CLASSROOM PERCEPTIONS OF PHYSICS AND THE INTRODUCTION OF TECHNOLOGICAL APPLICATIONS

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ABSTRACT

This study explores the classroom perceptions of physics held by both teachers and students. A method of introducing technological applications into the classroom based on the generative learning model is investigated.

Students' views of school physics were examined by interviews with 60 7th form (17-18 years) students and surveys with 426 6th form (16-17 years) and 168 7th form physics students. The interviews and surveys showed that physics students generally had negative perceptions of school physics. The students ascribed these perceptions mainly to the apparent lack of relevance. The study also examined the students' reasons for studying physics at secondary school and university. The major reasons given were career choice and interest. There were significant gender differences in career choice. The initial career destination of New Zealand physics graduates was also investigated.

The ideas of the generative learning model and mini-theories were used as a theoretical base for the introduction of technological applications. One of the important aspects of these models is the learner's existing knowledge (which includes interests). The students' interests in technological applications were explored by interviews (40 students) and surveys (500 students). The results indicated that students were interested in applications within their own environment, directly involving people and aspects which corresponded to their intended careers and anticipated needs. There were gender differences in interest. Students were generally not interested in 'school' physics or domestic applications.

Teachers' approaches to the teaching and learning of school physics were examined by interviews (12) and their views on the introduction of technological applications were investigated by surveys (204). The findings were consistent with a transmission view of teaching and an overloaded syllabus.

In a small study possible ways of introducing technological applications were examined. A new teaching strategy, based on the generative learning model, was developed for the two 7th form physics topics of electrical capacitance and the Doppler effect. These strategies were initially trialled with two classes and then with other classes at two other schools. The classes were observed throughout the trials and teacher and student interviews were undertaken. Compared with the previous teaching programmes the students were generally very positive about the approaches. The reasons students gave for being more positive were; the introduction of technological applications that they were interested in and could relate to, the experiments, individual projects, the class discussions and being able to explore ideas for themselves. They were also more confident to attempt traditional physics problems.

The implications of the findings for teaching and learning, the curriculum and further research are discussed in the final chapter.

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CHAPTER 1 INTRODUCTION

1.1 GENERAL BACKGROUND

In a society which is increasingly dependent on technological development, it could be assumed that there would be a close relationship between physics education and aspects of society, particularly the natural and technological (Reeder, 1979). However, physics education has developed somewhat independently of society (Reeder, 1979). Fensham (1985) criticized the science curricula of the 1960's and 1970's on the grounds that they assumed that schooling took place in a social vacuum. The emphasis was on the consolidation of specific scientific concepts; its usefulness and application in society was overlooked or omitted. In many western countries the emphasis in school physics courses has been on the fundamental and theoretical aspects (see section 2.5.2). Claxton (1984), commenting on school physics in the United Kingdom, suggested that it had a linguistic, mathematical and experimental superstructure which was hardly ever intuitive and not usually open to question. Diederich (1969) also noted that in the United States, school physics programmes emphasised the theoretical and experimental aspects. The PSSC physics courses and others were developed mainly for those who would continue to university and many of the new courses that were introduced in the early seventies used PSSC as a basis (Lewis, 1972). Claxton (1984) and Layton (1973a) suggested that this emphasis has led to school physics being divorced from the students' real world and even the scientists' real world. Layton (1973a) noted that this has caused severe problems in the learning of school physics. Fensham (1985) also noted that this approach to teaching results in students identifying physics as it is presented at school as the only way of learning or doing it. Aspects of society such as the students' everyday familiar world and technological change are often neither related to physics lessons by the teacher nor relatable by the students. Frequently students who can manipulate mathematical abstractions correctly are assessed as being good physics students.

The teaching of physics in isolation from the students' world must influence their image of physics and the learning of physics. Students' perception of physics in terms of technological careers may also be influenced. There have been suggestions that a more technological approach which emphasises the everyday aspects of physics could be beneficially introduced into school physics (e.g. Layton, 1973a; Ziman, 1980). How this could be achieved and how it affects the teaching and learning of physics is less certain. Fensham (1985) indicated that very little is known about how students would cope with conceptual learning if they began from a base of familiarity.

1.2. THE NEW ZEALAND SITUATION

The present research took place mainly in physics classes at the 6th and 7th form (16-18 years) level in New Zealand secondary schools. Students begin secondary school in form 3 (13-14 years), and usually study a general science course (biology, chemistry, physics and earth science), among other subjects for the next three years. (Science is compulsory for the first two years of secondary schooling.) At the end of these three years there is a national examination. In the 6th form (16-17 years) that follows the student may opt for a combination of any three separate sciences, physics, chemistry and biology. This year is now assessed internally but when this study began in 1985 there was still a national examination. In the final 7th form year the student again chooses from physics, chemistry and biology and there are national examinations - University Bursary and University Scholarship. Few students attempt both examinations and only about 190 University Scholarships are awarded each year.

There has been a relative decline in physics students numbers at the senior secondary school level since 1974, however their absolute numbers have increased slightly. This may reflect a changing population with broader abilities and interests rather than a trend away from physics (Osborne, 1983). About 30% of the 6th formers study physics. Girls account for 28% of these physics students. In the 7th form 39% of students take physics. Girls again account for 28% of the physics students. In comparison, 44% of the 7th formers study chemistry, girls accounting for 46% of the chemistry students.

The percentage of 7th form physics classes taught by a person with a degree in physics is approximately 50%. The proportion of physics graduates to the total number of science graduates (excluding mathematics) in schools is 11% compared with 50% for biology and 25% for chemistry (Dodd *et al*. 1985).

The major emphasis of the present 6th form physics prescription is on theoretical and experimental aspects, i.e knowledge and understanding of basic facts, principles, generalizations, theories of physics, familiarity with the experimental procedures and laboratory skills associated with the subject (Department of Education, 1972). The preface to the teachers' guide (Department of Education, 1972) mentions that each topic should be related to each student's own experience but does not give ways in which this might be best achieved. The 7th form prescription emphasises theoretical concepts, experiments and mathematical language (Department of Education, 1973). It concentrates on the unifying role of mechanics, the importance of atomic and molecular structure, waves, fields and conservation laws. Technological applications, or relating physics to the students' world or experiences, are only mentioned and virtually no guidance is given to the teacher how to introduce them. Therefore school physics tends to be taught in isolation from the students' real world. The removal of the 6th form external examination and reviews of the 7th form prescription may allow for the relating of school physics to the students' own experiences (Pinder, 1986).

Teachers have been keen to obtain resource material about technological applications (Jones, 1982a). However, there is less certainty about how useful they find it in their day to day teaching, how much it is used in classrooms, and the reactions of students to such material.

New Zealand is a relatively small and isolated society. It may be that the perceived lack of relevance, and the problems faced in the teaching of physics, could be different from that in the major industrial countries. Therefore students' perceptions of physics in New Zealand need to be examined.

1.3 THE OUTLINE OF THE STUDY

This study explores the image of school physics held by physics students as it is currently taught i.e. in isolation from its application to society. From these perceptions the study investigates ways in which the teaching of physics could more effectively relate the applications of physics to students at the secondary school level.

The ideas of the generative learning model (Osborne and Wittrock, 1985) and mini-theories (Claxton, 1984,1985) are used as a theoretical base for the introduction of technological applications. One of the important aspects of these models is the concept of existing knowledge. Another element of the generative learning model is the generation of links between sensory input and existing knowledge. The individual is considered more likely to attend to a learning situation which links to his/her existing knowledge (including interests). The strategy for this study is to explore students' interests in physics and technology in and out of school and to find appropriate technological applications to introduce into the classroom. It is proposed that such technological applications may provide some of these links and so improve the learning of school physics. Teachers' views of the present school physics programme are explored, as well as their views on the introduction of applications. Finally, various strategies for the introduction of technological applications are examined. A new approach which uses the ideas of the generative learning model is developed, trialled and evaluated.

A combination of qualitative and quantitative research strategies, especially individual interviews and classroom observations were used. Surveys were constructed from the interviews. The general outline of the study is detailed below.

Chapter 2 discusses the previous relevant research. Students' reasons for studying physics are explored, including career expectations and interests. Students' interests in physics and technology in and out of school are investigated. The theoretical basis of this research, with particular reference to constructivist and generative learning models and mini-theories are discussed. The background to the introduction of technological applications is analysed. **Chapter 3** explores senior physics students' perceptions of school physics, their career choices, and reasons for studying physics. **Chapter 4** presents students' interests in physics and technology in and out of school. Gender differences in students' interests are analysed. **Chapter 5** describes different teachers' approaches to the teaching and learning of secondary school physics. Teachers' views on the introduction of technological applications are explored. **Chapter 6** analyses possible ways technological applications could be introduced into the teaching and learning of physics. A new perspective utilising the ideas of the generative learning model is developed. **Chapter 7** describes the trialling and evaluation of the new perspectives. **Chapter 8** summarises the research findings, draws conclusions and outlines implications and areas for further research.

CHAPTER 2

PERSONAL RESPONSES TO PHYSICS: A REVIEW

2.1 OVERVIEW

This chapter begins by reviewing the literature on why students choose physics at secondary school. It seems that students' choice of science subjects may be influenced by their perceptions of the various subjects (Duckworth and Entwistle, 1974), (section 2.2.1). Subject choice may be an early stage of career decision, and therefore career expectations are also examined (section 2.2.2).

The study radiates out from the learner to explore the world outside the classroom and more particularly the students' interests in and out of school as far as physics and technology are concerned (section 2.3). Section 2.4 examines learning theories as they apply to the physics classroom and the affective factors involved. The emphasis is on the constructivist tradition of learning and more particularly on mini-theories and the generative learning model. These learning models emphasise 'the learners making sense of their world'. Today's world is basically technological and section 2.5 considers whether technological applications may provide links between the students' existing ideas (important from a constructivist perspective) and secondary school physics concepts.

2.2 WHY CHOOSE PHYSICS AT SCHOOL?

Head (1985) asked 'why do different pupils make different subject choices?' He suggested that there are two possibilities. One is that students have differing views of science and scientists and act depending on their perceptions. The other is that the students all share the same perceptions but react differently because they possess different 'self images'. Head noted that most students, those choosing science and those not, share the same perceptions. Subject choice, Head and Sutton (n.d) concluded, is therefore linked with the students' belief system or image of themselves.

Another reason put forward is that subject choice is an early stage of career choice (Entwistle and Duckworth, 1977; Reid *et al.* 1974).

2.2.1 Matching the self and the subject

Duckworth and Entwistle (1974) suggested that the students' choice of science subjects may be influenced by how they perceive various subjects. Their findings fell into three categories:

(i) Interest or lack of interest in the subject.

(ii) The difficulty or ease compared with other subjects.

(iii) The subject's social benefit.

They developed a repertory grid to explore four attitudinal domains among students (interest, difficulty, freedom and social benefit) towards nine school subjects. In terms of interest, physics was ranked sixth out of nine by fifth year secondary students. Subjects such as biology, geography and chemistry were perceived as more interesting. The subjects less interesting than physics were mathematics, Latin and French. Physics was considered the most difficult subject, and geography and English were considered the easiest. In the freedom domain, physics was again ranked sixth by the students. In the social benefit domain, English was ranked the highest with physics ranking seventh for girls and fifth for boys. Those subjects directly involving people ranked highest for interest, freedom and social benefit and lowest for difficulty. Similar conclusions were reached by Ashton and Meredith (1969) who found that physics in the senior secondary school was perceived by many students as being difficult, dull, boring and irrelevant.

In summary, physics was perceived as being of less interest than chemistry. It was considered to be the most difficult subject, and rated low in terms of freedom and social benefit.

- <u>The interest level of physics</u>

The Physics Interface study (Jones, 1979) in New Zealand noted that physics students found physics slightly interesting and slightly enjoyable. Gardner (1976) noted that a decline in enjoyment of physics was displayed by most senior secondary school physics students in Australia. However, intellectual-achievement-motivated students with intellectual-achievement-pressing teachers maintained a high level of enjoyment. Jones (1979) found that those students who indicated that physics was easy (2% of the sample) felt that physics lessons were interesting, enjoyable and they learnt a lot.

Weltner *et al.* (1980) summarised the relationship between physics and interest as follows;

(i) The interest of students in general in physics is relatively low.

(ii) Boys show greater interest in physics than girls do.

(iii) Interest in physics by physics students decreases in the higher levels.

In the evaluation of the PLON (Project Curriculum Development in Physics) project in the Netherlands boys scored higher on enjoyment and achievement tests. Girls had a slightly more positive belief in learning from investigation (Wierstra, 1984).

- <u>The difficulty of physics</u>

Physics is perceived as being difficult by nearly all students, even those who were keenly interested (Duckworth and Entwistle, 1974). Ormerod with Duckworth (1975) and Ormerod *et al.* (1979) suggest that the evidence for the difficulty of studying the physical sciences and its causes can be put into three categories:

(i) The views of students in general.

(ii) Science courses are taken by students of high intelligence.

(iii) Evidence from research studies indicating that chemistry and physics are among the most difficult subjects.

Bridgman and Welch (1969) noted that students felt that physics was always a difficult course. This was also found to be true in New Zealand (Jones, 1979). Welch and Walberg (1967) noted that there was a stigma of difficulty surrounding physics. Tamir *et al.* (1974) found that physics was perceived as increasing in difficulty with the level of schooling, that it was hard to learn and required special talents. It has also been found that enrolments are negatively related to perceived course difficulty and the severity of grading (Ahlgren and Walberg, 1973). Welch (1969) showed that girls and boys studying physics were among the academically elite. Selkirk (1973) in his study of Northumberland students also found high ability students in physical science courses. Shayer (1972), using the hierarchy of levels of mental development postulated by Inhelder and Piaget, concluded that the physics and chemistry at O level and physics at A level are conceptually too difficult for the average physics student.

Although much of this research was undertaken in Britain and the United States, these general trends were also found in New Zealand (Elley and Livingstone, 1972). They calculated the ability of 6th formers in terms of the mean mark obtained in the School Certificate examination for each student's best three subjects plus English. They found that students taking physics, chemistry and French in form 6 had gained higher School Certificate marks than those taking geography, biology and accounting. They also found that students taking physics had lower 6th form grades than those in other subjects, even though the former had had considerably higher School Certificate marks. Again, the Learning in Science Project (Tasker *et al*. 1979) in New Zealand showed that students have difficulty with concepts in the physical sciences.

- The mathematics prerequisite

Many students studying physical science have difficulty with the mathematics (Ashton and Meredith, 1969). Research in colleges in the United States (Brown and Elliot, 1973) found that nearly 40% of those questioned considered that they could do better in physics if they had a better mathematics background, although most in fact, had a good mathematics background. The introduction of new mathematics in

Britain could have caused problems since physics curricula have been designed for traditional mathematics syllabi (Ormerod with Duckworth, 1975). However, Hudson (1986), in his study of the relationship between mathematics and physics success, found that students' performance on tests of mathematics skills did not serve as an indicator of success or failure in a physics course. Those students who succeeded in physics appeared to have skills for solving the reasoning questions independently of the skills used in purely mathematical operations.

- The importance of the physics teacher

Students who are intellectually intense and who are taught by intellectually stimulating teachers tend to maintain a favourable view of physics throughout their schooling (Gardner, 1974, 1976). This study concluded that achievement-teachers exerted favourable influence on achievement-motivated students but not on students who were low in achievement motivation. It was found that the less serious students who were already more likely to decline in attitude during the year would decline even more if placed with a serious teacher (Gardner, 1976).

Rothman, Welch and Walberg (1969) concluded that changes in students' achievement and interest in physics were more strongly related to teachers' personalities and value systems than to the extent of the teachers' preparation in physics. Yager and Yager (1985) found that as teacher qualifications in physics increase, student motivation and interest may actually decrease. The teachers were seen by these students as knowing all the answers to questions. However, Lovell and White (1958) were unable to obtain a clear idea of whether liking or disliking a teacher affected students choice of physics. The influence of the teacher is obviously important, although it appears difficult to quantify that influence.

- The image of physicists

Students' perceptions of physics may also be influenced by how they perceive physicists. Several investigations have found negative perceptions of science and scientists (Ahlgren and Walberg, 1973; Gardner, 1974; Hudson, 1967).

Hudson (1967) questioned arts and science specialists at secondary school about how they perceived a physicist as compared with a novelist. Both groups considered that a physicist was 'dependable and hard-working' whereas the novelist was 'imaginative, warm and exciting'. Adult physicists were perceived as leading dull personal lives. In Australia, Mackay (1971) found that after students had studied physics they saw physicists as being 'less like other people'. Ahlgren and Walberg (1973) asked 96 high school students to rate eight different occupations - businessman, artist, teacher, plumber, biologist, secretary, physicist and doctor. The students were also required to rate another factor 'me' on a three dimensional grid with axis of maturity, importance and friendliness. It was found that most students perceived 'physicist' as being the most remote from 'me'.

Gardner (1974) suggested that students who are more likely to be submissive and conformists looked upon physicists with some sort of affection and tolerance. In general, girls perceived physicists as being completely opposite to the values they expressed (Bryhni and Lie, 1985).

- The social context of physics

It has been suggested that students may be deterred from choosing physics because the material presented at school was too cut and dried, and devoid of human content (Kelly, 1976; Woodall, 1967). Kelly (1976) suggested that this affected girls more than boys because they like to use their imaginations and express their own opinions.

It is generally accepted that girls are more interested in people-oriented activities (Kelly, 1978). In a survey (Ahlgren and Walberg, 1973) of 1000 physics students the PSSC physics course was rated lower on philosophical, social and humanitarian aspects than other courses. This was to be expected because PSSC was primarily intended to increase the accuracy and integrity of reasoning in the physics course. The newer Harvard Project Physics (HPP) was rated higher in three aspects and gender differences were apparent. There was a stronger correlation between interest in physics and the ratings of physics on humanitarian, social and artistic scales among girls whereas among boys there were stronger correlations between interest and applied practical ratings of physics.

Ormerod *et al.*(1979) showed that when social aspects of physical science were introduced there was a favourable response among girls. Their hypothesis was that physics, chemistry, mathematics and geography were boys' subjects, whereas the rest were girls' subjects.

- Summary and Comment

Physics is perceived by many senior secondary school students to be difficult, dull, boring and irrelevant. Interest in physics is relatively low and interest levels decrease in the higher level of school. Boys appear more interested than girls. Generally it is the more able students who take the physical science subjects. Certain types of students respond better to physics teaching than others e.g. more serious students. Students generally have negative perceptions of physicists although conformists tend to be more positive. Girls often perceive physicists' values as opposing their own. School physics generally appears to have a low social value although there might be a more favourable response from students, particularly girls, if social aspects of physical science were introduced.

2.2.2 Career considerations

Reyes (1984) argued that the perceived usefulness of a subject is an important factor in determining whether students will elect to study it. It has been suggested that one of the most important reasons for studying a particular subject is that of career choice (Head and Sutton, n.d; Lovell and White, 1958; Reid *et al*. 1974; Sjoberg, 1983). The perceptions the students have of a particular job and how the physical sciences relate to that job has a significant effect on the subsequent choice of school subjects (Harding, 1983). Butcher (1969) asked 300 Scottish students to rate 15 careers under the headings of like, interest, salary, prestige, qualification and usefulness. For 'like' and 'interest' (i.e. the least factual headings) there were striking differences in the rankings between the girls and boys. Boys were much more interested in scientific careers while girls were more interested in those careers which directly involved people. Baldwin (1975) examined the careers that students pursued on leaving college or university and found that physics was the least popular. People took elementary physics as a prerequisite to medicine, radiography etc. Harding (1986) asked students to list the occupations that interested them and the perceived importance of physical science in the list of careers was explored. She found that physical science was considered important by boys in all but two occupations whereas for the girls it was considered important in only two. Kahle (1985) noted that boys expressed considerable interest in using scientific knowledge for future careers while girls expressed significantly less interest. Again, girls were interested in working with and helping people but boys were more technologically orientated (Bryhni and Lie, 1985). In the United States, Thomas (1986) showed that career interest was a significant predictor of students' interest in high school science. She also found that having high occupational expectations had a positive and significant effect on high school science interest for males. These differences (particularly sex differences) may be the reason why students have different perceptions of physics.

2.3 PHYSICS AND TECHNOLOGY: SPECIFIC INTERESTS IN AND OUT OF SCHOOL

2.3.1 Introduction

In section 2.2.1, it was suggested that interest was a major reason for subject choice. The present section explores the question of interests more specifically and adopts the view of Lind (1982) that interest in physics and technology should be treated jointly.

Hasan (1975) concluded that the promotion of student interest in science lessons and science-oriented careers has long been thought of as an important objective. However, as Donovan *et al.* (1985) reported, little emphasis on student interest and career awareness has actually been studied. Sullivan (1979) also concluded that specific interests in science have not been extensively researched. Recently, however, there has been increased research in the area of student interest in physics. The following sections discuss the work of: Assessment of Performance Unit (A.P.U), 1985; Harvey and Edwards, 1980; Johnson and Murphy, 1986; Lazarowitz and Hertz Lazarowitz, 1979; Lind, 1982; Sjöberg, 1983; Smail and Kelly, 1984; Smail, Whyte and Kelly, 1982; and Sullivan, 1979.

