is constant).
- use the formula Pressure = Force / Area for solids.
- work out any one of the three given the other two.
- convert from Pascals to Kilopascals.

2.7 Pupil Difficulties

Pupils find it difficult to :

- differentiate between force as a push or a pull and pressure.
- work with ratios. Since pressure is a ratio, they find this difficulty again in calculations involving pressure.
- recognise the everyday and scientific meanings of the words force and pressure.

3. Solid pressure

3.1 Possible problems when teaching solid pressure

3.1.1 Problems with apparatus

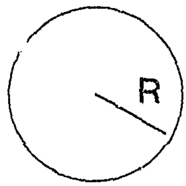
In some of the experiments we need to measure quantities eg. weight. If you do not have equipment to measure weight, you may use objects whose mass you know so that you can calculate the weight. Examples of these are objects you buy in shops like containers of fish, corned beef and packet of tea.

The mass of these is marked on them in grams. To find the weight of these in newton you need to convert the mass to kilograms. To convert to kilograms you must divide by 1000. This is because 1000 g make 1 kg. In fact the prefix 'kilo' means '1000'. You can then multiply the mass in kg by 10 to convert to the approximate weight in newton (N). This is the same as dividing the mass in g by 100.

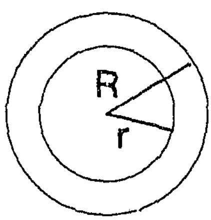
We use the word 'approximate' because the exact value differs from place to place. For that reason the weight of an object will not necessarily be the same at two different places. Only its mass stays the same.

In some cases the word 'weight' has been written on the containers although measurement of mass has been given. Remember to explain to your pupils that in such cases the word 'weight' has been incorrectly used.

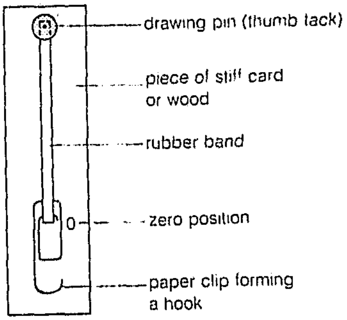
These objects also have different shapes. There are therefore different areas of contact with these different objects. You can use a metre rule or a 30 cm ruler to measure the areas of contact. For round containers such as a fish tin, use the formula πr^2 for the area of a circle. You should however be careful to see that the contact area is the whole circle with the radius 'r'.



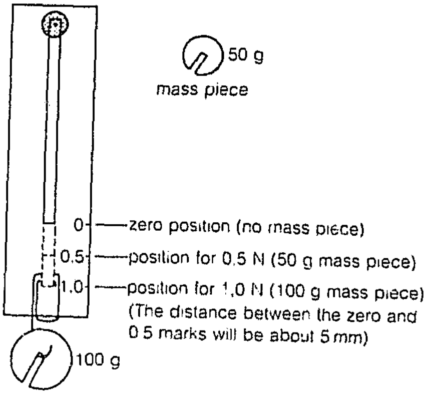
If it happens that the contact area is only a fraction of the cross sectional area then this formula can not be used. This is the case with many circular containers since very often there is a thin ring which forms the edge. This ring is often longer than the rest of the cross sectional area which in turn makes it the only part that which forms the contact area. It is possible to calculate this contact area by putting a string around the outside of the ring. You can measure the length of this string and then calculate the radius, r, of the circle (which was formed by the string) using the formula $2\pi r$. You can also do the same with the inner circle of the ring. The measurement of the inner circle will be less accurate because the string is not as tight as when you measure the circumference of the outer circle. Thereafter you can calculate the areas of both circles and subtract the area of the inner circle from the area of the outer circle. See the sketch below.



When you want to measure the weight of objects and you do not have laboratory apparatus, you can make your own force meter with simple apparatus. See fig. 1 below.



Making a forcemeter



Calibrating a forcemeter

You will need the following:

- Drawing pin
- Piece of stiff card/wood
- Paper clip
- 50 g mass piece
- 100 g mass piece
- Rubber band (circular typical to those used to hold money notes)

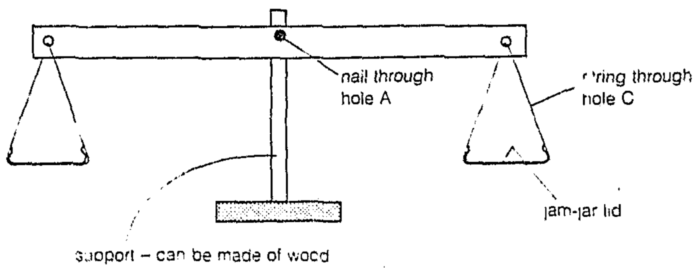
Procedure

- Use the drawing pin to attach one end of the rubber band to the piece of stiff card/wood
- Change the shape of the paper clip to form a hook on one end - Attach the paper clip on one end of the rubber band leaving the hook hanging freely.
- Arrange the system so that the rubber band hangs vertically.
- Decide on which part of the system you are going to take the readings eg the bottom part of the rubber band.

- Choose a spot on the stiff card corresponding to the bottom part of the rubber band (*if you have decided to use the bottom part of the rubber band for your readings*)
- Mark this spot as zero.
- Attach a 50 g mass piece to the hook. With the rubber band stretched, mark the size of the bottom part of the rubber band as 0,5 N. (This is because a 50 g mass has a weight of 0,5 N).
- Now remove the 50 g mass piece and attach a 100 g mass piece in its place. Mark this position as 1 N.
- Mark additional divisions by dividing equally between 0 and 0,5 N and between the 0,5 N and the 1,0 N. If you have made a total of 10 divisions, you can now measure weight from as little as 1 N.