The majority of instruments used a scale of interest, for example dislike - like, interested - very interested (e.g. Harvey and Edwards, 1980; Smail and Kelly, 1984; Sullivan, 1979). Smail, Whyte and Kelly (1982) gave the students a choice of essay subjects. Lazarowitz and Hertz Lazarowitz (1979) asked students to rank subjects and topics in order of preference. Sjöberg (1983) attempted to relate interest to success, perceptions and attitudes. Students were questioned on hobbies, attitudinal statements and vocational choice. However, few of the instruments probed the reasons why students responded as they did, although Weltner *et al.* (1980) did ask students why they would watch certain fictional television programmes.

The findings of the reviewed literature fall into three main areas of student interest;

(i) Interest in science topics generally.

(ii) Interest in existing physics lessons.

(iii) Interest in out-of-school activities.

Within each of these categories there are noticeable sex differences.

2.3.2 Interest in science topics generally

Smail and Kelly (1984) listed 42 everyday world topics which could be included in a science programme. Both sexes were interested in how a record was made but did not want to know how a vacuum cleaner or bicycle pump worked. However, 50% of boys but only 11% of girls wanted to learn about 'atoms and molecules', whereas 54% of girls and 24% of boys wanted to know 'how seeds grow into flowers', 'How machines work', 67% of boys compared with 26% of girls were interested. Seventy-one percent of boys and 46% of girls wanted to learn more about the stars and planets. Combining all the 42 items and using factor analysis it was found that boys were more interested in the physical and technological aspects of the world and girls appeared to be more interested in human and natural aspects. Lazarowitz and Hertz Lazarowitz (1979) also found that girls were more interested in the human body, life, plants and animals but boys were more oriented to electricity and technology subjects. They noted that students chose topics that were related to their personal lives and needs as well as those of general technological value. To find out what educational television programmes students watch, Weltner *et al.* (1980) presented the students with a list of 16 fictional programmes. Both boys and girls preferred practical T.V. programmes rather than theoretical ones, for example, 'Let's build a radio' versus 'Development of colour T.V'. Smail, Whyte and Kelly (1982) found that when students were required to write essays, most boys chose 'How cars work' or 'Rockets and space travel' while these were very unpopular with the girls. Girls predominantly chose 'The human body', 'Birds near my home', 'Seeds' or 'Pond life'.

As far as technological applications were concerned, girls had a greater interest in biological/medical applications and boys had greater interest in technological applications e.g. atomic weapons. Again, Sjöberg (1983) noted that the boys' more positive attitudes about technology carried over into the classroom. The A.P.U. (1985) survey found that boys tended not to like biological-type activities whereas girls did not like electricity. There is also a significant difference between girls' and boys' interest in physics and biology topics among younger children (8 years old) (Harvey and Edwards, 1980). Again, girls were more interested in biology than physics. In older children both sexes appeared positive about science but whereas boys were enthusiastic about physical science, girls were more interested in biological topics (Smail and Kelly, 1984). Harding (1986) noted that 75% of the topics preferred by girls are biological in nature. Boys' preferred topics are physics orientated (60%) and generally to do with the application of science (80%).

2.3.3 Interest in physics lessons currently offered

Physics students appeared to be interested in activity experiments, (A.P.U., 1985; Weltner *et al.* 1980) solving difficult problems and gaining a feeling of competence (Sjöberg, 1983). Lind (1982), using factor analysis, noted three categories involving student interest in physics lessons:

(i) Use of models of how physics and technical equipment works.

(ii) Exploration of interesting phenomena which raise questions.

(iii) Individual or group practical activities.

Weltner *et al.* (1980) noted that students were also interested in a course orientated towards technological applications, with the preference for technological aspects being more pronounced for boys. Girls showed greatest interest in classroom approaches to physics topics which refer to applications in medicine and in the home, (Hoffman, 1985). In evaluating the PLON physics curriculum programme in the Netherlands, Jöng (1985) found that boys displayed a strong preference for courses with technical topics whereas the girls were more interested in the relationship between physics and society and between physics and matters relating to the human body. In the classroom it appears that the boys' interests are met rather more than the girls' (Weltner *et al.* 1980).

2.3.4 Interest in out-of-school activities

According to Walberg (1969) hobbies are a powerful indicator of students' interests. Burns (1982) found that New Zealand girls have a greater interest in biological-related hobbies and medical careers and boys in physics and engineering hobbies and careers. Johnson and

Murphy (1986) noted that in the U.S.A., 10% more boys than girls had worked with batteries and bulbs, magnets, floating and sinking outside the classroom, but 10% more girls worked with music and sound. Among 11 year-olds, 45% of boys and 16% of girls had played with `electrics' and by 17 years of age 82% of boys and 34% of girls had used `electrics'. Johnson and Murphy (1986) concluded that boys were interested in `how things work' while girls were interested in health, body, colour etc. Weltner *et al.* (1980) also noticed that boys were significantly more interested than girls in `uses of experimental kits', `examination of technical equipment' and `model construction'.

2.3.5 Summary and Comment

There are significant differences between boys' and girls' interests in physics and technology. Boys are more interested in technological aspects whereas girls are more interested in human/biological aspects of life. Of the science subjects, boys are more interested in physical science and girls in biological science. Within currently offered physics lessons, students are interested in models of how physics and equipment works, exploration of interesting phenomena and practical activities. Boys are interested in technological applications whereas girls are more interested in applications to medicine.

The students' reasons for these differences are to be further examined in this study. If a technological approach to the teaching of physics is desirable then it is necessary to explore in detail how students respond to different types of technological applications e.g. scientific, industrial, `hi-tech', medical, domestic, etc.

2.4 PHYSICS AND THE LEARNER

2.4.1 Learning theories and physics education

Driver (1982) noted three traditions in research in educational psychology with respect to science education. These are the developmental tradition, the behaviourist tradition and the constructivist tradition. Each of these brings a different perspective to the teaching and learning of senior secondary school physics.

The **developmental tradition**, based on the work of Piaget and his team in Geneva, emphasises that learning is restricted by the age of the student. Each student develops the capacity to accommodate and assimilate increasingly difficult forms of knowledge with increasing maturity. The rate of maturation differs between individuals but the same path is followed. Although Piagetians acknowledge the role of experience, the primary focus is on maturation (Driver, 1984). Each maturation level is defined as stage development.

Shayer and Adey (1981) used the stage theory to recommend matching the level of demand of the curriculum to the assessed stage of development of the student. Renner and Lawson (1973) showed that in physics not all senior secondary school physics students reached Piaget's formal stage and suggested that physics programmes should be developed to promote more formal thought. Driver (1984) and Head (1985) noted that criticism of the developmental model is based on evidence that the performance of any task could be more experience-related than age-related. Also, Donaldson (1978) suggested that young children use sophisticated thought processes in situations where the content is familiar. Gilbert and Watts (1983) noted that, starting from a content-independent assumption, it seems possible to show an age-related graduation in the quality of understanding of specific content. However, when the opposite assumption was made (that learning is context-dependent) no evidence of age relatedness was found.

The **behaviourist tradition**, assumes that increasingly complex tasks can be built up by reinforcement and learning in small steps. The work of Gagné (1970) is based on a hierarchical scheme in which the learning of complex tasks is built up from simpler forms of learning in carefully constructed teaching programmes. This theory generally makes no assumptions about the prior internal knowledge structure of the student (Bell, 1985). No age limitations are assumed, i.e. the approach relies on external conditioning. This tradition has been used in building up physics concepts from simpler physics concepts using task analysis. Driver (1984) suggested that instructional programmes based on a logical task analysis may only be appropriate for practical skills or manipulative skills involved in solving equations. Similarly, White (1973) considered that verbal and conceptual knowledge cannot be learnt this way. White and Mayer (1980) suggested that different types of knowledge may be associated with core skills and subskills in a learning hierarchy. They categorise knowledge as consisting of intellectual skills, verbal knowledge, images and episodes.

Head (1985) pointed out that in physics, learning does not always occur according to an assumed logical teaching sequence. He used the example of the sequence velocity-acceleration-force as being a logical progression in physics. However it is found that students find it easier to gain some understanding of force than they do acceleration (Jones, 1983; Osborne, 1980).

As Driver (1984) noted, the behaviourist tradition does not take into account any existing knowledge structure which the student might bring to the learning situation and which might influence the way the new experience is assimilated.

The **constructivist tradition**, stresses the importance of a learner's existing knowledge in making sense of the world. Head (1985) noted that although there is still some uncertainty about the precise importance of a learner's existing knowledge, recent research places more and more emphasis on this factor. Osborne and Wittrock (1985) also noted that there is an increasing enthusiasm for a constructivist view of learning. The assumption behind the constructivist tradition is that all learners hold some personal view of a topic prior to its being taught. Learners are naturally mentally active, constructing for any experience a meaning that is consistent with their existing knowledge structures (Ausubel, 1968; Kelly, 1955). The learner's view of a topic, if it differs from the accepted scientific view, is not considered an error but rather an alternative construction of reality.

This present investigation lies within the constructivist tradition. In particular, it explores the notion of mini-theories (Claxton, 1984, 1985) and the generative learning model (Osborne and Wittrock, 1985).

2.4.2 Mini-theories

Claxton (1984, 1985) argued that in learning about the world we develop mini-theories which apply to specific situations that help us to make predictions and dictate actions. Mini-theories also provide explanations and descriptions. They may be subconscious, unarticulated and applied in spontaneous and intuitive ways. Each mini-theory is limited by the domain of experience to which it is applied.

This means that we can have a mini-theory on what we think about school physics, scientists, or our future employment. Claxton (1984,1985) suggested that mini-theories can be dynamic or at least temporarily fixed. For example, if the circumstances are changing fast then so will the mini-theory. If, on the other hand, a mini-theory has led to accurate predictions and has proved useful to the learner, then it will remain fixed.

Concerning learners' school science, Claxton (1984) argued that mini-theories can be grouped into three separate areas, gut science, lay science and school science. These types of mini-theories are bounded by their own domains and generally do not overlap at all. Gut science is in the domain of immediate experience and is based on intuitive and spontaneous reaction. Lay science is based on the language used in everyday situations and through the media. School science is based on a symbolic and an idealised world which Claxton described as a fantasy world. School physics, for example, has a linguistic, mathematical and experimental superstructure which is sometimes not intuitive and is not open to question. Teaching tends to be about a fantasy world where lines have no width, ropes have no weight and feathers drop like lead. The student, once he or she has decided to study physics accepts this knowledge because he or she has been told it is right or true. Claxton suggested that the distinctions between gut science, lay science and school science for the learner can be quite distinct. Gut and lay physics continue to dominate the students' out-of-school life and school physics is something quite different, i.e for use only in highly contrived classroom situations. Students could even have a mini-theory of what they perceive physics to be. For example, if physics is perceived as being just an extension of mathematics then this may influence what the student attends to in the classroom. They may have a mini-theory that consists of school physics not being relevant to the everyday world, or a mini-theory about what they need for a career or what they are interested in learning about. So there are many mini-theories that a student may have about school physics which may influence future learning. Physics students who try to relate school physics to gut physics may become confused and this may further reinforce separate physics mini-theories. Claxton suggested that successful physics students may be those that manage to keep the mini-theories separate and thus do not call up gut physics in the classroom. Indeed, Osborne (1984) suggested that a teacher who relates the ideas being taught to everyday examples may hinder rather than help because, in Claxton's terms this would call up unwanted aspects of gut and lay physics. However, Osborne noted that only limited meaningful learning arose from rote learning and the ability to solve problems was not developed significantly.

2.4.3 The generative learning model

The generative learning model is also within the constructivist tradition (Osborne and Wittrock, 1983, 1985). The basis of the model is:

> "... that people tend to generate perceptions and meanings that are consistent with their prior learning. Those perceptions and meanings are something additional both to the stimuli and the learner's existing knowledge. To construct meaning requires effort on the part of the learner and links must be generated between stimuli and stored information."
>
> [Osborne and Wittrock, 1985; p. 64]

The generative learning model therefore is principally concerned with the idea that a learner is not a passive recipient of stimuli and so learning does not occur automatically when teachers provide stimuli. The learner is responsible for attending to and relating stimuli and constructing a meaning from them. The learner will generate meanings which are consistent with existing knowledge, experiences, abilities, backgrounds and attitudes. The main feature of this model is the generation of links between the selected input and those parts of the memory store considered relevant by the student. The learner may test the constructed meaning to see if it makes sense to them, to the real world, and their own experiences. Ideas are then placed in long term memory. The new ideas may be integrated with existing ideas or be accommodated alongside. The key ideas of a generative learning model are the importance of existing knowledge, selection, attention, generating links and subsumption.

Existing knowledge is a key aspect of the theories of Claxton (1984, 1985) and Osborne and Wittrock (1985). Bell (1985) regarded existing knowledge as comprising not only conceptual knowledge but also social knowledge, memories of events, and associated experiences and affective aspects associated with this knowledge. In Bell's (1985) view, existing knowledge therefore includes how students perceive various school subjects, their attitudes, feelings, emotions, interests,and any factor which may influence future learning. Since 1976 there has been much research (e.g. Barker, 1986; Bell, 1985; Happs, 1984) to elicit and record aspects of students' existing conceptual knowledge. In physics, Osborne and Freyberg (1985) noted studies in kinematics (4), mechanics (13), force (6), energy (4), friction (1), floating and sinking (3), gravity (4), pressure (2), heat (3), temperature (3), light (5), and electric current (10).

However, non-propositional aspects of existing knowledge have also to be considered. These include interests, longer-term career plans, the desire to gain high marks, and whether or not lessons are perceived as being relevant. Schollum and Osborne (1985) suggested that there are three areas of relevance:

(i) to everyday events,

(ii) to pupils' existing ideas,

(iii) to human relationships.

The learner may consider formal school physics to be irrelevant to the real world because this 'fantasy world' (Claxton 1984) cannot be linked to existing knowledge structures. This means that appropriate learning is not achieved, i.e. new ideas are not subsumed. However, an independent knowledge structure which Claxton (1984) called 'school science' may result (Pope and Gilbert, 1985; Solomon, 1983). Outside the physics classroom intuitive ideas ('gut science' and 'lay science') work well and the student does not attempt to integrate the two structures. This means that school physics may be learned by rote and may not be retained in long term memory since it is not linked to other experiences. Osborne and Wittrock (1985) noted that from a constructivist view this learning is undesirable in the long term and does not help students to develop a coherent view of why things happen in the real world. They argued that to provide links to the memory, the historical, technological and everyday aspects of scientific ideas need to be integrated with the mathematical, experimental and philosophical aspects. If students have no existing ideas about a particular aspect of school physics then links can be created by using the students' interests or other aspects of existing knowledge.

2.4.4 Summary and Comment

The constructivist tradition stresses the importance of a learner's existing knowledge and its importance in making sense of the world. The perception which students have of physics i.e. their mini-theory of school physics, may influence how they approach the learning of physics. Physics knowledge may be in a separate cognitive structure and students may have difficulty relating it to other cognitive structures.

The key points in the generative learning model are that existing knowledge influences what will be selected and attended to in the environment. The learner generates meanings which are consistent with existing knowledge, experiences, abilities, backgrounds and attitudes. An important aspect in constructing meaning is the generation of links between the selected input and those parts of the memory store considered relevant by the learner. If students cannot generate links or make sense of the stimuli in terms of existing knowledge, then a separate cognitive structure will develop. To generate links with existing knowledge, lessons in physics must therefore be relevant in terms of everyday events, students' existing knowledge and human relationships. Links need to be generated through the interests of students, relating physics to their world, careers, future needs, etc. It may be that in introducing technological applications of physics, which are relevant to the learner, links would be generated between the input and existing knowledge. This is explored in section 2.5. There is however little evidence demonstrating how the generative learning model might be useful in the physics classroom generally (previous studies have mainly been in the area of conceptual change). This needs to be explored. Also, it may be possible to extend the generative learning model and mini-theories to encompass the affective side of learning. Motivation to learn physics is examined in the next section (2.4.5).

2.4.5 Motivation to Learn

As well as conceptual knowledge, affective factors, particularly motivation (Hopstein and Kempa, 1985), are important in learning science.

Kolesnik (1978) divided motivation into two broad categories;

(i) Extrinsic Motivation, i.e. outside sources, for example working for grades.

(ii) Intrinsic Motivation, which arises from within the individual, for example interest.

He suggested that extrinsic motivation is acceptable in some situations but argued that in general it is better to develop the student's interest in classroom material and stress its social relevance so that students will study it because they want to. This means the subject matter must be selected in relation to the students' present experiences, interests, needs, concerns and problems. Interests and concerns are by no means fixed, but an initial curiosity about a topic can motivate students to study successfully (Smail and Kelly, 1984). Interest could be used as a motivational device to set goals for student learning which are personally meaningful (Lazarowitz and Hertz Lazarowitz, 1979). Kolesnik (1978) implied that classroom learning depends not only on external stimuli but more on what the stimuli mean to the student personally.

The constructivistic tradition of learning emphasises intrinsic motivation. Osborne and Wittrock (1985) argued that learners are likely to be well motivated if they genuinely feel that classroom learning is helping them make better sense of their world. They argued that in the constructivist tradition of learning there is no need for an impulse-driven theory of motivation. Ausubel (1968) argued that it is unrealistic to expect that secondary school science and particularly physics can be meaningfully learnt and retained unless students feel a need to acquire knowledge as an end in itself. However, he also noted that it is difficult to stimulate the development of such a need until the subject matter itself is presented in a meaningful way. Thus motivational and affective factors, although not directly involved in the cognitive process, enhance effort, attention and immediate readiness for learning.

Head and Sutton (n.d.) listed two basic assumptions about motivation:

(i) the major motivating force for human beings is their need to make sense of their world.

(ii) the sense making experience is an important source of emotional satisfaction.

Talisayon (1986) suggested that methods used by physics teachers to motivate students can be categorised in two ways:

(i) showing that physics is fun.

(ii) emphasising the usefulness of physics to student life and careers.

Hasan (1975) noted that students with a high level of interest in science tended to participate well in science lessons, have a better image of their science capabilities, rate their teachers as better motivators and have more desire to follow a career in science. Thus enhanced student interest is a high motivational factor to learn science. Hopstein and Kempa (1985) suggested that learning environments and teaching procedures which physics students perceive as helpful to their future needs will enhance the enjoyment in learning activities, and affective variables such as interest and enjoyment will also be more evident (Reyes, 1984).

Future intention, e.g. a possible career is also a form of extrinsic motivation (Allport, 1961). The way a student approaches the learning of physics will therefore depend on how he or she perceives this future need. The student who perceives that physics is needed for a career because of its mathematical content will concentrate on that aspect of physics. A student who needs high marks in school physics to continue to some other field of study (for example, medicine) may adopt an approach to gain the highest marks. Secondary school physics in New Zealand appears to be high in extrinsic motivation such as career requirements, grades for restricted entry courses, and low in intrinsic motivation such as enjoyment and interest (Jones and Osborne, 1985).

The constructivist view of learning places the emphasis on intrinsic motivation. In a learning situation this means that subject matter needs to gain the attention of the learner and help the student make better sense of his or her world. The material must be related to the students' existing ideas, interests, needs, concerns and experiences.

2.5 SCIENCE, TECHNOLOGY AND SCHOOL PHYSICS

2.5.1 Science and Technology

The terms `science' and `technology' are difficult to distinguish (Ditchfield, 1984; Ziman, 1980). One approach is to apply these terms to sections along a continuum, *viz* academic pure research, through applied science to industrial development, technical innovation and service engineering (Zoller and Watson, 1974). Black and Harrison (1985) defined technology as being concerned with a wide range of human purpose but noted that science and technology are intimately connected. Ziman (1980) suggested that technology is concerned with the application of scientific knowledge and that it provides new and improved instruments which supply science with new phenomena. On the other hand science supplies technology with descriptions and explanations of the natural world (Aikenhead, 1980).

Technological applications of physics in this study are meant as applications of physics as used in society. For example, from simple levers through to microwave ovens, from foetal heart beat monitors to lasers. The learning of physics concepts through technological applications has been termed the 'science from technology' approach (Osborne, 1981a).

2.5.2 The abstract nature of school physics

In a society which is essentially dependent on improved technology for its continued survival it could be assumed that science education and technology would be closely related. In fact, although science education, technology and science itself have evolved somewhat independently (Reeder, 1979), science education is currently much more closely related to science itself than technology (Layton, 1973a). This trend, according to Layton, arose from the fact that as scientific explanations evolved and became more complex, scientists increasingly used mathematical abstractions to represent the universe. The mathematical abstractions greatly increased the power of science as a mode of enquiry but as Layton (1973a) noted, this meant that science could only be used and understood by those who were deeply versed in this special kind of learning. As scientists strove to explain the universe in terms of a few fundamental laws and scientific principles, science became less directly relevant to explaining familiar phenomena of the everyday world. The unifying abstractions became unreal and were irrelevant to any person unfamiliar with this new language (Wolfgang, 1971). According to Ziman (1980) while the predictive power and rationalities of theoretical representation of the natural world can be considered as the glories of science, they are only directly applicable in highly contrived and unnatural circumstances. As Layton (1973b p. 19) summarised:

"Much of science - and this is particularly true of physics - involves the understanding of concepts which are highly abstract and connected to observations only by complex logical and mathematical relationships."

The very thing that has increased the power of science has caused severe problems with its teaching and learning (Layton 1973b). The evolution of science has influenced science education. Fensham (1977) noted that there has been a great expansion in the number of university scientists and their influence on the scientific community since 1945. Few of these scientists have had any personal involvement in aspects of science and technology outside the university. Fensham (1977, p. 27) suggested that this led to the nature of secondary school science being:

"deeply influenced by the experimental and conceptual requirements of preserving and extending knowledge rather than by its application as technology or by its consequences for society."

When secondary school curricula changes began in the 1960's in the United States (e.g. PSSC), Australia (Cross *et al.* 1985), and New Zealand, the universities exerted a strong influence on them. Fensham (1977) suggested that the needs of the 5-15% of school students who would go on to university had been given the most consideration. The courses were academically orientated and their target population were the scientifically able (Zoller and Watson, 1974). Ormerod with Duckworth (1975) also suggested that many of the science courses, and this was particularly true of physics courses, had been designed for those who would continue the study at university. Bondi (1975) considered that the proportion of the university graduating class which are required to become academics (about 1%), should not dominate the needs of the other 99%.

Ebison (1972) suggested that some physicists who exercised considerable control over the physics taught in schools seemed unwilling to see physics as anything other than the reduction of physical phenomena to mathematical representation which took the place of reality. Physics education appeared to have assumed that the historical, philosophical, sociological and economic aspects of life were quite non-existent and not worth the attention of serious physics teachers (Ziman 1980).

That physics courses are dominated by mathematical abstractions is apparent in several Western countries, e.g. Australia (Wessen, 1985), Britain (Claxton, 1984; Layton, 1973a,b), Canada (George, 1981), Netherlands (Kortland, 1984) and New Zealand (Jones and Osborne, 1985).

The change in secondary school physics teaching which occurred in the 1960's and early 1970's in Western countries was oriented towards the internal structure of physics. In spite of some intentions about scientific literacy for the general populace, the transfer of concepts and scientific methods to scientific and technical problems in society and everyday life of the student is very limited (Paulsen, 1980). In the teaching of physics the main aim appears to be the transfer of physics principles. Applications only come in if they serve as tools for understanding the basic principles (Eijkelhof, 1985; Lijnse, 1986). Kortland (1984) suggested that physics courses in the Netherlands have focused on `correct explanations' and `solid foundations' as a set of messages to the students about physics. Fensham (1985) criticised this curriculum on the grounds that it assumes schooling and science education takes place in a social and political vacuum.

Ziman (1980) saw the present school physics curriculum as being mainly thought of as an entrance qualification for university where examinations are dominated by a high regard for abstract theory rather than practical technique and relevance. This was further reinforced by teachers who have been through the same system. Another aspect of this was emphasised by Ahlgren and Walberg (1973) when examining letters to the editor in *Physics Teacher*. They found that some teachers wanted to keep school physics 'pure', and that it should not be for those who are disinclined or unable to apply the desirable intellectual endeavour. The result was that many pupils have an elitist view of physics.

Secondary school science courses are the only means by which the majority of the population come into contact with scientific thought. Ziman (1980) suggested that the perception of the role of the scientist in today's society is largely determined by the way in which scientific knowledge is presented in the classroom. For example, the PSSC physics course seemed to give the impression that the scientist was a scientific explorer searching for new knowledge. Diederich (1969), in her study of PSSC and other science courses, suggested that there were two types of scientists, the experimenters and the theoreticians, who cooperated and hence made their work mutually informing. Physics at school therefore became theory and then subsequent experimental work validated the theory. Layton (1973b) suggested that all this led to a stereotype of the scientist who was oblivious to the applications and wider implications of his or her work. Several investigations have found negative perceptions of scientists (Ahlgren and Walberg, 1973; Dainton, 1971; Gardner, 1974; Hudson, 1967).

It is not surprising that people hold this view of scientists if they were taught science in a manner which was 'pure' and devoid of perceived relevance. Fensham (1985) argued that school physics for the 80's and 90's needs to avoid the mistake of imposing on the majority something that is and was important to a small minority.

In summary, science education has emphasised the abstract and mathematical models of current scientific practice and has neglected, in particular, the links which exist between science and technology. Science education may need to consider the introduction of technological applications much more seriously.

2.5.3 Technological Applications: Their potential in school physics

Attempts to produce science courses in the image of pure science means that realism and relevance have often been lost (Gallagher, 1971). Many people (for example, Dowdeswell, 1979; Layton, 1973b; Woodall, 1967) have suggested that one method of bridging the gap between school physics and the real world is to introduce technological applications. It has been through applications that science has influenced society. One of the main arguments for the introduction of technological applications into secondary school physics is because of relevance to the learner (Eijkelhof, 1985; Fensham, 1985; Kortland, 1985; Lewis, 1972; McKim, 1983; Penick and Yager, 1986; Ziman, 1980). Three discussion papers produced by the Science Council of Canada argued for a greater emphasis in science teaching on the applied aspects of science and the ways in which science and technology interact with society (Aikenhead, 1980; George, 1981; Page, 1979). As Layton (1973b) suggested:

> "If science is to succeed as an instrument of general education it is important that it retains its relevance to common life." [p20]

Layton (1973b) suggested that it is through being familiar with scientific ideas applied to situations which are relevant to students that ideas can best be understood and used. It is important therefore that applications have relevance for the learner, since scientific principles are unlikely to be learnt if the applications lack meaning to the student. Zuckerman (1971) also suggested that the base of science education should be broadened to reveal the relevance of some scientific knowledge in everyday affairs. It is only through this kind of understanding of science in everyday life, industry and applied science that people can be expected to make intelligent decisions about science. Wolfgang (1971) noted that people are also fascinated to learn how science can account for what they see in everyday life. Dowdeswell (1979) noted that in the past the relevance of physical laws to everyday circumstances in which students live has been largely overlooked. Frey *et al.* (1980) suggested this could be overcome by introducing technological equipment, familiar to the students, into physics teaching.

When discussing the advantages and disadvantages of the new A level syllabus for Britain, French (1981) suggested that not only should the course deal with the basic physics but it should also include some of the technological and other applications that involve basic physics. Physics teaching in the secondary schools should be concerned primarily with providing students with a basis for better understanding of their world, including the technological and everyday aspects (Casimir, 1976; Osborne and Wittrock, 1985). Woolnough (1975) believed that the way in which physics is taught at schools must change, becoming more concerned with making physics relevant to a technological age. If pure academic physics continues to be taught in schools it may become a minority subject studied only for its intellectual stimulation, rather than for its relevance. School physics courses should be changed so that they give the students opportunities to see the application of their knowledge (Woolnough, 1975).

The first aim of the 16+ physics course in Britain (McKim, 1983) was to stimulate and sustain an interest in and an enjoyment of physics and its applications. The PLON physics curriculum project in the Netherlands emphasised that physics should be taught in a technological context to make physics relevant to the students by improving their ability to cope with living in a technological society (Kortland, 1985). Penick and Yager (1986) indicated that science without 'societal' applications will mean little to students. In reviewing science courses in U.S.A. they found that the qualitative physics courses appealed more to the students.

The introduction of technological applications can provide a motivational effect for learners (Bansky and Suzkover, 1980; Lewis, 1972). If it is assumed that students are interested and enjoy learning about their world, then the most natural approach to society from science is through its applications. This approach appeals to most students (Ziman, 1980). In the evaluation of the PLON physics programme, which is heavily orientated towards technological applications in everyday life, most students stated they wanted more applications (Lijnse, 1986).

There appears however to be a reluctance on the part of some students to become involved in the learning of technological applications

(Eijkelhof, 1985). This reluctance may be partly caused by the feeling that learning to deal with the applications of physics is viewed differently from learning how to solve a pure physics exercise. Applications have to do with real life and are less ideal whereas a traditional school physics problem may be seen as a straightforward substitution of numbers. Another aspect may be that some students do not perceive technological applications as being real physics. Teachers may also be reluctant to introduce technological application. (This will be explored further in 2.5.5.)

2.5.4 Teaching physics through technology: a review of approaches

Ziman (1980) listed seven general approaches for teaching the relationship between science, technology and society; (i) application approach, (ii) vocational approach, (iii) thematic approach, (iv) historical approach, (v) philosophical approach, (vi) sociological approach, (vii) problematic approach. All these approaches may be valid in terms of relevance for the student. Fensham(1985) suggested that a variety of approaches can be taken to teach a scientific topic. It might be through its social impact, everyday aspects, scientific knowledge, measurement, raw materials, uses, alternatives, and energy aspects. There is no preferred sequence, it depends on the students' and teachers' preferences and experience. Each approach adds 'more learning to the always obvious object of the study' (Fensham, 1985). This study is concerned mainly with the applications and thematic approaches.

Two approaches to introducing technological applications into physics lessons, are frequently used (Osborne 1981a). In both, appreciation of a physics concept is the intended outcome. The first approach involves teaching the scientific concept and then showing a technological application involving that concept. Thus the application is given at the end of a lesson to illustrate a particular concept. The second approach is to start the lesson or topic with a technological device which illustrates a chosen scientific concept. This approach requires teachers to introduce a technological example that students have some prior knowledge of or express an interest in learning about (Jones, 1986; Thier, 1983).

Examples of the first approach (Osborne, 1981a) will be further explored. The Advanced Physics Project for Independent Learning (APPIL) (Murray *et al.* 1980) introduces the topic to be studied and develops the physics concepts. The applications tend to be at the end of each section in the form of a comprehensive exercise. There are a number of curriculum resource materials which lend themselves to this approach.

(i) *Physics at Work* and the revised edition of *Physics Principles at Work* (Barclay and Gibbon, 1980). This is a collection of 36 resource packages describing the applications of physics in the oil industry.

(ii) *Science Serves Society* (Sneed, 1975). This describes applications of physics used in medical, industrial and scientific sectors.

(iii) *Gas Applications for School Science*. This is a teachers' resource book which was written by a group of teachers and includes technological applications from chemical plants.

(iv) *Physics at Work in New Zealand* (Jones 1982a). This contains a number of technological applications from medical, agricultural, scientific and industrial sectors of New Zealand.

(v) Physics in Medical Diagnosis (Ronen and Ganiel, 1984). This is a teaching unit for high school students in Israel, discussing the uses of x-rays, radioactive traces and ultrasound.

In the Physics Plus Project (McKim, 1983) the technological applications of physics are intended to form a component part of the course, but the larger part of the course remains pure physics.

The second approach suggested by Osborne (1981a) was to start the lesson with a technological device. Lijnse (1986) suggested that to introduce a technological perspective the curriculum needs to be organized around coherent scientific-technological themes e.g. materials, communication, electronics etc. Black and Harrison (1985) also suggested that science teaching has to start from those everyday themes in which students are already interested. The PLON (Project Curriculum Development in Physics) uses themes as its focus. The major aims (Eijkelhof, 1985) are the growth of students' independence and a sense of social responsibility, and the practical usefulness of physics in real-life situations. The units are linked with the actual environment of students and with specific developments in society. This type of approach has been trialled in New Zealand by Cosgrove and Mueggenburg (1986) with the topic of refrigeration. This topic develops students' ideas of refrigeration and leads to scientific ideas such as heat transfer, heat pumps, changes of state, and latent heat. It has been evaluated by Newman (1987).

In Britain an A level Engineering course has been designed as an alternative approach to A level physics (Kelly, 1983). The physics is studied in the context of its engineering application. In the United States a similar programme was developed in the 1970's called the Technical Physics Project (Fibel, 1973; Di Lavore, 1973). Modules are laboratory based and centred upon a common device that would be familiar to the student. The aim is to teach the physics that flows naturally from a consideration of the device. In Israel, Bransky and Suzkover (1980) considered using applications to identify physics principles.

These projects illustrate what has been attempted. The effectiveness of introducing technological applications needs to be explored.

2.5.5 Teaching physics through technology: teachers' reactions

Physics teachers have the most responsibility for the student catching the excitement of physics and its applications (Bondi, 1975; Farrer and Searby, 1970). It is important for the teacher not only to be enthusiastic about physics but also to show students the relevance of physics in today's society (Bondi, 1975). Despite the evidence that the introduction of technological applications may be advantageous for the teaching and learning of physics, teachers appear reluctant to incorporate them in lessons.

Commenting on the PLON physics programme in the Netherlands, Eijkelhof (1985) noted that teachers have a certain image of physics and physics education which is deeply rooted and difficult to change. Their own education at school, university and teacher training college has a long-standing influence on their understanding of physics. The majority of teachers learnt highly simplified and idealised traditional physics (Kelly, 1983). They know what is expected of them and the neatness and logic of idealised physics is very appealing. Physics teachers tend to be primarily concerned with understanding principles, knowledge of basic facts and good examination results (Woolnough, 1975).

In implementing new curricula, McIntyre and Brown (1979) found that teachers minimally alter their conventional ways of teaching. They also noted that there is unlikely to be teacher change if teacher initiative is relied on. Teachers need clear guidelines as to the change required. They also need some sort of reward for changing their behaviour (for example, students achieving more, appearing more interested).

Cosgrove, Osborne and Carr (1984, p.257) listed what they considered to be the major reasons why teachers are generally reluctant to refer to technological applications.

(i) It is easier to ask abstract examination questions and set problems devoid of reality, than it is to find real life contexts for questions. (see also Thomas, 1985)

(ii) It is easier to relate physics principles to the artificial world of the laboratory than to real life applications.

(iii) Teachers have very limited resource material available to show them where, and how, the principles of physics relate to the technological applications of industry, home, hospitals and other everyday situations.

(iv) Some students seem to prefer physics to be about an abstract idealised world, uncontaminated by the complexities of reality.

The teaching of so-called 'pure physics' tends to take place in a teacher-centred classroom. The whole emphasis is on achieving high intellectual standards. The curriculum is directly derived from the scientific discipline. Peters and Miller (1976) noted that students will not be aware of the relevance of physics unless teachers are convinced themselves and point the way ahead. Lewis (1972) suggested that it is easier to teach the principles of electromagnetism than introduce technological applications to make physics more relevant. Help is needed for the conventional physics teacher to relate his or her classroom teaching more closely to a modern technological society (Nicholl, 1982).

2.6 RATIONALE FOR THIS INVESTIGATION

The present study was carried out to investigate students' images of school physics and to develop a technological perspective for the teaching and learning of physics.

The learner of physics lives within a technological society yet it appears from this literature review that school physics tends to be taught in isolation from that society. School physics has traditionally emphasised the mathematical and experimental aspects of the subject. This emphasis has resulted in students perceiving physics as very difficult, of limited interest, mathematical, often dull and of limited use. This study further explores the New Zealand situation.

There appears to be support for the introduction of technological applications in the physics classroom but little information about how this might be achieved. The main emphasis of this study is to explore the introduction of technological applications into the physics classroom utilising the ideas of the generative learning model. The constructivist tradition suggests that meaningful learning cannot take place without the generation of links between the input stimuli and the learner's existing knowledge. The learner will not attend to a learning situation unless the stimuli link to the existing knowledge.

CHAPTER 3

PHYSICS STUDENTS' PERCEPTIONS OF SCHOOL PHYSICS

3.1 INTRODUCTION

Physics as taught in New Zealand at the senior secondary school and first year university undergraduate level tends to emphasise the mathematical, experimental and philosophical aspects of the subject (Department of Education, 1972; Department of Education, 1973). Layton (1973b) and Claxton (1984) and many others have suggested that this emphasis may have led to school science being divorced from the students' real world and even the scientists' world. Claxton (1984) further suggests that students may not appreciate the relevance of learning physics for careers in technology or related areas. In a previous New Zealand study it was reported that younger students (14-16 years) apparently lacked understanding of what the study of physics would involve and of what physicists do, and as a result tended to be biased against it (Jones 1982b). Students' general perceptions of physics have been reviewed in section 2.2.

This chapter identifies the perceptions physics students have of physics at the senior secondary school level in New Zealand. In particular, it examines perceptions of enjoyment, interest, difficulty and confidence levels associated with school physics. The perceived usefulness and the reasons for studying physics are also examined. The anticipated careers of physics students are explored. A preliminary investigation on students' reactions to the introduction of technological applications is also included.

3.2 METHODOLOGY

The method used for obtaining physics students' perceptions of senior secondary school physics was to conduct audiotaped individual interviews. Larger surveys were later developed from the interviews.

3.2.1 Naturalistic Research

Interviews represent part of the general area of naturalistic research (Posner and Gertzog, 1982; Easley, 1982), and are becoming more widely accepted as part of the methodology in science education research (Barker, 1986). The advantages of this approach for exploring students' ideas (as reviewed by Bell (1985) and Barker (1986)) are that it:

(1) Helps to understand the complexity of the students' cognitive structure.

(2) Provides opportunity to further explore students' responses.

(3) Allows the students to express thoughts orally.

(4) Does not confine the students to a certain type of response.

(5) The collection of data can take place outside the confines of a classroom.

(6) Allows the interviewer to minimize incorrect interpretation of the students' responses.

(7) Data collection is not confined to a pre-planned programme as much as a pen and paper survey would.

Some disadvantages of the interview method (Cohen and Manion, 1980) are:

(1) Only a small population is being sampled.

(2) The potential bias of the interviewer.

(3) The interviewee may react to the perceived frame of reference of the interviewer.

(4) The problem of representing the data in a concise and true form.

To utilise the interview methodology and to overcome some of the weaknesses of interviews, a combination of qualitative and quantitative approaches is used, (Freyberg and Osborne, 1982; Carr, 1985).

3.2.2 Interviews

The first stage of the interview required the physics students at the seventh form level to rank (on a 5 point scale) their chosen subjects in order of (i) enjoyment (ii) usefulness for a career (iii) interest (iv) difficulty and (v) confidence in the capacity to do well. The reasons for the rankings were then discussed.

The second stage of the interview consisted of a more detailed examination of the students' views of physics by seeking information about: (i) an aspect of physics they enjoyed (ii) aspects they did not enjoy (iii) what they hoped to gain from the study of physics (iv) whether they considered the study of physics to be potentially useful in life, career etc. One of the advantages of the interview technique is that the interviewer could choose to probe further the responses to these key questions.

The final stage of the interview explored whether students had been taught about or knew of technological aspects of physics and what type of technological applications of physics they considered they might be interested in studying. This was assessed by showing students a series of cards with different technological applications of physics from the senior secondary school level.

The interview schedule is shown in Table 1. The schedule was used as a guide only as each interviewee would respond differently and their replies were then explored further.

Table 1. <u>Interview schedule for interviewing seventh form students</u>

1. (a) Let's look at the subjects you were studying last year.
    - (i) Can you tell me what these subjects were?
    - (ii) What did you think of them?

   (b) What I would like you to do is to rank these subjects in order of enjoyment.
    - (i) Why?
    - (ii) What did you do in this subject that made it enjoyable?
    - (iii) Continue depending on responses etc.

   (c) Rank in order of usefulness for your chosen career.
   (d) Rank in order of interest.
   (e) Rank in order of difficulty.
   (f) Confidence to do well or get best marks?

2. Can you tell me about a lesson or a day which really stands out as a day you really enjoyed physics?

3. What lesson or aspect of physics did you not enjoy last year? Can you tell me a little about that etc?

4. What do you hope to gain by the study of physics?

5. Are you planning to continue the study of physics?

6. (a) Do you consider the study of physics to be any use to you later in life, getting a job etc?
   (b) What do you think physics is?

7. Did you come across any uses for the physics that you learnt during the year?
   (a) Let me give you an example of what I mean.
   (b) I have a series of illustrations of physics here.
   (c) Which would you prefer to learn about?
   (d) Were you provided with illustrations like these?
   (e) Do you tend to think up illustrations for yourself or do you not relate what you learn to the world around you?
   Let me put it another way. Let's take a topic like total internal reflection. Can you give me an illustration of this idea?

- <u>The Interview Sample</u>

The sample consisted of 60 senior secondary school physics students who were in the seventh form (17-18 years). The interviews took place two months after the beginning of the school year. All the students had completed at least one year of specialist physics study. Prior to this the students studied a general science course. All the students were said by their teachers to be of average to above ability. The interviews were conducted individually and outside the classroom. Apart from six students, all the students lived in large metropolitan areas and attended schools with at least 1200 pupils. The other six students were from a town just outside the metropolitan area and the school had a student population of just over 1000 pupils. The schools consisted of eight co-educational and four single sex schools (two girls' and two boys' schools). The interviews took place at various times throughout the day, not just in the times students studied physics.

3.2.3 Structure of the Survey

The survey was developed from the student responses to the interviews. A copy of the survey can be found in Appendix A. The survey was comprised of three sections.

Section A consisted of getting students to rank the subjects they were studying under the headings of (i) enjoyment (ii) interest (iii) confidence to do well (iv) difficulty.

Section B was designed to explore students' reasons for studying physics. Question 8 consisted of 15 statements developed from student responses in the interviews and from a survey developed by Burns (1982). These statements were designed so that students could indicate the possible reasons why they studied physics and then the most important reason. Further questions were designed to explore students' career choices and the ranking of subject usefulness.