Please note that you should not try to measure large weights using this force meter. This is because if this is done, the rubber band may not go back to its original position.

If you do not have the mass pieces, you can make your own by using the following procedure (see the figure 2 below):



- Make a mini see - saw.
- Put/Hang a litre of milk on one side.
- On the other side put/hang a bag. The bag should be as far from the centre of the see-saw on one side as the litre of milk is on the other.
- Add sand to the bag until the milk and the sand bag balance.
- This bag of sand has a weight of approximately 1 kg.

- You can get a bag of sand that has a mass of 1 kg like before. If you now divide this bag into two equal portions, each one will have a mass of approximately 0,5 kg.

3.1.2 Problems with language and answers to questions

Each unit in the pupil worksheets contains words we think pupils may not know. Make sure that they understand these words so that they can carry out their instructions well. If there are other words or phrases they do not know, please address these as well. You can use any strategy you want to use. The following is only a guideline:

3.1.2.1 Unit 1

The words 'sharp' and 'flat'

You can show them flat and sharp objects and let them try to distinguish flat objects from sharp objects.

A second problem may be related to the manner in which the children handle the equipment. There may be no problems when the children push sharp end of objects against their hands. There may be problems when they use the flat ends.

The worksheets ask the question 'In general which hurts most, a sharp object or a flat object?' We expect them to say it does not hurt (or at least less so) when they push the flat ends of objects against their hands. It is however possible for the hand that pushes to feel pain if the child pushes directly on the sharp end.

When the child claims it hurts even when they push the flat end of objects against their hands, you should ask them 'in which hand does it hurt?' Let them show how they pushed. In order to avoid this problem, you can demonstrate to them that they should push by holding the sides of the pin. In this way it will not hurt both ways.

When the children have identified the sides that hurts most, The next question is: 'Why do you think the reason is?'
Answer: The pressure is greater when a sharp object is used than when a flat object is used.

The reasons the children give will form the basis of the lesson. We suggest that the children be taken through incorrect answers to show that those answers are not correct before they eventually learn about the correct answer.

In order to go through all incorrect answers, you can ask them 'What answers did you write?' List their answers to see if there is an answer which the worksheets do not address. You can then tell them that the following worksheets will show whether their answers are correct or incorrect. In the mean time this will give you time to think about how to address the unexpected answer.

One unexpected answer may be that the type of material affects the pain. We suggest the we tackle this only after they have understood the concept of pressure. You can then show that when they push a soft material against their hands, the material collapses. This increases the cross sectional area. An increase in the cross sectional area reduces the pressure.

A second unexpected answer may be that the pain also depends on how hardened a person's hand is (for example some boys may have hardened hands due to manual labour whereas the girls' hands are soft). An answer to this question lies in the difference in the sensitivity of the skins. Some people do not easily feel the pain because their brains do not get that information from their hands. Although the object may do them some damage, they do not quickly realise it.

3.1.2.2 Unit 2

The word 'upright'

The word means straight up. You can check their knowledge of the word by drawing different objects at various angles and ask them to identify the one that is upright.

In this unit we look at the first of the incorrect answers. That is, the force alone explains why some objects hurt more than others. We do this by showing that it is possible to have different degrees of pain even for the same force.

The activity is to let some children support an object such as a ball point pen upright on another child's hand. They should do these activities for both the sharp and the flat end of the object.

We then ask the following question:

'Does it hurt?'
Answer: No/Yes

It is possible for an odd child to say 'yes'. Should this happen ask him 'which side hurt the most'. This will be the sharp side. You can then explain that the force is the same although the pain is not the same. This shows that the force is not enough to explain the pain.

When the answer to the above question is 'no', the second part of the experiment becomes necessary. Here some children increase the force acting on the child by putting an extra object on top of the object. The question is repeated.

'Does it hurt?'

Answer: Yes.

We then ask the next question

Q3. Does the force you use affect the pain when you push different objects against your hand?
Answer: Yes.

Q4: 'Is it only the force?'
Answer: No

Many children are likely to answer 'yes'

This takes us to the next unit where we are going to look at the next incorrect answer.

3.1.2.3 Unit 3

The word 'contact'

This word means to touch. Show them how large the area of an object is. Thereafter show them that not all of that area can necessarily touch when you bring another object closer. It is only the portion of the area that touches which is called the area of contact.

You can expect some children to have problems with the question 'Is it only the force ..' or 'Is it only the contact area ...' i.e they may find it difficult to look at the force and the area separately.

It may be useful to briefly repeat the activity. You may quickly do the activities with one of the pupils while the rest of the class is watching.

In this unit we want to show that a sharp object will not necessarily inflict pain. We do this by reminding the children about what they had done in unit 2. This is done in the form of questions.

Q1: Does it hurt when a friend puts the flat end of the ball point pen on your hand without the book on top?

Answer: No.

Q2: Does it hurt when a friend puts the sharp end of the ball point pen on your hand without the book on top?

Answer: No.

Q4: In the experiment you had a book on top of a ball point pen for the flat and for the sharp side. Was the pain the same?.

Answer: No

Try to explain your answer.

The explanation is the fact that the pressure is greater when the sharp side is used than when the flat side is used.

We want to see the sort of answers they will come up with. At this stage they may come with answers like 'even when you use a sharp side, it hurts more when book is put on top'. This means the idea of increasing the force starts to take shape. Do not tell them about the pressure yet.

Q5: Name two things which will increase the pressure.

a) Increase in force

b) Decrease in the sharpness (contact area)/Increase in the flatness (contact area).

Q6: Is it only the contact area?

Answer: No

We hope by this time the children will have realised that the contact area alone is not enough to explain why it hurts when other people push objects against them.

3.1.2.4 Discussion of units 2 and 3

This section looks at units 2 and 3 together. It shows that the force alone is not enough to explain why it hurts when someone pushes an object against your hand. In the same way the cross sectional area alone does not offer an explanation. This unit goes on to show that it is a combination of the force and the cross sectional area which offers an answer which is sensible.

We start by asking again whether the force and the cross sectional are enough to explain why it hurts when somebody pushes an object against your hand. We then proceed with the following questions that lead the children to realise that it is the pressure that affects the pain. We have indicated the answers in bold below.

Q3: Complete the following sentences:

a) When the contact area does not change the pain gets bigger when the force gets ....**(bigger)**

b) When the force does not change the pain gets bigger when the area gets ....**(smaller)**

c) The pain gets bigger when the force gets .**(bigger)**....... and the area gets

.**(smaller)**........

d) The pain gets smaller when the force gets ..**(smaller)**..... and the area gets .**(bigger)**.......

e) The pain gets bigger when the ratio Force/Area gets bigger/smaller. This ratio is called the pressure.

f) The pain will always increase when the ...**(pressure)**.... increases.

3.1.2.5 Unit 4

Should you have difficulties with obtaining a sponge you can use the children's imagination as chances are that they have seen this experiment before.

You can draw a sponge with dents of different sizes. The question may now be 'identify dents that correspond to a brick when it is in this position or that position (show the positions).

Dry sand is also suitable. If this is still a problem, mud may be used. In these cases, the children can put the bricks on mud (sand) and study the marks left by the bricks. When the pressure is great, the mark left will also be large. The reverse is true for a smaller pressure.

In this unit we want to compare the pressure an object exerts when put down on sides that have different sizes. This is the visual effect of a change in cross sectional areas. We also look at the visual effect of a change in the force. We do this by putting an object on top of another one. The objects are then put onto a sponge. The dents on the sponge give us the visual effect of a change in pressure. This change is due to either the change in the cross sectional area or the change in the force.

Ask the following questions. The children should answer the questions before they do the activities.

Q1: Does an object exert the same pressure when it is on a table as in A and when it is on the table as in B?

Answer: No.

Explain your answer:

The pressure is greater in B than in A because in B the contact area is smaller than in A.

Q2: Do different objects always exert different pressure?

Answer: No

Explain your answer:

It depends on the force and the cross sectional area.

We ask the following question when they have done the experiment:

Are the dents the same?

Answer: No

Explain your answer

The smaller side of the object exerts greater pressure.

3.1.2.6 Unit 5

Remind the children to record their readings immediately in the right columns. A delay may result in the children forgetting the corresponding column.

This unit is an extension of unit 4. Measurements are introduced for the first time in this unit. The children measure the weight and the cross sectional areas of the objects.

They then calculate the pressure for different weights and cross sectional areas. They then relate the figures they obtained to the dents they have seen. This exercise relates the theoretical aspects of pressure with its effects in a practical way.

The weight of the brick may be too large to be measured with the spring balance. Instead of a full brick, the children may measure the weight of half a brick. They can then estimate the full weight of a brick by multiplying by two.

The children answer the following questions in this unit

Q1: Is the pressure which a brick exerts the same in both cases?
Answer: No. (The calculations show this)

Q2: Does this explain why the short side made a bigger dent?
Answer: Yes.

Q3: Will the dent increase when one brick is put on top of another brick?
Yes (We will be increasing the force but not increasing the contact area - the pressure will therefore increase)

Q4: How do the dents relate to the pressure the bricks exert?

The deeper the dents the greater the pressure.

The following questions are aimed at getting the pupils to discover the unit of pressure.

Q1: What is the definition of pressure?
Answer: Force divided by area.

Q2: What is the unit of force?

Answer: Newton.

Q3: What is the unit of area?

Answer: m^2

Q4: Now use your answers to the three questions above to find the unit of pressure.

The unit of pressure is Newton/m^2.

You can now tell them that this unit is called the pascal. You can now have a discussion with the pupils to show them how large a pascal is.

This unit is also called the pascal (Pa).

Remember pressure is force/area and we measure force in newton while we measure area in m^2. The unit is therefore N/m^2. This unit is called the pascal.

One pascal is therefore the pressure when a force of 1 N is applied over an area of 1 m^2. An object that has a mass of 100 g (0,1 kg) weighs nearly 1 N (If you like ask your teacher why we can not be sure that the object will have a weight of 1 N).

To find out how large a pascal is, you can use a card whose length is 1 m and the breadth is also 1 m. One pupil can hold two ends while another pupil holds the other two ends. The third pupil should now weigh 100 g of sand and spread it evenly over the paper. The sand now exerts a pressure of 1 pascal on each bit of the card.

Can you calculate one of force and area if you know only one of them and pressure?

One way of teaching the children how to calculate one of the quantities if they know two of the quantities is by making use of a triangle below. We have described how to use it in the pupil worksheet no 9. This is particularly useful when the children do not have the necessary mathematical background (cross multiplication).