Section C consisted of a semantic differential scale to examine physics students' perceptions of physics rather than just a comparison with other subjects. The 10 bipolar adjectives chosen were from words that students had used in the interviews. The adjectives were also developed from a similar scale used by Osborne (1976). Osborne (1976) and Schibeci (1977) discuss the advantages of this method of attitudinal evaluation. Osborne and Wittrock (1985) suggest that these types of grids are most useful in analysing people's feelings. However White and Mackay (1973) note that one of the disadvantages of this method is that more dogmatic individuals tend to choose the extremes.

The results of this section have to be examined in conjunction with the interviews.

- <u>Survey Trials</u>

The survey was trialled at a large co-educational school in three different classes. Students were asked for their comments about the survey and five students were interviewed from each class to find the reasons for his or her responses and any difficulty they had in responding to the survey. Their criticisms and comments were used to develop the final survey.

- <u>Survey Procedure</u>

The survey was administered by the researcher in the absence of the classroom teacher. This was done so that students could feel free to answer as honestly as possible. The researcher introduced the survey and went through it with the students. As this meant that it was not administered to a school which the researcher did not visit the possible sample size was reduced. However, it did mean that student questions could be answered and there was less room for confusion.

- <u>Survey Sample</u>

The sample consisted of 430 6th form and 168 7th form physics students. Two single sex schools were surveyed as well as eight co-educational schools. The schools were all city schools in the Hamilton, Auckland and Christchurch areas. (The results revealed no regional differences).

The 6th form sample was made up of 301 boys and 129 girls. The 7th was made up of 118 boys and 50 girls. The normal ratio for sixth and seventh formers is approximately 3:1 in favour of the boys (Norman, 1985). There are proportionally slightly more girls in the sample.

3.3 OVERVIEW OF THE RESULTS

The results of the interviews and surveys are reported in five sections. The students' perceptions of physics generally are discussed in section 3.4. Physics students' reasons for studying physics are reported in section 3.5. Their career choice and perceived usefulness of school physics for a career are explored in section 3.6 and 3.7. The desirability of a technological approach in the teaching of school physics is considered in section 3.8.

3.4 STUDENTS' PERCEPTIONS OF SCHOOL PHYSICS

In the 60 interviews, (section 3.2.2) students were asked to rank their school subjects on five criteria (enjoyment, interest, usefulness for a career, difficulty and confidence) and to give their reasons. The responses suggested that students had very distinct views about the position of physics relative to their other subjects and these views were subsequently amplified by presenting the same task in survey form (N = 430 6th formers and N = 168 7th formers).

Hence, in the report below, the uniquely qualitative material from the interviews (i.e. the reasons) is followed (in many cases) by the quantitative data.

3.4.1 Results of the Interviews and Surveys

A) **Enjoyment** of a subject for a physics student depended on four main factors.

(i) Teacher related: (by 23 students)[1]

"It's sort of drilled into us that you don't enjoy physics."

"I guess it was the teachers who made the difference."

"The (physics teacher) has a particular teaching method and it's not what I like."

Only seven students stated that they enjoyed being taught by their physics teacher.

(ii) Related to everyday life: (12 students)

"I like things I can relate more to everyday life."

"You can't relate it (physics) to everyday life."

Not one comment was made about physics being related to everyday life.

(iii) Experiments: (39 students)

One aspect of physics that students enjoyed was the experiments.

"I enjoy practical experiments."

"We did an experiment with a laser and a diffraction grating"

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1 This indicates that 23 students freely made comments about teachers affecting the enjoyment of the subject.

(iv) Abstractness and difficulty: (13 students)

"Some of the problems...I did not understand them at all."

"Trying to remember the formulae...I just could not picture it. It made it quite difficult."

Three factors that made subjects enjoyable were, the teacher, whether or not it was related to everyday life and the experiments done in class. Students did not enjoy the abstractness and the difficulty of physics.

Table 2:

Physics students' ranking of subject enjoyment[2] (survey results)

ENJOYMENT SIXTH FORM

Subject	5	4	3	2	1	N
History	41	24	14	11	11	37
Biology	38	22	19	11	12	152
Technical Drawing	34	23	14	19	10	108
Geography	32	25	13	13	17	63
Economics	29	18	20	24	9	45
Accounting	13	32	22	17	16	63
Chemistry	17	24	23	20	17	265
Mathematics	17	19	22	22	21	423
English	15	21	17	17	30	422
Physics	**11**	**14**	**26**	**30**	**20**	**427**

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2 The top ranking subject was given a 5 and so on to the lowest, a 1. This was then used to calculate the mean. The numbers in the 5,4,3,2,1 columns indicate the percentage of students who gave that particular ranking. S.E indicates the standard error of the mean and N the number of students who studied that subject.

ENJOYMENT SEVENTH FORM

Subject	5	4	3	2	1	N
Biology	38	33	9	11	9	66
Economics	13	20	33	28	8	40
Mathematics	22	15	18	19	25	147
English	19	16	20	18	23	104
Applied Maths	15	18	24	23	19	104
Chemistry	16	20	18	21	25	120
Physics	8	18	25	26	22	165

From the survey results (as shown in Table 2) physics is the least enjoyable subject for physics students with biology being the most enjoyable subject. Only 11% of 6th formers and 8% of 7th formers consider physics to be their most enjoyable subject.

B) Interest in a subject for the student was often created by practical work. This can be observed from Table 3 where the three practical science subjects are judged more interesting than many other subjects. Fifty percent of the students when asked about what interested them in physics stated that it was the practical and experimental work.

"It was the experiments, the practical side of things."

"Not only was it theory but we did experiments to prove the actual theory."

Nearly all of those interviewed found some aspect of physics interesting.

"Getting the right answer and stuff."

"I may find it interesting but I may not like it that much."

"It is quite rewarding to do something that is the hardest."

For some (8 students) physics was interesting because of its newness and variety.

"Ability to deal with a whole lot of problems you could not do before."

"Just discovering things using formulas."

"Physics was pretty interesting as it was the first year I had taken it."

For others it was not so interesting. Many of these comments reflected the manner in which it was taught.

"It was not interesting in the way it was taught. Just equations put up on the board."

"Physics was very much: here is the formula, here is the problem, solve these."

Table 3: Physics students' ranking of subject interest

INTEREST SIXTH FORM

Subject	5	4	3	2	1	N
Biology	44	23	14	13	7	153
Economics	36	16	34	9	5	44
Chemistry	29	26	20	13	12	262
Physics	**21**	**27**	**24**	**18**	**11**	**425**
Geography	31	15	18	12	23	65
Technical Drawing	13	24	29	19	14	104
Accounting	10	16	19	28	27	420
Mathematics	10	16	19	28	27	420
English	10	13	16	25	36	420

INTEREST SEVENTH FORM

Subject	5	4	3	2	1	N
Biology	41	29	11	11	8	65
Economics	26	18	21	21	15	39
Chemistry	13	31	27	18	11	118
Physics	**18**	**22**	**22**	**24**	**13**	**164**
Applied Maths	13	13	24	29	21	105
English	14	18	16	21	30	104
Mathematics	16	9	16	20	39	146

The survey shows that biology and economics are both more interesting than physics (see Table 3). Mathematics and English appear to be the least interesting subjects. Forty percent of 7th form pupils and 48% of 6th form pupils consider physics to be their second or most interesting subject.

C) Difficulty

Physics was consistently ranked as the most difficult. Eighty-four percent of the physics students who were interviewed considered physics the most or second to most difficult subject they had studied. The main reasons were:

(i) The mathematics and the formulae (22 students)

"The only reason I thought it was hard was because there were so many formulae."

"It just really annoyed me because you know the formula you were supposed to put into the equation, but just nothing happens."

(ii) Students generally did not seem to indicate that teachers were responsible for making the subject difficult, though there were (13) exceptions.

"We just got some notes and then handouts and I did not think that is good enough really."

"He taught at his own level and not at our level. Rather confused it."

These comments tended to be about individual teachers rather than comments about physics teachers in general. However, this may have a negative impact on students' perception of physics.

(iii) Students considered the subject abstract (15 students).

"Physics is abstract. I can't understand it most of the time."

"Kind of goes against things that you thought were right."

Part of the problem may be:

> "I think it is too much of a shock coming from (integrated) science to physics. There is heaps of biology in School Certificate science and quite a bit of chemistry. They need to put more physics with it. You need a basic understanding before you get chucked into the deep end."

Table 4: Physics students' ranking of subject difficulty.

DIFFICULTY SIXTH FORM

Subject	5	4	3	2	1	N
Physics	**46**	**29**	**16**	**7**	**2**	**424**
Chemistry	19	25	26	19	11	262
English	19	17	23	22	19	422
Mathematics	17	22	17	22	22	418
Economics	9	16	22	31	22	45
Technical Drawing	6	16	26	27	25	107
Accounting	6	14	25	27	27	63
Geography	8	14	15	29	34	65
Biology	2	12	19	33	35	150

DIFFICULTY SEVENTH FORM

Subject	5	4	3	2	1	N
Physics	**46**	**27**	**15**	**10**	**2**	**164**
Chemistry	19	24	31	15	13	118
Mathematics	21	26	17	16	21	145
Applied Maths	15	22	22	26	15	105
English	13	12	18	24	33	103
Economics	0	13	33	26	28	39
Biology	5	9	14	37	35	65

Physics was perceived as the most or second to most difficult subject by 75% of the 6th formers and 73% of the 7th formers (Table 4). Those subjects which are considered the least difficult are the same as those that appear to be the most enjoyable. Only 5% of 7th formers and 2% of 6th formers consider biology to be their most difficult subject. The level of difficulty is negatively related to enjoyment.

D) Confidence to do well

If students found physics to be their most difficult and least enjoyable subject, then it was not surprising that they lacked confidence in the subject. Students felt the least confident in understanding and doing well in physics and more confident in biology and mathematics.

"I felt I knew what I was looking for but did not seem to get it."

"Sometimes I passed and sometimes I did not pass. I was not sure where I was."

"Everything was so hard that you start to think, 'I am useless'."

"When you get something wrong you knew that it was your fault."

Confidence in physics is significantly lower than mathematics and chemistry (Table 5). Only 6% of the 6th form and 4% of the 7th form felt the most confident at doing well in physics.

Table 5: Physics students' subject ranking of confidence to do well.

CONFIDENCE TO DO WELL SIXTH FORM

Subject	5	4	3	2	1	N
Accounting	25	35	22	12	6	65
Economics	27	30	18	18	71	44
Mathematics	31	25	16	19	9	420
Technical Drawing	32	25	15	17	11	107
Biology	29	19	28	16	8	153
Geography	27	22	19	27	5	63
Chemistry	16	15	31	21	16	261
English	13	16	17	19	34	424
Physics	**6**	**14**	**19**	**26**	**34**	**425**

CONFIDENCE TO DO WELL SEVENTH FORM

Subject	5	4	3	2	1	N
Biology	27	33	13	20	8	64
Economics	26	23	21	23	8	39
Mathematics	31	19	16	17	17	144
Applied Maths	18	22	21	27	11	103
Chemistry	17	17	25	16	25	116
English	13	21	24	20	21	104
Physics	4	15	22	24	35	162

E) The perceived relationship between physics and mathematics.

For many students physics was equated with mathematical manipulations (26 students).

"Learning about mathematical applications."

"Physics is the same as maths, using formulae and stuff."

"Mathematically solving problems."

Students appeared to perceive physics as being an extension of mathematics and to be of limited use.

Useful for problem solving (16 students).

"It's the relationship between aspects in nature. Dry subject you can't really feel them. All those awful formulae."

"Solving problems. It's a help for maths."

Limited Use (13 students)

"Well it did not come into any use as such."

"It's not useful for everyday life. It's quite interesting and a bit of a challenge to solve the formulae."

"Understanding how to throw simple equations around."

Yet students find mathematics more enjoyable, less difficult and are more confident in it. Students may have difficulty in transferring mathematics out of an idealised environment into a more applied situation such as in physics. Another aspect of this problem could be that students have difficulty translating an idealised physical situation into a mathematical language.

"We just did a lot of maths, pages and pages which seemed to take an awful long time. I enjoy maths on its own but trying to link the maths with the physics is quite difficult."

However other students did not associate physics with just mathematics.

Learning about idealised situations (9 students)

"A form of science more involved in things of motion, learning the technique of doing experiments and recording them accurately."

"It's used for studying more than for research I suppose."

"You can see the effects of gravity but when you go into it deeper it seems utterly pointless, it gets harder."

There were some students who described physics in terms of mechanical and electrical aspects (8 students).

"It's largely learning forces and electrical components."

"Physics is all the mechanical aspects of life."

"...like working out acceleration, speed with cars. That's really the only thing I can think of."

Students perceived physics as being highly mathematical, useful in idealised situations such as solving school physics problems, and of limited use in everyday life. The views expressed by these physics students are similar to 6th form students' responses in a study conducted by Jones (1982b).

3.4.2 Students' feelings about school physics

This section details results that further identify how senior secondary school students feel about the school physics course. The semantic differential technique used means that a profile could be obtained about how students perceived physics generally, not just in relation to other subjects.

There were 10 adjectives chosen to cover interest, difficulty, career, enjoyment and type of teaching. The 10 bipolar adjectives were developed from words used by the student in the interviews and are shown in Appendix A. A seven point scale was used, therefore the number 4 was a neutral point. The mean response was calculated for each bipolar adjective.

The results for 6th and 7th form using the semantic differential technique can be observed in Table 40 (Appendix C). A profile of these results can be seen in Figure 1.

The 6th form students perceived physics to be:

(1) Slightly interesting (mean of 4.50).

(2) Difficult (3.01).

(3) Relevant to a career (4.85).

(4) Slightly irrelevant to everyday life (3.80).

(5) Slightly enjoyable (4.25).

(6) Complicated (3.16).

(7) Very mathematical (2.19).

(8) A subject with many calculations (2.1).

(9) Theoretical (3.12)

(10) Taught with reasonable instructions (3.94).

Figure 1

Sixth and seventh form physics mean score profiles.

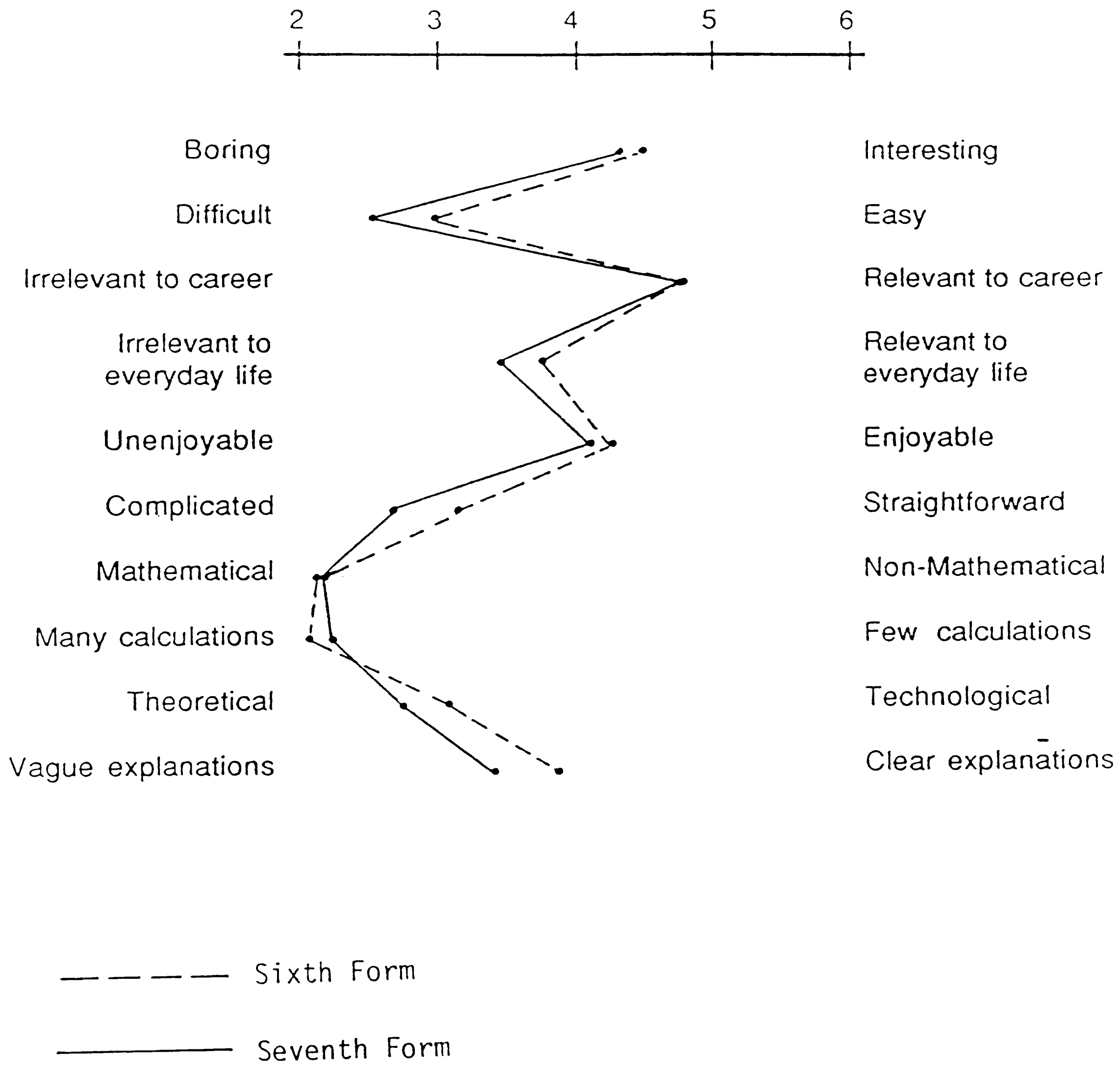


Figure 2 Sixth form girls and boys mean score profiles.

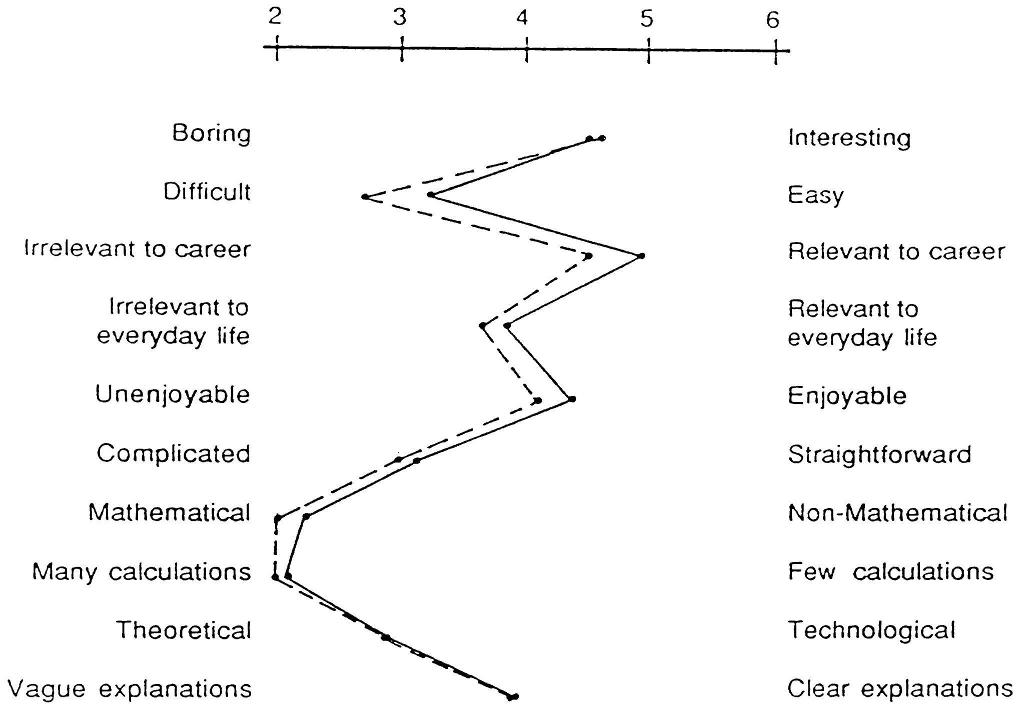
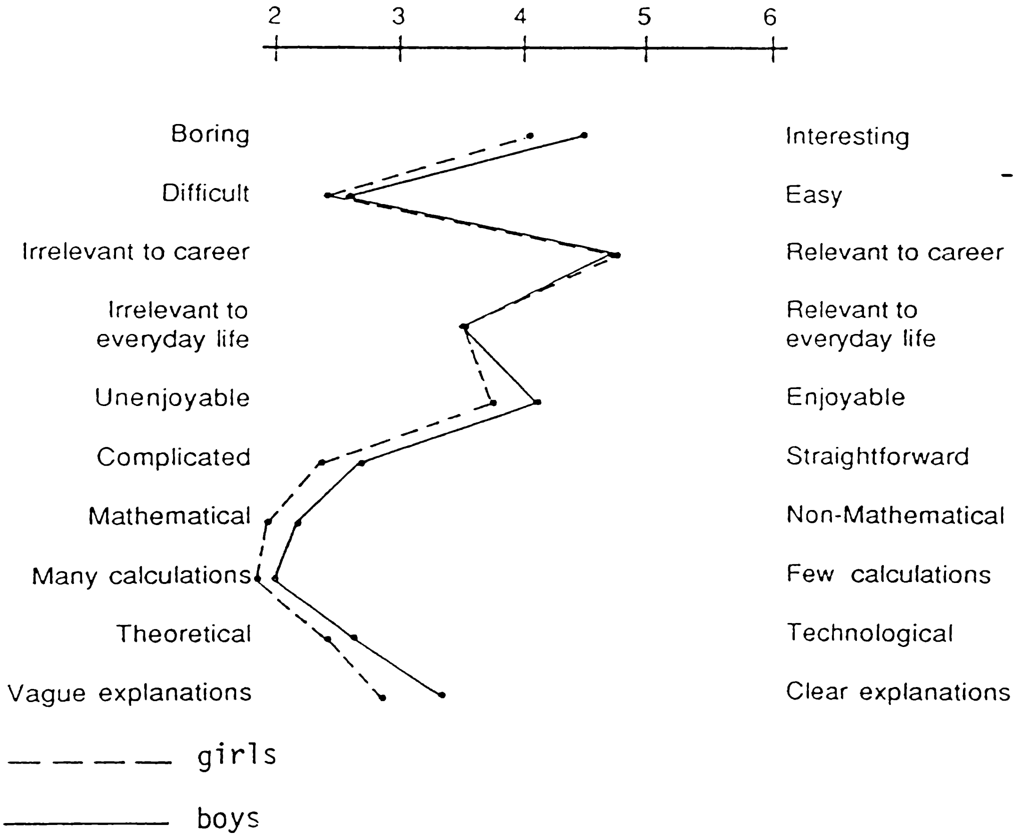


Figure 3 Seventh form girls and boys mean score profiles.