4. Hydrostatic Pressure

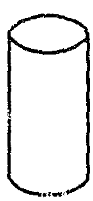
4.1 Background information

4.1.1 What is hydrostatic pressure?

The word hydrostatic consists of two parts, hydro- which means liquid and static- which means stationary. The word therefore refers to pressure due to a fluid that is not moving. The word fluid includes both liquids and gases. However in this guide we are only concerned with the pressure in liquids.

We can still use the definition of pressure, $P = F/A$ which was used with solids. However we can find an easier formula for calculating the pressure at any depth 'h'. The diagram below shows how you can do that.

Imagine a liquid column below. F is the weight of the liquid given by mg, where m is the mass of the liquid and g is the acceleration due to gravity.



i.e $F = mg$

But $m = \rho V$ (ρ is the density and V the volume)

Therefore $F = \rho Vg$.

Since $V = Ah$ (h is the depth of the liquid column)

$F = \rho Ahg$.

We know that $P = F/A$

$= \rho Ahg/A$.

Therefore $P = \rho hg$.

We can see that 'A' is missing from the term ρgh in the equation above. This means the cross-sectional area does not affect the pressure. The pressure will be changed only by h and ρ.

The above formula enables us to calculate the pressure in a liquid at any depth 'h'. It is not necessary to use this formula with children as it may be too difficult for them. For children who need to know more, you can explain that it is possible to calculate the pressure at any depth. You can follow the following steps.

a) Pour water into a container A.
b) Mark the depth at which you want to calculate the pressure.
c) Pour the water up to this mark into container B the weight of which is known.
d) Find the weight of container B with water.
e) The difference in weight between container B with water and container A is the weight of the water you have poured out.
f) Calculate the cross sectional area of container A (Use the 'string method' we discussed under solid pressure).
g) Divide the weight of the water by the cross sectional area.

The above steps for using the formula $P = F/A$ to calculate the pressure in a liquid can only be used for containers with constant cross sectional areas. When the cross sectional area changes, only the weight of the liquid column that rests on that area affects the pressure. This is difficult to do without calculations that will involve the depth and the density of the liquid. This research does not go to the extent of using the above formula with containers that have a varying cross sectional area.

4.1.2 The effect of the depth of a liquid on hydrostatic pressure

Pressure at points that are at the same depth is the same. For this reason if you pour water into a container with holes at the same depth, the water jets will hit the floor at exactly the same distance.

Pressure in liquids increases with depth. In a particular liquid the depth below the liquid surface is the only factor that influences the change in the pressure (ρ and g are fixed -- see the equation above).

Figure 4 below shows a container with three holes, one above the other

- Note the rate of flow from each hole.
- What effect does depth have on pressure in a liquid?

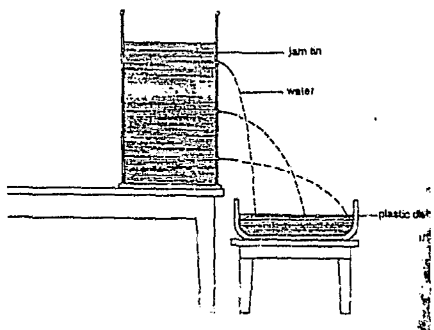


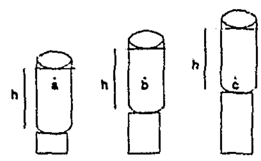
Fig. 2.17 The pressure is different at different depths in a liquid

Figure 5 Water jets from holes

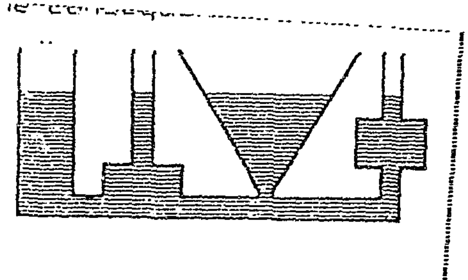
The bottom hole shoots out water the furthest, followed by the middle hole, and then the top hole. This shows that the pressure is the greatest at the bottom and the least at the top. Therefore, we can say that the pressure increases with depth.

The above experiment is tricky. The bottom hole should be sufficiently far from the bottom of the container to allow its water jet to complete its maximum horizontal distance. You can achieve this by elevating the container from the place where the jets hit the floor. If the container and the place where the jets hits the floor are at the same level, you will see that the middle hole tends to shoot out its jet further than the other two. This is because the bottom hole does not have the height advantage which the other two have. As a result despite the fact that the bottom hole shoots out its jet at the highest speed, it can not successfully reach its maximum distance because it hits the ground before completing a curve that would eventually land it at a spot further compared to the other two.

There is another way of doing the above experiment. This way eliminates the possibility of making an incorrect observation we have mentioned above. In this experiment, we use three containers. The holes are kept at the same height from the table. This is illustrated in the sketch below.



You should explain to them that in this case the height does not affect the results because it is the same in all the tins. This experiment has been described in the pupil worksheets. Figure 5 shows the consequence of the fact that the pressure depends on depth.



We often refer to the above as the 'hydrostatic paradox' because the water always rises in such a way that it exerts equal pressure at the bottom of the tubes. For the pressure to be the same, the water must rise to the same level if the tubes are connected in such a way that water can flow through the tubes from one container to the other.

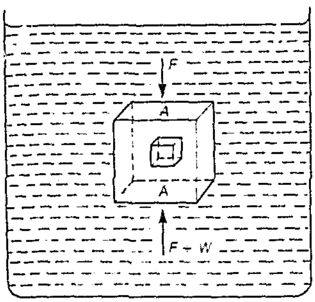
We can see from figure 5 that the liquid rises to the same level in all vessels regardless their sizes and shapes.

4.1.3 The direction(s) of hydrostatic pressure

We can see from the equation that defines the pressure that the symbol ρ for the density also appears. This means the pressure also depends on the density of the liquid. For that reason mercury which is 13,6 times as dense as water, will exert 13,6 times greater pressure than water if their depth is the same.

Unlike solids, liquids exert pressure in all directions. Solids can only exert pressure downwards. This is because the weight acts downwards and they can only exert pressure because of their weight. Liquids also exert pressure downwards because they too have weight.

In order to explain the fact that liquids exert pressure in all directions, it is useful to consider a portion of a liquid. We shall choose a portion that has the shape of a cube. This portion of the liquid is in equilibrium, figure 6. That means all forces acting on the cube are balanced by other forces in opposite directions.



In figure 6 above, there is a downward force on a point, A at the top of the cube. This is due to the weight of the liquid above it. This force also acts on a point B, at the bottom of the cube. experiences a force due to the weight of the liquid above the cube. In addition the weight of the cube also acts on point .B. This means the downward force on point B is greater than the downward force on point A. As a result to keep the cube in equilibrium, there should be greater force at point B than at point A. There will therefore be greater pressure at the bottom than at the top.

The weight of the cube becomes smaller when the cube becomes smaller. As we go on making the cube smaller you will realise that ultimately when the cube becomes a point, the upward and the downward pressures will be the same.

Some people (and school books) often ignore the fact that the cube should be small. We feel this is not correct because the pressure can not be the same in all directions on the cube if the cube is large.

4.1.4 The nature of hydrostatic pressure at a point

Sideways pressure is the same.

We have explained in section 4.1.2 that the pressure is the same at all points at the same level. That means the pressure on both horizontal sides of a point is the same. The question is whether pressure acting vertically is equal to pressure acting horizontally.

You should remember that a point is small so upwards and downwards pressure is the same. Also we are referring to a point that is not moving (it can not move because the fluid is stationary). If it does not move then the force towards it from the right is equal to the force towards it from the left. Because of its smallness its dimensions are the same at the left hand side and the right hand side. The pressure will therefore be the same from both sides.

Looking at the cube, it is not rotating if the fluid is stationery. That means there are no shearing forces (forces parallel to the sides). In fact we can not have shear forces in a stationery fluid. All forces are therefore acting perpendicular to the cube and inwards (towards it).

4.1.5 Pascal's principle

We state the principle as follows: 'If you apply pressure on an enclosed liquid, this additional pressure will be spread equally all over the liquid'.

You must stress the following facts
- the liquid must be enclosed
- it is only the additional pressure that is transmitted.
- this additional pressure is going to add to the pressure that was already there due to

the weight of the liquid.

We use this principle in our everyday lives. It is because of Pascal's principle that the little force that we use on a jack is changed into a large force that is able to lift up a car. To understand this you can do the following

- Fill a U tube with water.
- Put mass pieces that just fit on each side
- The mass pieces support each other.

In this example the force that was exerted by one mass piece is just converted into an equal force that supports the other mass piece. Now tell them to be careful here the pressure and not the force is transmitted. Think of the car again. If the force was transmitted the small force that we applied to the jack would have been transmitted to the car and that would have been too small to lift up the car.

Ask the pupils to think of a U tube which is thin on one end and thick on the other end. If the diameter is 5 cm on one end and 50 cm on the other end, would a small mass placed on the thin end support a large mass on the other end? Think of a 5 kg mass and a 50 kg mass. The 5 kg mass can support the 50 kg mass.

4.1.6 How density affects pressure

Matter is made of particles. Particles are very small. We can sometimes see the particles under a microscope. The behaviour of these particles determines some of the properties of matter.

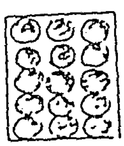
We can use models to try and understand why matter behaves in certain ways. A model can be made larger or smaller than the real object. If the real thing is very big we make the model smaller than the thing. If the real thing is very small we make the model bigger than the real thing. For this reason we draw particles bigger than their real size.

In order to understand why the pressure in liquids acts in all directions, we need to think of the particles.

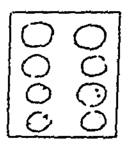
For instance in a solid the particles are held together more tightly together than in a liquid. As a result liquids can flow. The flow takes place in any direction and this is stopped by the walls of the container. The liquid therefore exerts pressure on the walls of the container

The pressure also increases with density. In order to understand this, it is important to understand what it is that makes one substance more dense than another substance. Again we must look at the particles. Their arrangement within a substance determines the density of the substance.

In a dense substance the particles are more closely packed than in a less dense substance, figure 7.



Model of iron particles



Model of glass particles

Figure 7: The arrangement of particles in Iron and glass

Equal volumes of a dense and a not so dense substances will have different weights. A dense substance will have greater weight than a not so dense substance.

When two substances of different densities occupy equal volumes, then the one with greater will exert a greater force (its weight) on the area on which it is. The dense substance will therefore exert greater force on each unit area of that total area. That means it will exert a greater pressure.

5. Teaching hydrostatic pressure

The following section contains ideas that may be used to teach hydrostatic pressure.

5.1 What the pupils should know before you teach hydrostatic pressure.

Before you teach hydrostatic pressure, the pupils should be able to

- state the definition: pressure is force / unit area
- calculate area from the formula Area = length x breadth for a rectangular shape.
- achieved objectives mentioned under solid pressure.