The profile indicates the area of change between the 6th and 7th form is that the subject becomes more complex ($p<0.01$)[3] (i.e. more difficult, vague, complicated. theoretical).

The data obtained by the semantic differential technique was also analysed to find if 6th form physics was perceived differently by the girls and the boys. The analysis of this data can be observed in Table 41 (Appendix C). The profile of the data is shown in Figure 2. The significant areas of difference between girls and boys are difficulty and relevance to career. Girls consider physics to be more difficult ($p<0.01$). Boys consider 6th form physics to be more relevant to their chosen careers ($p<0.05$). This is consistent with girls tending to choose more biological-type careers whereas boys have opted for more technical careers (see further analysis in section 3.5).

Analysis of the perceptions that 7th form girls and boys have of physics is included in Table 42 with a profile of this information in Figure 3. At the 7th form level there did not appear to be any significant differences between the way in which boys and girls perceived physics.

3.4.3 Summary

Using the methodology of the interviews and then administering a large survey, provided more useful information on physics students' perceptions of secondary school physics.

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3 A two tailed t-test on the complexity factor as noted above.

This investigation found that physics students perceived school physics to be a very difficult subject, very mathematical, and of limited use. Although school physics was perceived as slightly enjoyable (on a 1-7 scale), when compared with other subjects it was considered the least enjoyable. The students also appeared to lack confidence to do well in it. The reasons for this, as given by the students, were that school physics lacked relevance, the influence of the teacher, the mathematics and formulae, the abstractions and the limited use of the subject. It was considered to be a complicated subject which became even more complex at the higher levels of secondary school. The explanations were pèrceived as being vague in the 7th form. It did appear however that students were interested in some aspects of physics particularly the experimental aspects. Sixth form girls perceived physics as being more difficult than did the boys and less relevant to future careers. At the 7th form level there were no significant differences between boys and girls in the way they perceived physics.

3.5 REASONS FOR STUDYING PHYSICS

3.5.1 Secondary school students' reasons

The reasons physics students freely gave in the interviews for studying physics could be grouped into three main categories - (i) prerequisite for further study or career, (ii) good marks, (iii) interest, further knowledge, enjoyment. There were 51 students who stated why they had studied physics.

(i) <u>Further study or career</u> (37 responses)

"If you have got physics you can get into heaps of things."

"I took physics so I could do engineering. There is no other subject with mechanics."

"Reason I took physics was because I had to take it for engineering."

(ii) <u>Good Marks</u> (4 responses)

"Eventually nothing apart from marks."

"Good marks."

"A good mark in bursary."

(iii) <u>Interest, further knowledge, enjoyment</u> (6 responses)

"It's a wider base of knowledge."

"Learning to use formulae."

"Wider scope of science,...how all the fields interrelate."

"It's a help for maths."

Students' reasons for studying physics were explored further in the survey. Students were allowed to select, from a list, any number of reasons applicable to them for studying physics. The results appear in Tables 6 and 8. Students had to also identify their most important reason for studying physics. Tables 7 and 9 show these results.

- <u>Sixth Formers' Reasons for Studying Physics</u>

Four hundred and twenty two 6th formers answered these questions (124 females and 298 males). The reasons for studying physics were given as a percentage of the total and are shown in Table 6.

Table 6: Sixth form physics students' reasons for studying physics.

	% ALL	% GIRLS	% BOYS
I am interested in Physics	53	56	52
I found Physics interesting last year	24	31	21
I enjoy doing practical laboratory work	32	27	34
I need Physics for everyday life	10	8	11
I need Physics for my career	69	69	69
I am likely to score high marks	13	10	14
My friends are taking Physics	8	6	9
I was advised by my parents to take Physics	24	24	23
I was advised by my teachers to take Physics	19	20	18
I like the teacher	11	10	12
I had to take physics because of the timetable	1	1	1
I needed another subject	15	16	15
It was recommended to me by a student who had previously taken the course	8	6	8
I enjoyed the Physics I did last year	29	35	26
I did well in the Physics I did last year	26	25	29

Table 7: Sixth form physics students' most important reasons for studying physics.

	% ALL	% GIRLS	% BOYS
I am interested in Physics	15	15	15
I found Physics interesting last year	1	1	1
I enjoy doing practical laboratory work	1	0	1
I need Physics for everyday life	1	3	0
I need Physics for my career	59	59	61
I am likely to score high marks	1	1	2
My friends are taking Physics	0	0	0
I was advised by my teachers to take Physics	2	3	2
I was advised by my parents to take Physics	3	6	1
I like the teacher	1	0	1
I had to take physics because of the timetable	0.5	0	1
I needed another subject	6	5	6
It was recommended to me by a student who had previously taken the course	1	0	1
I enjoyed the Physics I did last year	4	4	4
I did well in the Physics I did last year	3	3	3

The major reasons for students studying physics in the 6th form were career choice (69%), interest (53%), practical work (32%) and past experiences of physics (24-29%) together with advice from parents (24%) and teachers (19%). Only a small percentage chose physics because they liked the teacher.

Thirty-one percent of the girls said "I found physics interesting last year" while 21% of the boys said the same. This was the only significant difference between girls' and boys' reasons for studying physics ($p<0.05$)[4]

- <u>Sixth Formers' Most Important Reason for Studying Physics</u>

Students were asked to indicate the most important reason for studying physics. The results are shown in Table 7. Career choice was the most important reason indicated by 59% of the 6th form physics students. Interest in physics counted for only 15% of the students. There were sex differences. "I need physics for everyday life" ($p<0.01$) and "I was advised by my parents to take physics" ($p<0.01$) were favoured by girls.

- <u>Seventh Formers' Reasons for Studying Physics</u>

The reasons given by the 7th form students are displayed in Tables 8 and 9. One hundred and sixty-eight 7th formers completed this question, 50 of whom were females and 118 males. The possible reasons for studying physics were again given as a percentage of the total.

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4 Significance of the difference between proportions, Z with Yates correction. Two tailed test.

Table 8: Seventh form physics students' possible reasons for studying physics.

	N=168 % ALL	N=50 % GIRLS	N=118 % BOYS
I am interested in Physics	54	42	59
I found Physics interesting last year	51	42	54
I enjoy doing practical laboratory work	24	18	27
I need Physics for everyday life	5	6	5
I need Physics for my career	69	78	65
I am likely to score high marks	18	10	21
My friends are taking Physics	2	2	3
I was advised by my parents to take Physics	10	8	10
I was advised by my teachers to take Physics	14	18	12
I like the teacher	11	22	7
I had to take physics because of the timetable	2	0	3
I needed another subject	16	20	14
It was recommended to me by a student who had previously taken the course	5	6	5
I enjoyed the Physics I did last year	56	50	60
I did well in the Physics I did last year	49	42	52

Table 9: Seventh form physics students' most important reason for studying physics

	N=168 % ALL	N=50 % GIRLS	N=118 % BOYS
I am interested in Physics	10	6	12
I found Physics interesting last year	3	4	3
I enjoy doing practical laboratory work	1	2	0
I need Physics for everyday life	0	0	0
I need Physics for my career	59	68	55
I am likely to score high marks	3	3	3
My friends are taking Physics	0	0	0
I was advised by my teachers to take Physics	1	0	1
I was advised by my parents to take Physics	0	0	0
I like the teacher	0	0	0
I had to take physics because of the timetable	0	0	0
I needed another subject	5	6	5
It was recommended to me by a student who had previously taken the course	1	0	1
I enjoyed the Physics I did last year	5	5	4
I did well in the Physics I did last year	12	6	14

The main reasons for the study of physics in the 7th form were an interest in physics (54%), needing physics for career choices (69%) and interest in or enjoyment of the subject previously (51-56%) combined with the fact that they had experienced success in physics (49-54%).

The "like of the teacher" accounted for a difference of opinion between the sexes with 22% of the girls indicating that this was a reason for the study of physics as did 7% of the boys ($p<0.01$).

- Seventh Formers' Most Important Reason for Studying Physics

The seventh form physics students were asked to indicate their most important reason for studying physics (see Table 9).

Career was the most important reason with success (59%), with interest (10%), enjoyment and interest (3-5%) in previous physics courses much lower.

Further Analysis of Career and Interest

Further analysis was undertaken to analyse the possible reasons of those who had indicated that career and interest were the most important reasons. The results for the 6th formers appear in Tables 10 and 11.

Table 10: Possible reasons for studying physics for those who indicated career was the most important reason (sixth form)

	Female N=72	Male N=164	All N=236	%
I am interested in Physics	33	89	122	52
I found Physics interesting last year	19	38	57	24
I enjoy doing practical laboratory work	13	66	79	33
I need Physics for everyday life	2	14	16	7
I need Physics for my career (only)	6	12	18	8
I am likely to score high marks	15	33	48	20
My friends are taking Physics	5	21	26	11
I was advised by my teachers to take Physics	4	10	14	6
I was advised by my parents to take Physics	15	30	45	19
I like the teacher	5	18	23	10
I had to take physics because of the timetable	0	0	0	0
I needed another subject	10	4	14	6
It was recommended to me by a student who had previously taken the course	4	5	9	4
I enjoyed the Physics I did last year	23	41	64	27
I did well in the Physics I did last year	13	43	56	23

- Career the most important reason (6th form)

Table 10 shows possible reasons for the study of physics from those who indicated that physics for their career was their most important reason. The sample size was 236 being 59% of the total.

Fifty-two percent of those who stated that career was the most important reason also indicated that they were interested in physics. The enjoyment of practical work was the second most popular reason (33%). They were also influenced by their previous experiences of physics (23-27%).

- Interest the most important reason (6th form)

Table 11 shows the possible supporting reasons for those who indicated that interest was the most important reason. Five percent considered that interest was the only reason for studying physics. "I need physics for my career" was indicated by 40%, as was past experience in physics (30-37%) and the enjoyment of practical work (38%). These students' reasons for studying physics were spread over a wider ranger of choices than those who stated career was the most important reason.

- Career the most important reason (7th form)

Table 12 shows the 7th form students' responses when career is the most important reason.

Although these students chose `career' as the most important reason for studying physics, they were obviously influenced by their interest

Table 11: Possible reasons for studying physics for those who indicated interest was the most important reason (sixth form).

	Female N=20	Male N=43	All N=63	%
I am interested in Physics (only)	1	2	3	5
I found Physics interesting last year	7	12	19	30
I enjoy doing practical laboratory work	8	16	24	38
I need Physics for everyday life	3	7	10	16
I need Physics for my career	4	21	25	40
I am likely to score high marks	4	8	12	19
My friends are taking Physics	4	9	13	20
I was advised by my teachers to take Physics	2	3	5	8
I was advised by my parents to take Physics	1	7	8	13
I like the teacher	2	2	4	6
I had to take physics because of the timetable	1	0	1	2
I needed another subject	2	4	6	10
It was recommended to me by a student who had previously taken the course	1	8	9	14
I enjoyed the Physics I did last year	8	15	23	37
I did well in the Physics I did last year	7	13	20	32

Table 12: Possible reasons for studying physics for those who indicated career was the most important reason (seventh form).

	Female N=34	Male N=60	All N=94	% All
I am interested in Physics	13	28	41	44
I found Physics interesting last year	13	32	45	48
I enjoy doing practical laboratory work	7	15	22	23
I need Physics for everyday life	2	6	8	9
I need Physics for my career (only)	6	6	12	13
I am likely to score high marks	2	9	11	12
My friends are taking Physics	2	11	13	14
I was advised by my teachers to take Physics	0	1	1	1
I was advised by my parents to take Physics	7	10	17	18
I like the teacher	7	3	10	11
I had to take physics because of the timetable	1	2	3	3
I needed another subject	6	3	9	10
It was recommended to me by a student who had previously taken the course	3	3	6	6
I enjoyed the Physics I did last year	13	31	44	47
I did well in the Physics I did last year	6	27	33	35

Table 13: Possible reasons for studying physics for those who indicated interest was the most important reason (seventh form).

	Female N=4	Male N=16	All N=20	%
I am interested in Physics (only)	0	1	1	5
I found Physics interesting last year	3	9	12	60
I enjoy doing practical laboratory work	0	8	8	40
I need Physics for everyday life	0	0	0	0
I need Physics for my career	4	9	13	65
I am likely to score high marks	0	5	5	25
My friends are taking Physics	0	0	0	0
I was advised by my teachers to take Physics	0	0	0	0
I was advised by my parents to take Physics	0	1	1	5
I like the teacher	1	2	3	15
I had to take physics because of the timetable	0	0	0	0
I needed another subject	0	1	1	5
It was recommended to me by a student who had previously taken the course	0	1	1	5
I enjoyed the Physics I did last year	1	9	10	50
I did well in the Physics I did last year	1	8	9	45

(44%) in the subject, past success (35%), enjoyment (47%) and past experience (47-48%).

- Interest most important reason (7th form)

The possible reasons for studying physics, by those who considered interest as their most important reason, is shown in Table 13. The sample size is small N = 20. However, the general trends are evident.

Career choice (65%) and previous year's experiences in physics (45-60%) along with interest also influenced the students' decisions to study physics again.

Summary

The major reasons physics students gave for studying physics in the 6th form were career choice and interest. The enjoyment of practical work, past experiences in physics and advice from parents and teachers, influenced the study of physics to a lesser extent. The most important reason for studying physics was because school physics was a prerequisite for their chosen careers.

The reasons 7th formers gave for studying physics were again because of 'career' reasons and interest. However, in the 7th form, the influence of school physics from the previous year was also significant. The single most important reason for studying school physics was because of career requirements (59%).

3.5.2 First Year University Physics Students' Reasons

To further explore students' reasons for studying physics, a survey was developed after some preliminary interviews with first year university students. The actual survey and results are found in Appendix D. It is very similar to section B of the 6th and 7th form survey. The analysis is also similar. The survey was undertaken at the end of the first academic term.

The reasons why students select physics at the first year university level are similar to those at secondary school (Table 43). These are primarily interest and enjoyment (interested in physics 66%, interesting last year 57%, enjoyed the physics last year 53%), required for a career (68%) and success in the subject last year (42%). The most important reason for studying physics was "I need physics for my career" 44% and "I am interested in physics" 30%.

The possible reasons for studying physics, by those who considered `career' as their most important reason, are shown in Table 45. Although career was the most important reason, 63% of the students indicated that interest was also an important factor.

The percentage of students who indicated that `interest' was the most important reason, is shown in Table 46. Interest (75%) and enjoyment (82%) in the previous year appeared to be important factors in determining whether these students would study physics. These students also indicated that they required physics for a career (61%).

It would appear that career is the most important reason for studying physics at first year university level together with enjoyment of the subject in previous years and present interest.

The career choice of first year university students is shown in Table 47. The main career options appear to be computing and engineering. To further explore the relationships between career choice and the reasons for studying physics, Table 48 was developed. Most students' reasons for studying physics are interest and career. However, those students choosing computing have a variety of reasons for studying physics.

The majority of students consider a knowledge of physics to be both important and relevant for their chosen career (see Table 49). Sixty-seven percent of the students indicate that a pass in first year physics is required for their career while 31% of the students hope to continue to second year level (Table 50). This total includes those who will go to engineering school. Only nine students are considering majoring in physical sciences.

3.6 CAREER CHOICE OF PHYSICS STUDENTS

3.6.1 Career Choice of School Students Studying Physics

Career and interest have a large influence on whether students study physics, therefore their intended careers could be examined. The complete list of career choices for both the 6th and 7th forms is shown in Table 14.

The raw scores have been used rather than converting to a percentage as the numbers are small. The data is presented in three columns; the total number, females and males. The number of females is approximately 30% of the total in both the 6th and 7th form. The students' proposed careers appeared to fit into 18 different

Table 14: Career choice of sixth and seventh form physics students.

FORM SIX

N = 428	N	F (N=128)	M (N=300)	
Architecture	10	2	8	
Art/SocSci/Law	34	14	20	
Biological Sciences	27	14	13	**
Chemistry	4	2	2	
Commerce	65	15	50	
Computing	12	0	12	*
Draughting	24	4	20	
Electrician	15	0	15	**
Electronics	13	0	13	*
Engineering	54	2	52	**
Mathematics	0	0	0	
Medicine	59	39	20	**
Outdoor/Sur/Forest	17	5	12	
Physics	3	0	3	
Police/ArmSer/Fly	35	2	33	**
Sci/Labwork	22	11	11	*
Teaching(P)	13	8	5	*
Trade	5	0	5	
Undecided/Uni	16	6	10	

FORM SEVEN

N = 162	N	F (N=50)	M (N=111)	
Architecture	11	4	7	
Art/SocSci/Law	6	1	5	
Biological Sciences	17	8	9	
Chemistry	2	1	1	
Commerce	23	4	19	
Computing	5	1	4	
Draughting	0	0	0	
Electrician	0	0	0	
Electronics	3	1	2	
Engineering	31	3	28	**
Mathematics	2	0	2	
Medicine	29	16	13	**
Outdoor/Sur/Forest	10	2	8	
Physics	1	1	0	
Police/ArmSer/Fly	10	0	10	
Sci/Labwork	4	3	1	
Teaching	4	4	0	**
Trade	0	0	0	
Undecided/Uni	4	2	2	

* 5% level
** 1% level
Using significant difference between proportions Z with Yates correction.

categories with one for those who were undecided. Art/Social Sciences/Law for example, would include psychology, graphic design, law etc. Biological sciences would include veterinarian as well as another occupations associated with biological courses. Chemistry would include industrial chemistry. Engineering includes both professional and New Zealand Certificate of Engineering (NZCE). Medicine is not just training to be a doctor but includes nursing and radiography. Outdoor/Surv/Forest includes farming, horticulture, forestry and surveying. Physics includes astronomy. Science/Labwork includes technicians and those who stated they would want to be involved in scientific work etc. Police/Armed Services includes those people who wanted to join the police force and the armed services particularly the airforce and those who wish to fly as a career. Trade includes those interested in an apprenticeship or something similar.

<u>The actual choices</u>

The career choices which are greater than 5% of the total samples are arts/social sciences/law (34), biological sciences (27), commerce (65), draughting (24), engineering (54), medicine (59), police/armed services/fly (35), and Sci/Labwork (22). Electronics and electrician together give a total of 28.

Apart from three occupations (arts/social sciences/law, commerce, teaching), the other career choices could, and in most cases certainly do require at least school physics to 6th or 7th form as a prerequisite. However, that is not to imply that the study of physics would not be useful in those other careers. If the "undecided/Uni" are removed from the total then those careers that definitely do not require a prerequisite in physics are chosen by 27% of the students.

However this figure is on the low side because to join the police force, or to be a farmer physics is not necessary. However, physics is required in the majority of the other occupations in those individual groupings i.e. outdoor/surveying/forestry and police/armed services/flying.

In the 7th form the percentage of careers that do not require physics as a prerequisite or as an advisable option, has dropped to 21%. Again this figure is low because of the two career groupings mentioned earlier. However, this data does show that the career choice of the majority of the students does require some background in physics. This may be as a prerequisite or as a recommended option.

There is of course, a change in the distribution of students among the various categories. In the 7th form the students have tended to move into the more professional fields. For example, medicine has increased from 14% to 18% and engineering from 13% to 19%.