5.2 What pupils should know after you have taught hydrostatic pressure

When you have taught hydrostatic pressure, the pupils should be able to

- explain the difference between hydrostatic and solid pressure.
- state that hydrostatic pressure acts in all directions.
- state the relationship between hydrostatic pressure and the density of a liquid.
- state the relationship between hydrostatic pressure and the depth of a liquid.
- state pascal's principle.

5.3 Pupil Difficulties

The following are some of the things in which pupils have difficulties:

- Unlike solids, liquids exert pressure in all directions.
- The pressure at any depth in a liquid depends only on the depth of the point and its (the liquid) density.
- The shape of the container.

Some pupils feel that if the container is narrow, the liquid inside will be squeezed. The pressure will therefore be greater than in a wider container.

Other pupils think since there is a lot more water in a wide container than a narrow container, it will have greater weight and therefore greater pressure.

- Pascal's principle is also known to be very problematic.
- The wording of the principle is confusing. Pupils confuse the pressure that is transmitted with the total pressure. As a result of this misunderstanding, the fact that the pressure is transmitted uniformly is interpreted to mean the pressure is the same throughout the liquid. It is only the pressure which is transmitted which stays the same. However the total pressure remains different at different depths.

A second difficulty with Pascal's principle is the fact that second language learners see some words only for the first time in the wording of the principle. These are words like 'transmit', 'enclose', 'compress'.

Many pupils can not make sense of the word 'transmit' because they have not seen it before. Some pupils interpret 'enclose' to mean close, or close together. They associate 'compress' with press. The two words are slightly different. The word 'compress' means there must be an effect of squeezing in the action of pressing. The word 'press' means the effect is not necessarily visible.

5.4 Possible practical problems when teaching these units

The following are some of the things to be careful with when doing experiments on liquid p ssure. These experiments have been described in the pupil worksheets.

5.4.1 Making holes

The holes should be made the same shape and point in the same direction. If you have not done this, the water coming out will follow different directions making comparison of the distances at which the water hits the ground difficult.

The problem with metal containers is that as you hit the nail into the container, a dent is formed. This dent will then affect the direction which the hole will face. The hole in turn will affect the direction of the water jet.

In order to get around the problem, it is easier to make holes in plastic containers than metal containers. A pointed object such as a nail or a ball point pen can be used. The object you use to make the holes should be as sharp as possible.

5.4.2 Measuring the distance

It is important to make the students aware of the fact that they should measure the horizontal distances from the holes to the places where the water hits the floor. Should you not do this they may only measure the distances from the containers. This will not be correct in the case of some shapes of containers, for example containers that have the shape of a V.

In this experiments you should only use one liquid to compare the distances at which the liquid hits the floor. This is because different liquids have different properties such as the viscosity (friction in liquids). The viscosity will also affect the distance at which the water hits the floor.

We use different liquids only when we compare the effect of the density on pressure in a liquid. We then avoid the effect of the viscosity by avoiding experiments that need the liquids to come out of the container. Instead we use the manometer to compare the pressure.

When you use the manometer (which) is described in the next section, you should look out for air bubbles in the manometer. You should remove any air bubble by pouring out the water from the manometer and starting again.

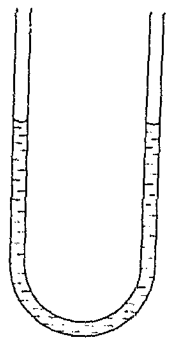
5.5 Making simple equipment

Laboratory facilities are not always available at many schools. It therefore becomes necessary to make simple equipment you can use. It is not always as easy to use these equipment as you would use normal laboratory equipment. We think however that to a large extent they facilitate understanding. In addition the children themselves can make their own equipment.

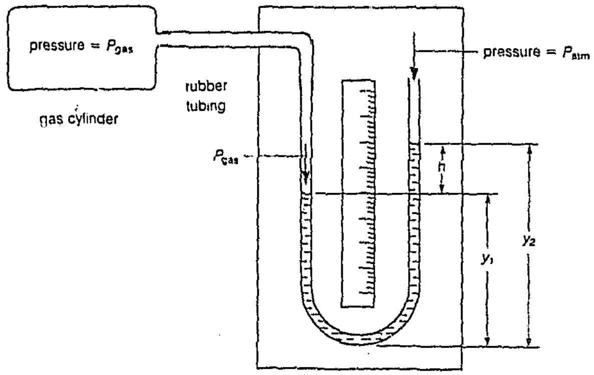
You may use a manometer to reinforce some of the properties of hydrostatic pressure. For instance when you do the activities with the tins, some pupils may not be convinced that the liquids exert pressure in all directions. This is because the containers only show the properties of liquid pressure when exerted against the walls of the container. The activities fail to prove conveniently and convincingly that the pressure is exerted in all directions anywhere in the liquid (even in the middle). You can go around this problem by making your own manometer.

5.5.1 How the manometer works

The manometer is an instrument which we use to measure the pressure in liquids. Fig. 8 shows what a manometer looks like.



The manometer consists of a U tube open at both ends. If you pour a liquid into the manometer tube while both ends are open to the air, you will see that the liquid rises to the same level in both arms of the manometer. Fig 9. shows a manometer with only one end open to the atmosphere.



The closed end of the manometer contains a gas. This exerts pressure p on one end of the liquid column. The pressure p_2 on the open end is atmospheric, p_a.

If we consider the left half of the U tube, we realise that the pressure at the bottom is given by p + $\rho g y_1$. Similarly if we consider the right hand half, the pressure is given by $p_a + \rho g y_2$. Since we are referring to the pressure at the same point in both cases, it follows that $p + \rho g y_1 = p_a + \rho g y_2$.

Therefore $p - p_a = \rho g(y_2 - y_1)$.

Hence $p - p_a = \rho gh$. $(h = y_2 - y_1)$

We call ρgh the gauge pressure and p the absolute pressure at that point.

The gauge pressure is the reading we get from a gauge when we measure the pressure. That means it is not accurate to say the pressure exerted is the pressure you read. This is the reading over and above atmospheric pressure.

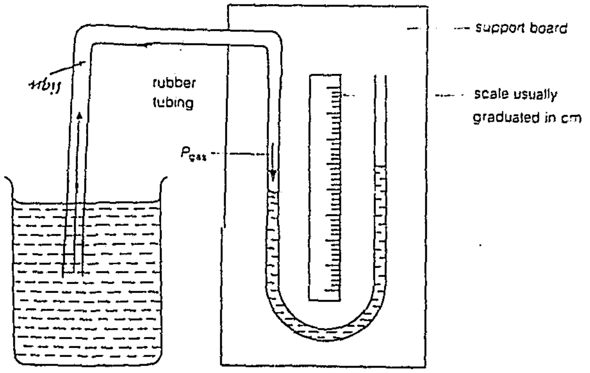
If you blow some air on the one arm (say the left) the liquid level on that arm will drop because of the additional pressure. The liquid level will rise on the other arm (say the right). In that case p will be the pressure you exerted by blowing.

You can now measure the additional pressure by measuring the difference in the liquid heights.

5.5.2 How to make a simple manometer

You can use the following guideline to make your own manometer
You need the following apparatus:

- Transparent U tube (This may be rubber/plastic which may be bent into this shape - It does not have to be glass!)
- Narrow rubber/plastic tube.
- Glass with water
- Hard board



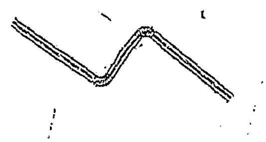
<u>Procedure</u>

- Bend the wide tube into the form of a U
- Attach the tube firmly to the board using nails while it is bent in this form (Take care not to make holes in tube)
- Firmly connect the narrow tube on one end by inserting its tip into the thick tube.
- Pour water into the rubber tubing
- Mark the water levels on both arms of the rubber tube. This level is your reference. You can regard this level as representing a pressure of 0 pa.
- Dip the free end of the rubber tubing in water
- Push the rubber tubing lower to the depth of 10 cm. The pressure here is 100 Pa.
- Mark the new level on the side which has risen.
- Now make 10 equal divisions from the reference level to this level.
- Each division will then represent a pressure of 10 Pa.

You can also let the pupils do their own little manometers.

They can make use of straws which they can connect together by sticky tapes. In this way one straw can act as a U tube while the second one acts as an extension that goes into the water.

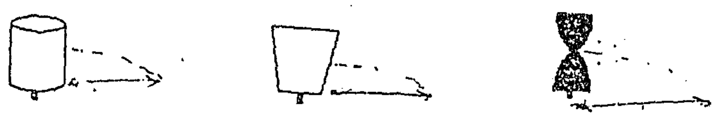
This is shown in the sketch below.



5.6 Problems with the language and answers to questions

The problem posed in the worksheets centres around the distance from the containers at which the jets of water hit the floor.
Please make sure that the pupils understand that by 'the distance' we mean the horizontal distance.

We have identified, in each unit, words which we think are difficult for the pupils. These words are explained in the units. There may also be problems regarding the distance at which the water jets hit the floor. The following sketches illustrate the distances for containers of different shapes:



Distance Distance Distance

5.6.1 Unit 1

Difficult words and phrases in the unit

The following are words and a phrase which the pupils may not understand.

The phrase 'hit the floor'

Make a sketch that shows a jet of water coming out of a container and show the pupils that somewhere the water jet will hit the floor.

The word 'spot'

You can tell them that this means a small place.

The following is an example of such sketches.

The words 'water jet'

You can draw a water jet from a container to show what a 'water jet' looks like.

The word 'quantity'

This means how much liquid we have. In particular draw their attention to the fact that in containers that have different widths, the same quantity of the liquid will have different heights from the bottom of the liquid. The liquid level will be higher in a narrow container than in a wide container when the quantity of the liquid is the same. When the height of the liquid in the two containers is the same, the wider container will have a larger quantity. The children can easily see this by transferring the liquid from one container to the other. They will notice that the height of the same quantity of the liquid is different in the two containers.

Questions in the unit

This unit introduces the question 'what causes the water jet to hit the floor where it does?' We require the children to choose an answer from the alternatives that follow. We have obtained these alternatives from interviews with children. We call these incorrect answers the 'misconceptions'. They are ideas about the questions which the children have before they are taught. We are aware that there may be answers some children may give ich are not in the list. The question 'is it something else?' will enable those children to write down their ideas.

We suggest that when the children have answered the question, you ask them to give you answers they have written which do not appear in the list (i.e 'something else') This will give you time to think about the strategy of addressing these answers while the children will be looking at the alternative answers in the un' s that follow.

Find out whether they understand all the questions. Explain these questions because if they do not understand the questions they will not be able to make a choice without guessing

The answer to the key question is the depth of the water above the hole. However you should not tell them this answer. They should first go through the units to find out why their other answers can not be correct.

5.6.2 Possible unexpected questions from the pupils

The following are two different questions that your pupils may ask. The pupils may not necessarily ask these questions in this unit but may do so in other units.