Differences between male and female career choices

The gender differences in career choice occur in the technological and medical careers. The 6th form physics girls tended to have a narrower range of careers than did the 6th form boys. The following career choices: computing, electrician, electronics, physics and trade-were not chosen by any girls. Generally, girls showed more interest in biological-type careers and those careers which deal directly with people. Specifically, girls are significantly more interested in biological sciences, medicine (1% level), scientific laboratory work, primary school teaching (5% level). Boys' choices were over a larger number of careers and they were significantly more interested in electrician, engineering, police/armed services (1% level) and computing and electronics (5% level).

In the 7th form, the career choices of physics students have reduced and so have the differences in career choices between the sexes. Boys were significantly more interested in engineering (1% level) and girls were more interested in medicine and teaching (1% level). It appears that boys are more interested in technological-type careers whereas girls prefer those careers involving direct contact with people such as biological sciences, medicine and teaching.

3.6.2 Career Destination of New Zealand Physics Graduates

The surveys of secondary school and first year university physics students revealed that very few were considering majoring in physics. The total number of students who have graduated in all physics degrees in all New Zealand universities since the 1975-76 academic year has a yearly average of 117. (Complete analysis is in Appendix E, Tables 51-54). Figure 4 indicates the general destination of New Zealand physics graduates.[5] The data over an eight year period (no information available for 1976-77) reveals that 59% of Bachelors graduates continue with some form of further study. Eleven percent go directly into private employment and 12% into employment in the public sector. Sixty-nine percent of honours students continue with further study while 25% go into public employment. Masters graduates also tend to continue with further study (43%), with 9% taking up employment in the

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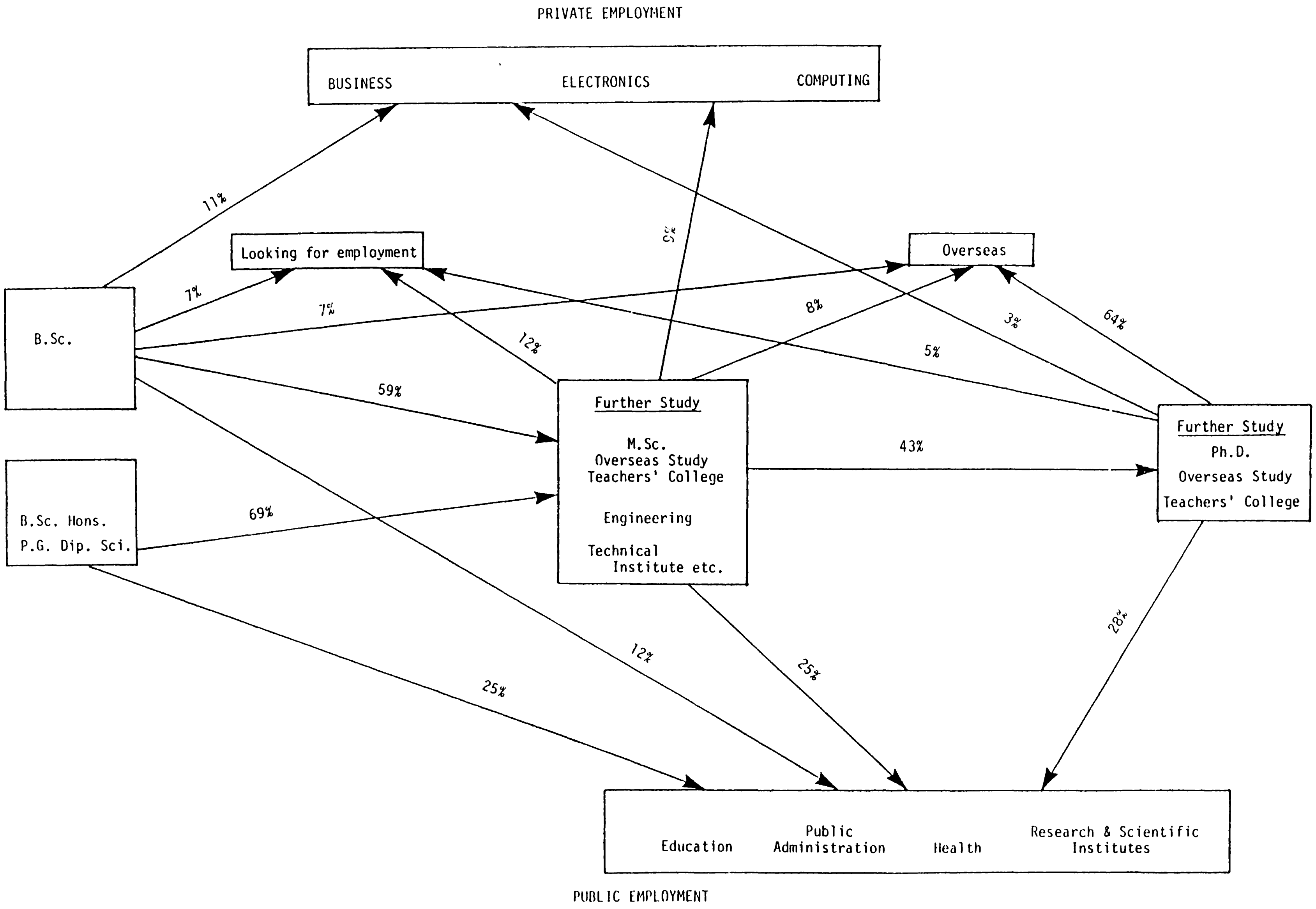
5 This information comes from data provided by graduates upon graduation. It therefore only provides data on their first destination.

Figure 4: Initial career destination of New Zealand physics graduates.



private sector and 25% taking up employment in the public sector. Sixty-four percent of New Zealand doctoral graduates move overseas while 28% move into the public sector and 3% move into the private sector.

The general trend appears to be that 60% of undergraduates will continue with further study. Approximately 40% of Master graduates will continue with further study or public employment. Graduates with doctorates move overseas for employment and further study (post-doctoral). The public sector appears to be the largest employer of physics graduates. Approximately 10% of physics Bachelor graduates go to Teachers College.

3.7 USEFULNESS AND IMPORTANCE OF PHYSICS FOR CAREERS

3.7.1 The perceived usefulness of school physics for a career

The perceived usefulness of physics for a career depended on how the physics students viewed physics. Table 15 indicates the areas in which 7th form physics students (interviewed) were considering careers.

Table 15: Career preferences of 7th form physics students (Interviewed).

Related Area	Number
Agricultural/Biological Sciences	6
Engineering	15
Medicine	16
Commerce	7
Science (Physics, Chemistry, Electronics, Astronomy)	5
Other	11
Total	60

The majority, 70% of students, were studying physics as a prerequisite for further study. Only two students considered studying physics beyond first year at university. From further exploration of these students' perceptions of the relevance of school physics to careers, it seems that physics tends to be seen as being mainly useful for solving mathematical problems.

Engineering

"More important for the formulae. Understanding problems."

"I don't know much about engineering but that's what people have told me to take."

"You need it to get into engineering school."

Medicine

"Some of the more complicated maths might help you as a doctor."

"I don't see how it (physics) would have anything to do with it (medicine)".

"More important to do the formulae. Understand problems a bit. Cope with hard problems better."

Biological Sciences

"I suppose it's like maths. It does not seem as if it's going to incorporate into your career, but they say it does."

"It makes you think things out."

"I did not think physics was important ... only for measurements like to make up an anaesthetic injection and you have to work out all the measurements."

Although the majority of students are studying physics because of career choice, they did not appear to know how a knowledge of physics would help them in their chosen career. It would appear that if physics is viewed from a largely mathematical perspective, then students will have difficulty relating the physics they are taught to their proposed careers and life in general.

The survey of 6th and 7th form physics students revealed how useful school physics was perceived to be relative to other subjects,(Table 16).

Table 16: Ranking of school subjects in terms of usefulness for a career.

CAREER FORM SIX

Subject	5	4	3	2	1	N
Mathematics	24	35	23	14	14	407
Accounting	36	14	14	16	20	64
Biology	32	16	13	21	18	146
Physics	**22**	**23**	**22**	**18**	**15**	**413**
Chemistry	19	25	19	19	19	253
Economics	26	20	9	22	24	46
English	13	11	22	23	31	409
Technical Drawing	10	8	26	32	24	102
Geography	8	3	17	28	43	60

CAREER FORM SEVEN

Subject	5	4	3	2	1	N
Biology	37	22	13	10	19	63
Physics	**25**	**24**	**20**	**15**	**15**	**161**
Mathematics	19	30	18	22	10	146
Chemistry	21	23	24	23	19	115
Applied Maths	10	17	39	27	6	99
Economics	18	23	3	18	39	39
English	12	4	18	20	46	103

The perceived usefulness of physics is shown in Table 16. In the 6th form, mathematics appears more useful than physics whereas in the 7th form, physics is considered to be one of the most useful subjects.

Apart from a career, school physics was not perceived to be useful in everyday life (10 comments). However, it may be helpful in other areas such as mathematics (23 comments).

"A lot of the things you learn in physics you can't really apply to normal everyday life."

"Understanding how to throw simple equations around."

"If you take maths, a lot of it is pretty much the same."

3.7.2 The Perceived Importance of Physics for a Career

The physics students who were surveyed were asked how important they considered the study of physics to be for their chosen career. The results can be seen in Table 17. In the 6th form, 56% of the students indicated that physics was important, 19% neutral and 25% considered it to be unimportant. The results are very similar for the 7th form where 59% considered physics to be important for their career, 15% were neutral and 25% considered the study of physics to be unimportant for their chosen career. Sixty-seven percent of the 6th formers stated that a pass in physics was required compared with 71% of 7th formers.

The destinations of the 6th and 7th form physics students are shown in Table 18. From the 6th form, only 16% were considering leaving to get a job. This also includes those who would be attending a technical institute part-time. Only 4% were considering going on to university directly from the 6th form. Those interested in returning to school made up 61%. Very few (12%) of the 7th form were going directly into a job. A total of 86% would be continuing to some form of tertiary education.

Table 17: The importance of physics for a career.

FORM SEVEN

How important students consider the study of Physics to be for their proposed career. N = 147.

		1	2	3	4	5	
UNIMPORTANT	N	22	15	22	33	54	IMPORTANT
	%	15	10	15	22	37	

Whether a pass in University Entrance or University Bursary is required for their career?

	%
YES	71
NO	28
NOT SURE	1

FORM SIX

How important students consider the study of Physics to be for their proposed career. N = 378.

		1	2	3	4	5	
UNIMPORTANT	N	52	42	71	115	98	IMPORTANT
	%	14	11	19	30	26	

Whether a pass in University Entrance or University Bursary is required for their career?

	%
YES	67
NO	31
NOT SURE	2

Table 18: Destination of sixth and seventh form physics students.

FORM SIX N = 394

	%
Job	16
Other	1
School	61
Teachers College (primary)	0
Technical Institute	17
University	4
Unsure	1

FORM SEVEN N = 147

	%
Job	12
Other	0
School	0
Teachers College (primary)	1
Technical Institute	10
University	76
Unsure	1

3.8 THE USE OF TECHNOLOGICAL APPLICATIONS IN THE CLASSROOM

One implication from the previously presented data is that students seem to have a very limited view of physics. This was further examined by asking students if they had been shown any applications for physics during the year. The students were given a series of technological applications to illustrate the question. The applications are shown in Appendix B. Each application was explained to the students.
From the interviews it was evident that technological applications were only introduced occasionally into the classroom, if at all.

Some applications were introduced (32%)

"My teacher picked up examples from here and there ... it was not done for each topic."

'Yes, we were but not often, just when it came up (not every topic)."

Could not remember any examples (38%)

"Can't say we actually did because sort of not shown how it worked practically like outside."

"Probably given examples. He (teacher) probably knows about them but they could be a bit complex to talk about."

"Definitely no."

"Not at all ... I think it would be better in the 7th form. Concepts of physics in the 6th form were a bit limited."

Limited to laboratory experiences (22%)

"Butter intensity gun for spreading butter" (Common example showing $A \propto r^2$)

"Seen trolleys tied together."

"Get a couple for plugging into formula. You don't get much applied physics."

High tech and others (4%)

"Sort of space technology."

"Example of frictionless world and $E = mc^2$."

Students generally were unable to link the physics they had learnt to technological application of physics. This was investigated by asking the students to give an example of 'total internal reflection', a topic that was taught during the previous year. This concept was also explained to them. If they answered 'no' they were shown a few examples.

The majority had not come across any examples before (78%).

"Never come across the examples before."

"We were not shown any examples."

However, some did mention telescopes and binoculars (14%). Others had read about examples of total internal reflection (8%).

"Fibre optics ... I read about it somewhere."

"My father's a doctor. He showed me."

S[6] "I don't think of it as physics though."

I "You don't tend to think of these (examples) as physics."

S "No, just amazing technology."

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6 S = student, I = interviewer

It may be that it is unreasonable to expect students to remember applications for one specific area even when it is explained to them, and examples are shown. However, 7 students were asked the same questions from a class who had been shown technological examples of total internal reflection during the previous year. Six of the students specifically remembered one or more application and where these were used.

"Signals on the harbour bridge with fibre optics."

"Rainbows. it's quite easy to relate to."

"Well, like last year, the oil tanker and washing out the oil at sea."

The other student remembered fibre optics but could not remember where they were used.

It would appear that a technological perspective could be required to show students how school physics relates to the technological society in which they live. Such an approach was trialled informally by the researcher. Some positive attitudes have appeared. Students were more able to see the relevance of physics to medicine, engineering and other careers.

"You will have to use all the equipment when you are a doctor. It's not just a case of looking at someone and prescribing drugs anymore."

"If you have a background in physics, it helps I suppose in understanding how things work."

The students did not just view physics as an extension of mathematics.

"It's about how things work, the way they are."

"Things you take for granted that you do every day and how they come about."

All 7th form physics students (7) who had been introduced to technological application in the 6th form, stated that physics was the most or second most interesting subject.

"I was able to relate it to things around me."

"It made the understanding a lot easier."

The preliminary trial indicated that it might be valuable to introduce a modern technological perspective into the teaching of physics at the secondary school level.

A further pointer to the likely value of this approach came from the 60 students who were interviewed. Examples of modern technological applications of school physics were presented and the students were asked to choose one or two they would like to study further (see Appendix B). The examples gave background information of the application and details of how the device worked. The students were also free to ask questions. All but two of the students expressed an interest in learning more about the application of physics principles. The exceptions stated:

"We have to adhere to the syllabus."

"It won't help me learn it."

The rest (97%) were very positive indeed.

"I can relate now to what I have learnt."

"Something that would hold my interest."

"... it would make it more interesting being able to relate it to something."

Table 19 presents the type of applications that students were interested in learning more about.

Table 19: Technological applications chosen by students.

Example	%[7]
Foetal Heart Monitor	70
Cerebral Bleeding Detector	60
Burglar Alarm	28
Biomagnetism	17
Detection of Inversion Layers	15
Optoelectronic Level Indicator	2

Students appeared to prefer the medical examples. The reasons students gave for choosing the devices could be grouped into three categories.

(i) Interest in biological/medical aspects (34%)

"I had only thought of physics as mechanical things and not living things."

"I was interested in the medical ones."

(ii) Related to human aspects/everyday life (52%)

"It's useful and deals with people."

"Because it's the type of thing I would come across."

"... an example which can be of use ... it's saving life."

(iii) Useful for career (10%)

"Because of the career I want to do."

"I want to be a vet or a doctor at some stage."

- Summary

Physics students have in general not been exposed to technological applications in the classroom and were unable to link the physics they had learnt to technological applications of physics. The preliminary trials indicated that it might be helpful to the student to introduce

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7 More than 100% because the students could choose two examples if they wished

a modern technological approach into the teaching of physics at the secondary school level.

3.9 GENERAL SUMMARY AND CONCLUSIONS

The methodology of interviews followed by larger surveys has revealed how New Zealand secondary school physics students perceive school physics, their reasons for studying physics, the perceived usefulness of school physics for a career, and their response to technological applications. The major findings are summarised below.

1. School physics was perceived as being the least enjoyable, very mathematical, the most difficult subject and the one students were the least confident in. It was of average interest with most interest being in the experimental aspects.
2. The students ascribed these perceptions to the apparent lack of relevance, the influence of the teacher, the mathematics, the formulae involved, the abstractness and the apparent limited application of the subject.
3. Students viewed school physics from a mathematical perspective and this influenced how useful they saw physics in their intended careers.
4. Sixth form girls perceived physics as being less relevant to their chosen careers and more difficult than boys did.
5. As the level of physics increased so did the apparent level of complexity, e.g. more vague, complex, difficult, theoretical.
6. The single most important reason for studying physics was because of career choice.
7. The other major reasons for studying physics were because of interest and the influence of the previous year's physics. Girls were influenced more by parental advice than boys.

8. At least 70% of the careers chosen by the students required school physics as a prerequisite. The most popular careers were social sciences/law, biological sciences, commerce, computing, draughting, electrical engineering, engineering, medicine, police/armed services, scientific laboratory work. In the 7th form the major career aspirations narrowed down to biological sciences, commerce, engineering and medicine.
9. Boys tended to be choosing technological careers whereas girls were choosing biological/medical sciences.
10. The majority of New Zealand physics graduates continue with further study after their first degree. Graduates mainly work for government agencies with very few finding employment in the private sector.
11. The perceived usefulness of physics was in terms of solving mathematical problems.
12. Students appeared to see school physics as being isolated from the real world and were shown few technological applications.
13. Students reacted positively to the introduction of technological applications.

CHAPTER 4

STUDENTS' INTERESTS IN PHYSICS AND TECHNOLOGY

4.1 INTRODUCTION

It was previously indicated (section 3.8) that seventh form physics students may be interested in medical applications of school physics. This section of the study further explores students' interests in technological applications and attempts to identify factors involved in students' interests. It has been argued that the interests of a learner are part of that individual's existing knowledge (section 2.4). Thus if aspects of the physics lesson can be related to a learner's existing knowledge then the learner is more likely to attend to the learning situation and links may be generated between the stimuli and existing knowledge. Student interest in physics and technological applications have been reviewed in section 2.3.

4.2 METHODOLOGY

The method for obtaining students' interests in physics and technological applications was with the use of structured interviews and large surveys, and has been outlined in section 3.2.

4.2.1 Interviews

The method for obtaining information regarding what students were interested in learning more about was to develop a series of cards with various examples and to interview the students. The technique was similar to that developed by Osborne and Gilbert (1979) and the Learning in Science Project (Tasker *et al.* 1979) to elicit children's ideas about various scientific phenomena.

The examples consisted of:

(i) solar water heater

(ii) refrigerator

(iii) vacuum cleaner

(iv) finding the kinetic energy of a trolley

(v) an apnoea mattress

(vi) optoelectronic level indicator

(vii) measuring the purity of water

(viii) finding the sugar content in kiwifruit

(ix) using fibre optics for stomach investigations

(x) acoustic sounder

(xi) household burglar alarm

(xii) foetal heart beat monitor.

These particular twelve were used because they provided examples of (a) school physics, (b) using physics in agriculture, horticulture, etc, (c) industrial applications and (d) domestic appliances.

As is shown in Appendix F the cards each had a diagram of the particular device and in some cases a couple of sentences describing the device.

- <u>The sample</u>

The interviewed students were fifth form students (15-16 years) all of whom were taking a general science course, which included physics, chemistry, biology, and earth science. Fifth form students were chosen as they had not yet opted for physics and could be considered representative of all science students. There were 40 students interviewed, 20 girls and 20 boys. These students were chosen by their science teachers and were considered to be of average to above average ability (Typical of the students who would study physics). The students were from five different schools, four from the Hamilton area and one from the Auckland region.

- <u>The procedure</u>

The interviews were each approximately 20-25 minutes, were audiotaped and later transcribed by the interviewer. In the first stage of the investigation the students were told why this study was being undertaken. For example:

> "I am interested in finding out what you would like to learn more about in science lessons. I have a series of cards which I will explain to you and then you tell me how interested you would be in learning more about that and why. You are free to ask any questions about the card. I am going to use a tape recorder if that is all right with you because I am interested in your ideas and what you have to say. If you do not want to be taped that is all right and if you do not want something recorded we can wipe it off. There are no right or wrong answers I just want to find out how interested you would be in learning about the following. Have you any questions?"

The students were shown each card and the device on the card was explained to them, e.g. how it worked, who used it and examples of its application. They were then free to ask any questions that they might have. They also given the following scale (1-5).

1	2	3	4	5
Not Interested	Indifferent	Slightly Interested	Interested	Very Interested

They were asked to say how interested they would be in learning more about a particular device by indicating on the scale. The reasons for their answers were then sought by using such questions as;

"Can you tell me why you indicated that particular number?"

"Why do you say that?"

Similar questions would explore further the students' responses and the reasons for the students' choice. A clearer idea could thus be obtained about what makes a particular application of physics interesting or uninteresting to the student.

Several interviews in addition to the forty were conducted for trialling purposes. From these interviews the final questions were obtained. The interview technique had to be developed so that there were no leading questions and the questions were not too difficult (Bell and Osborne, 1981).

The following is an extract showing how the interview method was used to clarify student responses.

S [1] "Well I would be slightly interested in that because, you know, it is new technology."