1. The atmospheric pressure affects the distance at which the water jets hit the floor. The children may simply refer to the 'air outside the water' when they have not been taught about atmospheric pressure.

The above statement is correct. When you are busy with unit 1 in particular you can not dismiss this statement. In fact you can prove it to be true by closing the container you will be using. This is because you are dealing with only one water jet. Therefore there is no room for comparison with other water jets. However in other units you can show that this answer is not sufficient because whether or not the containers are closed the relative distance at which the different water jets hit the floor will not change. This means although the atmosphere has an effect, water jets from holes that have the same depth of water above them will hit the floor at the same distance (if their height above the floor is the same).

2. Air in the water affects the distance at which the water jets hit the floor.

Ask them 'What is it that can show that there is air in the water?'When you see a bubble you can tell there is air in the water. Usually there will be no air bubbles. Therefore you can tell them there must be a different reason.

A second explanation is the fact that the air in the water is dissolved. This happens throughout the liquid. Dissolved air can therefore not be the reason.

5.6.3 Unit 2a

The word 'affect'

You can explain this word by referring to everyday incidence where the word is used. These are examples such as 'depressing the accelerator affects the speed of the car. The word 'wide'

You can ensure that they know the word 'wide' by drawing different sketches where they will be required to identify the 'wide' and the 'narrow' objects. A wide container and a thick container are not the same. A wide container will have a large distance from one side to the other but the material the container is made of may not necessarily be thick.

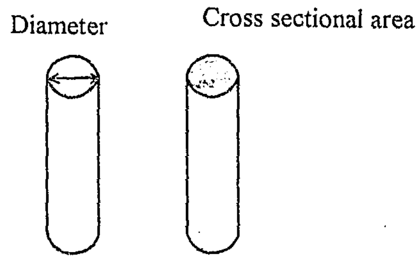
The word 'narrow'

This unit looks at the first of the misconceptions, namely that the total quantity of water affects the distance at which the water jet hits the floor.

We address this question by performing an experiment where we compare the distances at which the water jets from different volumes of water hit the floor. The size of the containers is different. This makes the volume of water in the containers different. Stress the fact that the holes should be at the same height from the bottom of the containers. In addition the water levels should be the same.

You may interpret the words 'narrow' and wide in two different ways. One meaning may be the distance from one end of the surface to the other (i.e the diameter in case of a round object). A second meaning may be the cross sectional area. The two meanings are not the same although they are connected.

The following diagram shows the difference:



We ask the following questions in this unit.

Q1: What can you say about the distances at which the water jets hit the floor?
Answer: The distances are the same.

Q2: Which container had the most water in it?

Answer: The wide container.

The next question finds out whether the children are still holding the misconception.

Q3: Is it the quantity of water which causes the water jets to hit the floor where it does?
Answer: No (because the distances were the same).

In order to cater for children who may have made incorrect observation, we ask the children to check with other groups to compare their answers.

5.6.4 Unit 2b

This unit shows that the quantity of water and the width of the container are related. We have mentioned both the quantity of water and the width of the container because we have realised that some children relate their misconception to one while others relate it to the other.

We ask the following questions:

Q1: When the height of the water in the two containers is the same, what do you notice about the places where the water jets hit the floor?
Answer: The places are the same distance from the containers.

Q2: Does the width of a container affect the distance at which the water jets hit the floor?
Answer: No.

Questions 3 and 4 are language exercises. There can be no exact answer for question 3, for example, some children may describe individual containers.

Q3: In the next unit we look at the distances at which the water jets hit the floor for **containers of different shapes.**

Q4: Describe an experiment you can do to find out if the shape of a container affects the distance at which the water jets hit the floor.

Answer: You can find the answer by reading unit 3.

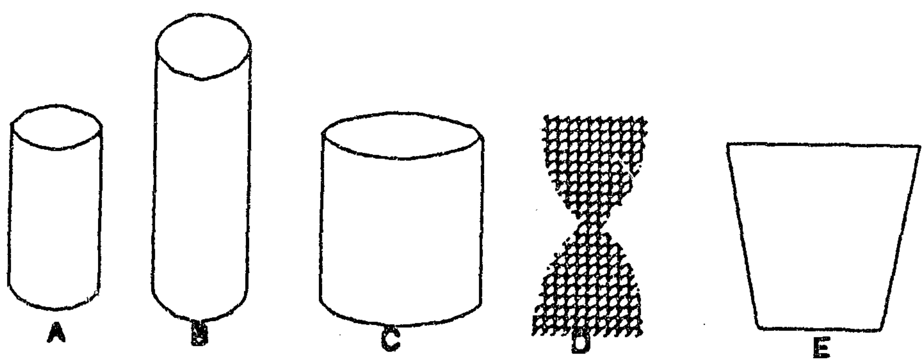
NB. In this unit, as it is still the case in unit 3, you may use containers that have the same height. In that case the pupils may simply fill the containers with water. However it happens that the heights are different. When this happens, it becomes necessary to be more precise in the language you use. The pupils should now ensure that the height of water (not necessarily volume) from the bottom of the containers is the same.

It will become clear later (units 4 and 5) that it is the depth and not the surface area of a liquid that affects the pressure in a liquid.

5.6.5 Unit 3

The word 'shape'

You can show them (or draw) objects of different shapes. Some objects should be the same shape but different size while other objects should be the same size and different shapes. This is shown in the sketch below.



You can ask them to sort the objects into different shapes.
You can then ask them to sort the objects into different sizes
This unit investigates the effect of shape on the distances at which the water jets hit