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1 S=student I=interviewer

I "New technology, what do you mean by that?"

S "Well it is becoming more common in everybody's house whereas a refrigerator or a vacuum cleaner has been around for a long time. It's like a computer, something new."

4.2.2 Surveys

- The structure

To examine student interest on a larger scale a multichoice survey was constructed. The same scale was used as in the interviews (see section 4.2.1). Technological examples that could be used in the 6th and 7th form physics classes were included. Most of the examples came from the teacher resource book *Physics at Work in New Zealand* (Jones, 1982a).

Five major categories of illustrations of technological applications were used.

(i) **Medical:** apnoea mattress, fibre optics, foetal heart beat monitor, blood flow meter, x-ray machine, cerebral bleeding detector.

(ii) **Theoretical Physics:** kinetic energy of a moving trolley, gravity, light, forces, and different types of energy.

(iii) **Domestic Applications:** refrigerator, vacuum cleaner, bicycle pump, solar water heater, burglar alarm, microwave oven, transistor radio, motor car. Of particular interest was the student response to the microwave oven since in the interviews students indicated they were not interested in domestic appliances yet interested in modern technology.

(iv) **Nature:** measurement of the purity of water, detection of sugar in kiwifruit, rainbows, muscles in the human body.

(v) **Technological/Industrial:** The industrial examples were; temperature measurement of the kiln at New Zealand Steel, discovering how a microphone works and studying the operation of the Huntly power station. The 'hi-tech' examples were; a nuclear powered ship, communication satellites in space and learning how a laser works.

The total number of examples was limited to thirty. The complete survey can be seen in Appendix G.

- The procedure

The survey was trialled in three classes at an Auckland co-educational school. The survey was explained to the students by the researcher. The students were questioned later to ascertain whether they had understood the survey. This trial was carried out among average fifth form students and the survey appeared to be satisfactory with only one or two minor clarification changes made to the wording of some questions.

It was decided that the survey would be administered by the researcher so that the purpose of the survey could be mentioned, any explanation or assistance could be given and the amount of written material could be reduced. This method seemed to indicate to the students that this was not a test in the normal sense, that there were no right or wrong answers, and it was their own personal response which was important. It was stressed that the survey was confidential and that the teacher would not see the completed questionnaires.

- <u>The sample</u>

The sample consisted of 250 boys and 250 girls from the fifth form level (15-16 years) from 10 different secondary schools in the Hamilton, Auckland and Christchurch regions. Two of these schools were single sex schools. The survey was completed by those students who were considered to be of average to above ability, in the final third of the academic year.

The data from the survey was then statistically analysed to identify the topics that were considered interesting and to note any gender differences. These statistical techniques are discussed with the results.

4.3 RESULTS OF THE INTERVIEWS

The students were asked why a particular instance or device was interesting or not interesting to them. The replies ranged from, "I do not know", through to such replies as "I would not mind having one in the house. I would be able to protect the house you know." There are many individual reasons why a student may or may not be interested in a particular technological device. In this study only the major reasons for interest or lack of it are discussed. The level of student interest (1-5 scale) is shown in Table 20. The level of girls' and boys' interest in technological applications is shown in Table 21.

Table 20: The level of student interest in technological applications (N=40).

Technological device	Mean
Apnoea mattress	4.2
Fibre optics	4.0
Foetal heart beat monitor	3.9
Burglar alarm	3.8
Kiwifruit sugar content	3.8
Purity of water	3.5
Solar water heater	3.4
Acoustic sounder	3.3
Optoelectronic level indicator	3.0
Refrigerator	2.8
Kinetic energy of a trolley	2.6
Vacuum cleaner	2.5

Table 21: The level of girls' and boys' interest in technological applications.

Technological device (Male N=20)	Mean
Apnoea mattress	4.2
Kiwifruit sugar content	4.1
Burglar alarm	4.0
Fibre optics	3.8
Solar water heater	3.7
Purity of water	3.6
Foetal heart beat monitor	3.5
Acoustic sounder	3.4
Optoelectronic level indicator	3.3
Refrigerator	2.9
Kinetic energy of a trolley	2.8
Vacuum cleaner	2.5

Technological device (Female N=20)	Mean
Foetal heart beat monitor	4.3
Apnoea mattress	4.2
Fibre optics	4.2
Burglar alarm	3.6
Kiwifruit sugar content	3.5
Purity of water	3.4
Acoustic sounder	3.2
Solar water heater	3.1
Optoelectronic level indicator	2.9
Refrigerator	2.7
Vacuum cleaner	2.5
Kinetic energy of a trolley	2.4

1. The direct involvement of people

The main reason for students being interested in a particular device was whether or not it directly involved people. Nearly every student (18 boys and 20 girls) when commenting on why they felt a particular device was interesting, included reference to the direct involvement of people. These comments ranged from those who thought a certain device would "help horticulturalists" through to a device for "saving someone's life".

> "Well it's the sort of thing I suppose you'd want to learn about because it saves lives and that."
>
> "Things to do with people."
>
> "I guess just being related to living things holds more interest."

The cards of the apnoea mattress, fibre optics and the foetal heart beat monitor appeared to be interesting because they were medical examples and involved the welfare/caring of people. In addition, devices such as the burglar alarm and measuring the sugar content of kiwifruit were also regarded by the boys and to a lesser extent the girls as helping people. Although boys were interested in the apnoea mattress they were not as interested as the girls were in the foetal heart beat monitor. The reason could be as one girl stated;

> "Cause you are a woman and you are going to have a baby sometime and you want to know what they are doing to you."

The girls were more concerned about the people involved than the actual device.

> "Because I feel sorry for the baby."
>
> "It's a lifesaving device...if they did not have it the baby would probably die."

The boys were interested in devices which directly involved people but did not place as much emphasis on medical examples.

> "It concerns New Zealand with all our horticulture and all that." [Kiwifruit sugar content]
>
> "It helps people to protect their property." [Burglar alarm]

There were some students (6) who were not interested in the medical examples. These were all boys.

> "Well it's really medicine and I'm not really into medicine."

Over all, students appeared very interested in those aspects of technological applications in which the helping of people could be directly observed.

2. Related to the students' environment

Another aspect of student interest was whether or not the technological applications were related to their environment, things that they could use or have observed.

"We have got one at school. Sounds pretty good detecting moving objects."

"... you could do it to your own house or something."

"Well you see them in the neighbourhood and you do not know how they work."

Or as was summed up by one girl;

"It's what is going on around us. So I think it would be quite interesting to know about it."

The devices in this category that tended to be related to our environment were the solar water heater, burglar alarm and the purity of water. There were 16 girls and 9 boys who commented that they were interested in certain technological applications because of the perceived relevance to their environment. Conversely those examples which did not relate to everyday life or the environment around them were not considered interesting by the students.

"I don't think it would have anything to do with me."

"It's not very appropriate to everyday life."

Girls appeared more concerned if a particular technological application did not relate to everyday life. Not only does their environment include the physical world around them but also other matters, such as subjects they study at school.

"It concerns us with horticulture. I like biology that type of thing."

"Well I'm doing that in geography at the moment."

Five students made reference to being interested in a device because they had seen it on television.

"I saw this movie where they had one and I thought that was pretty interesting."

"You see them on television and wonder how they work."

However just because a technological application is in the students' environment does not mean that they will necessarily be interested in learning about it. This appears particularly so for household items such as refrigerators and vacuum cleaners, which are placed at the bottom of the rankings (9 comments).

"It just keeps food cool."

"Because it's around all the time."

"Just taken for granted really."

This decreased enthusiasm may be because the students feel they know about these devices and they have no questions about them (9 comments).

"Well there are plenty of them and most people know how they work."

"It has already been done, explained."

Interest depended not only on whether the device related to their environment but also how it affected them personally (12 comments).

"Does not have any relevance to me."

"Probably because it does not have anything to do with me."

"It has not really got much to do with me."

The majority of the these comments came from girls (80%). The girls tended to refer more to themselves and their personal feelings. Often using the words `me' and `I'.

It became clear that devices such as vacuum cleaners and refrigerators are not interesting to the students because they feel familiar with them, and feel they do not need to know about them. In general however, students appeared to be interested in those devices which were in their environment, which involved both people and also had some new technological aspect.

3. Related to future careers and anticipated needs.

The interviews indicated that it was not just the students' present environment which may influence what they were interested in but also the students' perceived future environment. This included whether or not they will need that information for future careers or anticipated needs.

There were 14 students (8 girls and 6 boys) who mentioned career as a reason for being interested in a particular technological area.

> "I will be doing that quite a bit in the future I suppose."
>
> "I would not mind being a nurse. I reckon that would be good."
>
> "Probably in case I become a doctor or something."

Conversely there were those students who were not interested in certain areas of technology as they seemed to have little to do with their hopes for future employment (5 comments).

> "It could be (interesting) if you wanted to be an electrician or whatever but I'm not interested in refrigerators."

Interest in a technological application for some students depended on what they regarded as their future needs. Sixteen students commented that it may be useful to have that information for later in life.

"I will be using that in my future."

"In the future we will probably need that sort of thing."

The girls who commented seemed more concerned about the medical areas for later life and particularly linking them to children. Thus it appeared necessary that the students received useful and relevant information about technological applications for them to be considered interesting.

Those examples which students did not consider useful in later life were not thought to be very interesting (10 comments).

"Because I would hardly ever use it."

"Because it would not help me with anything."

Some students considered that there was no need to know about certain technological examples (11 comments).

"Do not really need to know about that."

"It is sort of more for a male."

"Indifferent I suppose. What is there to find out?"

4. Finding out how things work

Sometimes, technological devices of themselves may motivate the curious to find out how they work (23 comments; 16 boys, 7 girls).

"I was really interested in how it all works really."

"We have not got one but it would be interesting to find out how they work."

"You sometimes wonder how they work."

The devices put in this category tended to be placed lower on the 1-5 scale, usually around 3 (slightly interested), and included refrigerator, optoelectronic level indicator, solar water heater, etc. Of the 23 students interested in the actual operation of devices, only 7 were girls and these were concerned solely with the refrigerator.

Allied to interest in finding out how things work, is the need to be able to repair a device, particularly those in domestic use such as refrigerators and vacuum cleaners. The 'interest scores' in this category were again at the lower end of the scale (10 comments; 5 boys and 5 girls).

"Just in case it breaks down. Stuff like that."

"... because when I've got a house and my refrigerator breaks down I can fix it instead of getting someone else to fix it."

5. New technology and electronics.

The novelty of the technology involved was also an attractive feature to some (14 boys, 6 girls).

"I like the advances in medical science."

"How technology has advanced quite fast."

"I would be interested because modern technology is about new things that are happening."

It would appear that boys are more interested in new technology than girls. The girls talked about new technology with regard to the medical examples, but were more concerned about the people involved. For 8 students (7 boys, 1 girl), the interesting technology was electronic.

"I like putting electrical things together."

"The only stuff I like about that is the electronics."

6. Other reasons

Previous work has indicated that students enjoy doing experiments (Jones, 1982b). Twelve students indicated that they may be slightly interested if they could do an experiment with the device.

"Quite a good experiment."

"It would be quite a good experiment to do."

Fifteen students (11 girls, 4 boys) also indicated that for some examples they found them 'just boring' or were not interested.

"It was done in science and things. Not very interesting."

"I do not think that it is important to learn."

Some of the girls appeared to be more willing to admit that they did not find an example interesting.

Summary of the interviews

Generally fifth form students were interested in those technological devices which directly involved people with girls being more interested in medical applications, for example the apnoea mattress. Some aspects of the immediate environment (home, school, television) generated some curiosity, but domestic appliances did not. Girls were more concerned than boys about how a device would affect them personally.

An interest in understanding devices for use in future careers was evident, as was an interest in uses related to later life generally. Girls were more interested in medical examples for later life and specifically in things they felt they should know about for themselves or their future families. Those examples which were not considered relevant or useful to the student were ranked lower.

Boys showed greater interest than girls in both the operation and the novelty of the individual devices, as well as their use of electronics.

The devices that students were not particularly interested in were domestic and industrial appliances and those activities closely related to present school science.

4.4 RESULTS OF THE SURVEY

4.4.1 Data analysis

The survey was successfully completed by 496 fifth form (16 years) students. This total was made up of equal numbers of boys and girls. Equal numbers were used so that a 'rank sum test applied to grouped data'[2] (Bolstad, 1979) could be used to compare girls and boys interest. It was decided that this may provided a more accurate picture of gender differences than the Standardised Sex Difference test used by Smail and Kelly (1984) with its reliance on calculated means.

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2 For explanation, see Appendix G.

The percentage profile responses for each category[3] for the total sample and the separate boys and girls samples can be found in Appendix G. The mean, mode, and the percentage of responses that indicated `interested' and `very interested' was calculated for each question. To calculate the mean the different categories, `not interested', `not sure/indifferent', `slightly interested', `interested', `very interested', were given the values 1,2,3,4,5, respectively, with `slightly interested' tending to be the neutral point.

A mean interest level of greater than 4.0 would be considered to be `interesting to very interesting; 3.0-4.0, slightly interesting to interesting; 2.0-3.0, indifferent to slightly interesting; 2.0-1.0, definitely not interesting.

The level of interest fifth form students show in various devices and activities is shown in Table 22. The level of interest students show is ranked in decreasing order of the mean value. The mode indicates the most popular category indicated by the students. The percentage of those students stating that they were interested or very interested is indicated in the third column. Using the value of the mean and the percentage of interest shown appears to give a reasonable indication of the level of student interest.

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3 The complete question will not be repeated on the tables but rather key words will be used, e.g `How doctors tell if there is bleeding in the brain' replaced with `Cerebral bleeding'.

Table 22: Ranking of interest in technological applications.

	Mean	Mode	% Interest
Apnoea Mattress	3.73	4	67
Fibre Optics	3.59	4	66
Lasers	3.58	4	58
Motor Cars	3.55	4	57
Foetal Heart Beat Monitor	3.52	4	56
Cerebral Bleeding	3.51	4	56
Muscles	3.49	4	53
Microwave Oven	3.42	4	53
Burglar Alarm	3.30	4	47
Nuclear Powered Ships	3.25	4	52
Transistor Radio	3.20	3	44
Communication Satellites	3.17	4	46
Kiwifruit Sugar Content	3.14	4	46
X-ray Machine	3.13	3	42
Speed Detectors	3.08	3	39
Rainbows	2.97	3	37
Blood Flow	2.95	3	36
Purity of Water	2.81	3	29
How light bends	2.70	3	26
Microphone	2.67	3	24
Solar Water Heating	2.56	3	23
Gravity	2.55	3	22
Huntly Power Station	2.37	1	20
Refrigerator	2.36	3	13
Different types of energy	2.32	1	16
Vacuum cleaner	2.04	1	8
Forces on a moving object	2.03	1	11
Kiln Temperature	1.87	1	9
Kinetic Energy	1.83	1	7
Bicycle Pump	1.73	1	6

4.4.2 Interest Level

The devices' have been grouped according to the level of student interest in them. The first group of devices all recorded means greater than 3.3. They included medical applications and new technology in the students' environment. Students considered learning more about the apnoea mattress to be the most interesting technological application of those proposed. The apnoea mattress has a mean of 3.73 with 67% of the students indicating that they would either interested or very interested in learning about this device. The others in this group (fibre optics, lasers, motor cars, foetal heart beat monitor, detection of cerebral bleeding, muscles in the human body, microwave ovens) were all perceived as being interesting by over 50% of the students.

The second group of devices are those with a mean of less than 3.30 but greater than 3.0. The percentages of students interested in these devices is in the region of 40%. These devices (burglar alarm, nuclear powered ships, transistor radio, communication satellites, measurement of kiwifruit sugar content, x-ray machine, and speed detectors) are ones with which the students might be familiar within their environment. However they may not be seen to involve people directly and tend to be of the new technological type. From the interviews it could be assumed that students may be interested in how these devices operate. Almost a subset of this group are the 'rainbows' and the 'measurement of blood flow' which only 37-36% of the students found interesting.

The third group is different from the second in that it includes activities and events which relatively few students are interested in learning about. The level of interest in this group ranges from 29% to 6% of students indicating that they would be interested. In this group are industrial and domestic technological applications, and school science activities. The school science activities although all having a low percentage interest appear to form two distinct levels of interest. 'How light bends' (26%) and 'what gravity is' (22%) are distinct from 'different types of energy' (16%), 'forces on a moving object' (11%) and 'kinetic energy' (7%). Industrial examples (Huntly power station, measurement of kiln temperature) are seldom considered interesting by the students. None of the other devices (domestic applications) seem to arouse any significant level of interest.

Summary of the survey

The results of the survey agree with the interviews on student interest. Medical and modern technological devices related to people are considered interesting, whereas school and industrial based examples are considered to be uninteresting.

4.4.3. Sex differences

During the interviews it appeared that girls and boys gave significantly different answers for being interested in a particular technological device or activity (section 4.3).

To note any differences between the fifth form boys' and girls' interests in technological devices and activities the mean level of interest for each question was ranked in decreasing order, separately for girls and boys. Further differences were analysed using a rank sum test applied to grouped data. The rank sum test was designed to indicate the difference between girls and boys not just in terms of difference between the means but in the way they categorised each response on the 1-5 scale. One method of analysis does not give an accurate indication without the other. The rankings of the mean interest level for girls and boys can be observed in Tables 23 and 24 respectively.

The mean interest ranking tables indicate the difference in interest that boys and girls have in technological devices and activities. These mean interest ranking tables show that girls tend to be more interested in medical applications and have a high level of interest in aesthetic examples such as rainbows. Girls found modern technological devices (microwave oven, lasers and motor cars) the next most interesting. The boys however appeared to be more interested in the new technology (e.g. cars, lasers) than medical applications (apnoea mattress, fibre optics).

The devices and activities that scored less than 3 are rated similarly by boys and girls. However, the boys consider the 'measurement of blood flow' to be uninteresting along with the 'rainbow' whereas the girls ranked these highly.

The differences between the girls and boys can be shown more clearly in Table 25, using the analysis of the grouped data. A negative value indicates that girls are more interested whereas a positive value would indicate boys are more interested. A $|Z| > 1.64$ is significant at the 10% level (Bolstad 1979).

The girls appeared to be more interested in medical technology, biological and aesthetic aspects of physics. Boys appeared to be more

Table 23: Girls' ranking of interest.

	Mean	Mode	% Interest
Apnoea Mattress	4.22	4	84
Foetal Heart Beat Monitor	4.01	4	74
Cerebral Bleeding	4.01	5	73
Muscles	3.78	4	62
Fibre Optics	3.75	4	64
Rainbows	3.44	4	50
Microwave Oven	3.39	4	51
Blood Flow	3.38	4	51
X-ray Machine	3.33	3	47
Lasers	3.23	3	45
Burglar Alarm	3.17	3	39
Kiwifruit Sugar Content	3.15	4	44
Nuclear Powered Ships	3.10	3	36
Transistor Radio	3.07	3	38
Motor Cars	3.06	3	36
Communication Satellites	2.91	3	35
Purity of Water	2.80	3	25
How light bends	2.75	3	27
Speed Detectors	2.74	3	25
Gravity	2.56	3	21
Microphone	2.44	3	15
Solar Water Heating	2.30	3	12
Refrigerator	2.27	3	8
Different types of energy	2.15	1	13
Huntly Power Station	2.12	1	13
Vacuum cleaner	2.06	1	7
Forces on a moving object	1.87	1	8
Bicycle Pump	1.78	1	4
Kinetic Energy	1.67	1	4
Kiln Temperature	1.60	1	5

Table 24: Boys' ranking of interest.

	Mean	Mode	% Interest
Motor Cars	4.05	5	78
Lasers	3.95	5	72
Nuclear Powered Ships	3.56	4	63
Burglar Alarm	3.45	4	53
Microwave Oven	3.45	4	53
Communication Satellites	3.45	4	55
Fibre Optics	3.42	4	55
Speed Detectors	3.43	4	53
Transistor Radio	3.38	3	49
Apnoea Mattress	3.23	4	49
Muscles	3.20	3	44
Kiwifruit Sugar Content	3.12	4	49
Foetal Heart Beat Monitor	3.01	3	37
Cerebral Bleeding	3.00	3	38
X-ray Machine	2.92	3	36
Microphone	2.90	3	32
Solar Water Heating	2.84	3	35
Purity of Water	2.81	3	35
How light bends	2.66	3	15
Huntly Power Station	2.62	1	29
Gravity	2.55	3	24
Blood Flow	2.52	3	20
Different types of energy	2.51	3	20
Rainbows	2.48	1	22
Refrigerator	2.46	3	18
Forces on a moving object	2.19	1	14
Kiln Temperature	2.14	1	14
Vacuum cleaner	2.03	1	10
Kinetic Energy	1.99	1	12
Bicycle Pump	1.67	1	7

Table 25: Significant differences between girls' and boys' interest.

All significant at least at the 1% level using rank sum test applied to grouped data.

BOYS		GIRLS	
Solar Water Heater	(10.6)	Apnoea Mattress	(-16.2)
		What makes a rainbow appear	(-22.53)
Kinetic Energy of trolley	(8.8)		
Household Burglar Alarm	(4.2)	Fibre Optics (Medical)	(-4.65)
Transistor Radio	(4.05)	Foetal Hear Beat Monitor	(-16.02)
How motor cars work	(8.74)	Measurement of Blood Flow	(-17.85)
Nuclear Powered Ships	(8.30)	X-ray Machine	(-7.54)
Microwave Speed Detectors	(9.32)	Muscles in the human body	(-9.29)
Communications Satellites	(7.29)	Bleeding in the brain (detection)	(-17.54)
Kiln Temperature	(14.13)		
How a microphone works	(7.64)		
Huntly Power Station	(9.79)		
Forces on a moving object	(7.55)		
Different types of Energy	(8.43)		
How lasers work	(5.98)		

No Significant Differences	
Vacuum cleaner	(-1.4)
Purity of water	(0.05)
Sugar content of kiwifruit	(0.55)
Microwave oven	(0.82)
What gravity is	(-0.47)
How light bends	(-1.74)
Refrigerators	(1.4)
Bicycle pump	(-1.85)

interested in the technical type devices. Although neither girls nor boys appeared interested in 'school physics' type examples or 'industrial applications' there was a significant difference in that boys were more positive about them. This analysis also indicated that any interest girls do have in something was likely to be more unqualified than that which boys displayed. This was shown by the high value of some of the grouped data analysis e.g. What makes a rainbow appear (-22.53) whereas the boys scores tended to be ranging from 4-10. The areas where there did not appear to be significant differences were the more routine technological applications, such as two domestic appliances and two areas of physics which examine aspects of nature.

4.5 GENERAL SUMMARY AND CONCLUSIONS

The interviews and surveys have proved useful for discovering students interests in technological applications. The interviews elicited the reasons why students were interested or not interested. The trends shown in the interviews were similar to those in the surveys.

The general findings suggested that:

1) students were generally interested in technological applications which directly involved people.

2) students, particularly girls, preferred those examples which were medical applications.

3) students, particularly boys, were interested in modern

technological devices.

4) students also were interested in technological devices within their environment e.g. home, school, society.

5) there were sex differences in what students prefer to learn about and these need to be taken into consideration when developing teaching programmes.

6) students did not appear interested in domestic appliances apart from new technology e.g. microwave ovens.

7) students did not appear interested in remote industrial applications.

8) students generally did not appear to be interested in `school physics' type activities.

9) boys were more interested than girls in the more technical aspects of devices, especially how they operate and their use of electronics.

10) students were interested in those devices which corresponded to their intended careers and anticipated needs.

CHAPTER 5

TEACHERS' VIEWS OF PHYSICS EDUCATION AND TECHNOLOGY

5.1 INTRODUCTION

This section of the study investigates the approach of teachers to teaching physics in the senior secondary school and their reactions to the introduction of technological applications. The previous sections (Chapters 3 and 4) of this study have indicated that students may react positively to the introduction of particular technological applications into the physics classroom. It was also considered important for teachers to show students the relevance of school physics to today's society (Bondi, 1975). However, physics teachers may be reluctant to introduce a technological perspective (section 2.5.5). The teachers' views of school physics and the introduction of technological applications were explored through interviews and surveys.

5.2 METHODOLOGY

The methodology for exploring teachers' views of physics education and technology was similar to that used in Chapters 3 and 4. Initially, teachers' ideas about the teaching and learning of school physics were explored through interviews. A survey based on information thus gained was developed specifically to investigate teachers' reactions to the introduction of technological applications.

5.2.1 Interviews

The interviews used in this section of work were not as structured as those used for the students (see section 3.2). A general outline of the interview schedule can be seen in Table 26. The interview consisted of three distinct phases of enquiry: (i) A general overview of the teaching of secondary school physics, (ii) The emphasis on experimental work, (iii) The use of technological applications in the classroom.

- Interview Sample

The 12 teachers in the interview sample were those who taught the 60 pupils who were interviewed on their perceptions of physics (see Chapter 3). The teachers were mainly from large (1200 pupils) co-educational schools in urban areas, and their teaching experience ranged from just over two years to 30 years. The sample consisted of two women and 10 men.

- Interview Procedure

The procedure consisted of audiotaped discussions with the teacher during a non-contact period in the day or at lunchtime. These were later transcribed with the consent of the teacher. The prepared schedule was used as a rough guide only as the teachers talked freely, the interviewer interrupting to clarify points or to ask further questions.

Table 26. Teacher interview structure.

1. Can you give me a very general overview or picture of how you teach 6 form Physics.
    - Lecture
    - Demonstrations
    - Homework
    - Problems
    - Internal examinations
    - School constraints
    - Society's needs and expectations
    - Pupil/Parent needs and expectations
    - Syllabuses

2. What experimental work do you do? Do you do much experimental work?
    - How important do you see the role of your type of experimental work in the physics syllabus?
    - Light relief for pupils
    - Pupil enjoyment
    - Validation of theory
    - Manipulation of gear
    - How often do you do experimental work?
    - What are your experiments designed to show?

3. Use of examples, applications and illustrations to show how school physics applies/relates to the outside world.

    (a) The illustrations I am interested in are these sorts of things.
        i) How desirable/useful are these do you think?
        ii) Do you know if teachers introduce these types of illustrations?
        iii) What constraints are there? Time, exams, pupils, etc.
        iv) What form should they be in?
        v) Where do you place the emphasis on applications at the present time?
        vi) What are the difficulties you have in introducing applications?

    (b) i) Have you heard of the book P.A.W.N.Z.[5] ?
        ii) Do you have a copy and do you use it?
        iii) If so, how do you use P.A.W.N.Z.?
        iv) How could it be more effectively present and used?

    (c) How could further illustrations/applications be introduced?

        i) Exam questions
        ii) Video tapes
        iii) Experiments
        iv) Illustrations for lectures, O.H.P. transparencies
        v) Demonstrations

SYLLABUS - Have you any views for the rewrite of the 6th form syllabus?

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5 *Physics at Work in New Zealand* (Jones, 1982a)

5.2.2 Surveys

The surveys were developed directly from (a) the results of the interviews with the teachers, and (b) a trial survey administered to teachers who had attended a national physics teacher refresher course. The administered survey which is contained in Appendix H was compiled and sent out in conjunction with the Auckland Science Centre who published the teacher resource book *Physics at Work in New Zealand* (Jones 1982a). The survey consisted of four distinct sections.

Section 1 was designed to find out the participants' academic qualifications and length of teaching service.

Section 2 consisted of eight statements made by teachers in the interviews about technological applications. The participants could respond to these statements on a 1-5 Likert type scale with stems of strongly disagree to strongly agree. There was also room for the participants to comment on their responses. Included in the survey were three examples of what was meant by technological applications. These were from *Physics at Work in New Zealand*.

Section 3 was designed to explore how often teachers introduced technological applications into their lessons, the resources they used and what was required to encourage teachers to use technological applications in the teaching of school physics.

Section 4 was an evaluation of the book *Physics at Work in New Zealand*. This section explored the perceived usefulness of the book, its level of difficulty, modifications required, and the relationship of the book to the syllabus and existing lessons. It also investigated the type of support material teachers would like if they wanted to introduce technological applications.

- Survey Sample

A postal survey was undertaken in which a form was sent to approximately 80% of the secondary schools in the country. It was addressed to the Head of Physics. A covering letter from the Science Centre explaining the nature of the survey was included, jointly signed by the Director of the Science Centre and the researcher. Two hundred and four completed questionnaires were received (a response of 67%).

The background information revealed that the average respondent had been teaching physics for 11 years. Thirty-nine percent had been teaching for more than 10 years. The physics academic background of the respondents can be observed in Table 27.

Table 27: Physics background of questionnaire respondents.

None	Stage 1	Stage 2	Stage 3	MSc/BSc(Hons)
7%	24%	25%	26%	18%

The major subject of study at the tertiary level undertaken by the respondents is shown in Table 28.

Table 28: Major subject of study at tertiary level (teacher).

	%
Physics	37%
Mathematics	22%
Chemistry	20%
Biology	9%
Engineering	8%
Geography	2%
Social Science	2%
None	0.5%

There were some respondents who had studied engineering who indicated that they had studied physics to a stage 3 level, as did some mathematics graduates.

This information suggested that the majority (63%) of the physics teachers in New Zealand are not physics graduates but 69% have studied physics to at least second year university. These figures are consistent with other research in the area of qualifications of physics teachers (for example, Osborne, 1973, 1981b).

5.3 RESULTS

The results of the interviews will be presented followed by the results of the nationwide questionnaire.

5.3.1 Results of the interviews[1]

The teachers who were interviewed all had a similar format for teaching senior secondary school physics. The format appeared to be a lecture style introduction of the concept (transmission teaching), followed in some cases by a demonstration, theoretical problems and occasionally a student experiment.

> "Implicit in any physics (teaching) is the scientific method. Theory-practical-problems."
>
> "Lecture and demonstration."
>
> "Give a lecture which will introduce the hypothesis which will be verified by doing experiments."

The textbook and/or the syllabus was closely followed by the teachers.

> "Follow very closely Advanced Senior Physics (text book), basically we open together on the same page and we read together."
>
> "In general I stick to the text, we say 'right', the objectives of this chapter are ... these sections are not necessary for the exam so you can forget them."
>
> "We are very much bound by the syllabus."

It appears that in the senior secondary school the external exam structure dictates the approach adopted by teachers for the teaching and learning of physics.

> "This school is exam oriented so we tend to teach theory-experiment-problems."
>
> "In the third term out come the old exam papers and we grind through those and it gets good marks."

---

1 The general ideas are reported rather than idiosyncrasies.

"Mainly give bursary (exam) type problems."

The teachers who were interviewed all commented on experimental[2] work in the teaching and learning of physics. The experiments carried out by the students were mainly validation of some previously taught theory, and some experimental techniques.

"Designed to show the application of scientific method."
"Designed to show that experiments have a theoretical backing."
"... are the results what you expect from the theory, but the real objective has to be head knowledge."
"To show that they can clearly demonstrate that they have got it in their head."
"Just the experimental technique is important. I think you can teach Newton's law in two minutes. You don't need to do a 2 period experiment."

The experiments that the students were required to do tended to be ones where the instructions on all aspects of the experiment were given.

"They (students) are given a set of instructions with a bit of theory and they go through the experiments, they do it and that's it."
"I basically say this and this and put the equipment in front of them."

---

2 In their comments teachers tended not to distinguish between investigations, demonstrations, practical exercises, projects etc.

"The experiments are pretty much cooking book sorts of things."

Apart from doing experiments to develop scientific skills and validate theory some teachers thought that experiments also made physics interesting. In section 3.4 it was noted that the students also thought that one interesting aspect of physics was the experiments.

> "... one of the reasons for doing experiments is to make physics more interesting."
>
> "... very important for increasing the interest."

Many (44%) of the students who were interviewed in Chapter 3 equated physics with mathematics (Section 3.4.1). Teachers were not asked specifically about the mathematics in physics but eight did comment on the mathematics.

> "A piece of physics we leave to the mathematicians is calculus. That's superb physics ... sure, some of it is hard."
>
> "I think physics is mathematics."
>
> "I spend a lot of time on simple mathematical concepts. Mathematics is the hardest part of physics."

It appeared from talking with the teachers that their ideas and methods of teaching were reflected in their students' perceptions of physics (see Chapter 3). It was evident from the student interviews that students did not generally perceive physics as being relevant to the world outside of the classroom. Teachers were asked if they used examples of technological applications of physics principles in their teaching. The teachers' comments indicated that technological applications were not introduced very often.

"I sometimes point them out from my own experience, just recall from memory ... but I can't always think of one. I am paid to teach the syllabus so I do that."

"I might use them as examples but pupils are very exam oriented."

"I try to encourage them to read about holograms and space habitats."

"Applications are good only if they are meaningful to the teacher."

The reasons teachers gave for not introducing technological applications were the factors of:

(i) Time

"We are stuck with problems of time."

"Time is a major constraint."

"It takes too much time to go into industrial applications."

(ii) Too large a syllabus

"Lots of pressure to get through the year."

"The syllabus itself, there is too much to do."

"It's not in the syllabus really."

(iii) The teachers' perceptions of school physics

"Unless it's directly in the syllabus we would have trouble justifying it."

"The emphasis should be on pure physics."

(iv) Examination structure

"I place no emphasis on applications ... I want to be fair to the kids to get bursary."

"We can't spend two periods on something that's not in the exam."

It appeared that it would be difficult for technological applications to be introduced into the present structure of school physics. Another reason why applications may not be introduced may be because of what society and parents demand of physics teachers. Society's expectations of school physics may be reflected in the teachers' comments rather than teachers' individual views of the subject. For example, the emphasis is on pure physics because it is in the examinations, which society uses as a measure of understanding of the subject content.

Teachers did, however, think that there may be some benefit to the students if technological applications could be introduced.

> "I would see it more as a hook to get them interested."
> "I think it makes it (physics) more alive."
> "I think applications are very important otherwise it (physics) just sits in a vacuum of its own."

However, even though some teachers thought technological applications might be useful in the teaching and learning of physics, they did not introduce them for syllabus, examination and personal reasons indicated earlier. As one teacher stated:

> "During the year we are a bit pushed for time and so I leave some of the interesting things until the end of the year."

In 1982 a teacher resource book *Physics at Work in New Zealand* (Jones, 1982a) was produced which contained 85 specific applications of secondary school physics. This book was written to overcome the lack of resource material in this area. Teachers had previously stated that the lack of such material was one of the reasons for not introducing technological applications (Jones, 1982b). Since a resource now existed it would be useful to evaluate the use of it by teachers. Of those teachers interviewed, all but one had a copy of the book. Even so, they did not use it in the classroom.

> "I haven't used it ... It's only for the ones that really show an interest."
>
> "I haven't used it ... It's the sort of thing you buy thinking that it's a good idea and you put it on your shelf and you leave it there all the time."

It did not appear easy for teachers to incorporate technological applications into their existing physics lessons.

> "It's good reference material but it's something extra you have to look at."
>
> "It will only be taught by teachers who have an interest in that direction. I don't see how we could use it."

5.3.2 Results of the Survey

The survey consisted of Likert scales and space for written comments. Ninety-six percent of the respondents made some sort of written statement on their opinions about the introduction of technological applications and the resource book *Physics at Work in New Zealand* (Jones, 1982a) although not every teacher commented on every aspect of the survey.

Teachers' responses to the introduction of technological applications are shown in Table 29. Teachers generally indicated that students need to know about technological applications to understand physics and strongly agreed technological applications help students to be more interested in physics. However they felt both that there was not enough time to introduce technological applications in the 6th and 7th form physics course and that there was a lack of good examples of technological applications available. The respondents disagreed slightly that there was too much extra work required to introduce technological applications. Opinion was divided as to whether the topics in the present syllabus meant that technological applications were difficult to introduce, however they rejected the suggestion that applications should not be introduced because they were not in the examinations. These results appeared to be consistent with the comments made in the interviews that the introduction of technological applications might be a good idea but there were too many constraints. The comments teachers made for and against the introduction of technological applications are shown below.

Reasons against the introduction of technological applications

(i) Teachers wanted to just teach pure physics (28 comments).

> "I suggest that technological applications only have a minor place in the development of physics as a science."
>
> "I feel we must not disadvantage the brilliant student. Let's keep all the beautiful theory."
>
> "The basic syllabus is an excellent basis for university work. I don't consider that more use of technological examples in teaching is necessary."

Table 29.

Teacher responses to the introduction of technological applications.

	Item	1 (Strongly Disagree)	2	3	4	5 (Strongly Agree)
2.1	"Students need to know about technological applications to understand physics." mean = 3.2	7	18	25	38	12
2.2	"Technological applications are difficult to introduce because of topics in the present syllabus." mean = 2.9	12	16	28	26	7
2.3	"There is not enough time to introduce technological applications." mean = 3.5	5	19	18	39	19
2.4	"There is no point in introducing technological applications because they are not in the exam." mean = 1.7	54	26	10	7	3
2.5	"There is too much extra work required to include technological applications in my teaching." mean = 2.7	15	26	38	15	6
2.6	"Technological applications help the students to be more interested in physics." mean = 4.3	3	·5	5	39	49
2.7	"There is a shortage of good examples of technological applications available to teachers. mean = 3.7	5	11	22	39	23
2.8	"Technological applications of physics are really covered in experimental work." mean = 1.99	26	55	12	4	2

(Values in %.)

(ii)Teachers lacked the confidence to introduce them (6 comments).

"There are many teachers of physics who have insufficient background."
"If I had been teaching for longer I would have had a chance to use and accumulate that sort of knowledge."

(iii)The lack of resource material available (8 comments).

"More resources must come first."
"Lack of good resource material and the relatively few applications in New Zealand industry make the teaching difficult."

(iv)The present examination structure and the current syllabus created difficulties (24 comments).

"Our teaching history has been based on examinations and the syllabus."
"There is a problem in spending time or technological applications beyond just mentioning them. The current course requires the entire year to complete."
"Pupils seem to shy clear of this material as irrelevant to the exam course."
"It's a matter of getting out of a rut."

(v) The problems of the potential extra demand on preparation and teaching time (23 comments).

"There is no time to do that."

"Time can be a limiting factor."

"Personally the introduction of technological applications introduces more work into my teaching load and it is not always possible because of the time restriction."

In summary the reasons teachers gave against the introduction of technological applications were: (i) their own personal view of physics, (ii) lacked the confidence, (iii) lacked adequate resources, (iv) the constraints of the examination structure and current syllabus, (v) the extra demand on preparation and teaching time. However, the current school physics teachers' guides (Department of Education, 1972,1973) do suggest that applications should be introduced but no guidance is given as to how this might be best achieved.

Reasons for introducing technological applications into the classroom

Technological applications were seen as desirable in the teaching and learning of school physics by some teachers (15 comments). Some of these respondents were attempting to use them in their classrooms.

"Physics is a practical subject. It should be taught and tested with its application to modern technology."

"Every opportunity to introduce these puts our teaching in perspective."

However, one of these teachers saw this as additional to the teaching of physics, rather than as part of it.

"It takes up a minimum of class time and the students appreciate the short breaks in the lessons that these asides are."

Although there might be the difficulties in introducing technological applications these applications did increase the interest and relevance of physics for students (37 comments).

"It must be obvious to all teachers that if they can demonstrate that some of the work covered is actually useful in its own right then it will be more easily accepted by the pupils."

"To provide interest so that it reinforces concepts."

"For interest's sake the emphasis should be on the applications and bringing them into the classroom to learn the theory behind them."

In summary, it would appear that applications are considered by the teachers to be of relevance and interest to some of the students but there were still major constraints in their introduction. The majority of written comments were against the introduction of technological applications, although the scales indicated teachers may consider their use. The comments made by the teachers in the survey were similar to those in the interviews.

Frequency of Technological Applications in Classroom

Section 3 of the questionnaire enquired as to the frequency with which technological applications were introduced and investigated what might be effective methods of encouraging the classroom use of some such examples. Table 30 indicates how often teachers employed technological applications in their teaching.

Table 30. Frequency with which technological applications are introduced in the classroom.

	Not at all	Once a week	Once a fortnight	Once a month	Once a term	Once a year	Uncertain
F6	7%	23%	22%	24%	9%	5%	9%
F7	7%	22%	23%	24%	8%	6%	9%

It would appear that the majority introduce technological applications during the course of the year. However, 75% introduced such examples at a frequency of once a fortnight or less which means that these students would be exposed to a technological application for, at most, one period in ten. This amount of time would be unlikely to show the relevance of physics to the student or encourage links between school physics and the students' world. This scale did not distinguish those who introduced them more than once a week. However, from the trial and the interviews there appeared to be very few in this category. The reasons given by teachers for not introducing technological applications more often have been stated previously. The main reasons given by teachers for introducing applications fortnightly or even more frequently, were for student interest, understanding and relevance. Others (16) admitted they would use more applications if further resources were made available.

Effective ways of encouraging the use of technological applications

Developments that are seen to be the most effective in encouraging the classroom use of technological applications are shown in Table 31. Teachers suggested that the provision of adequate resources would be the most effective way of encouraging the use of technological

Table 31.

Most effective way of encouraging teachers to use more modern technological examples in their teaching.

		%
Clear indication from physicists that such an approach is desirable.		30
Change in syllabus emphasising this approach.		51
Provision of resources based on such examples.		
e.g.	O.H.P. Transparencies	73
	Students readers	57
	Videos	78
	Student workbook	44
	Teacher guide material	82
	Assessment items	37
	Greater emphasis on applications in examination questions.	36
	In-service courses.	61
	Visits by science advisers.	34

applications. The most useful resources appeared to be Guide Material 82%,[3] Videos, 78%, and Overhead Projector Transparencies, 73%.

"What we need is material at the ready to be used from day to day in the classroom situation."

"You have to have really good resources to make this work, I think."

"Any resources are most useful particularly if prepared with worksheets or exercises included. Well designed short videos (10-20 minutes) with associated worksheets for students and O.H.P's are also useful."

Student material such as student readers 57%, student workbooks 44% and assessment items 37%, appeared to be less popular. The establishment of in-service courses emphasising the introduction of technological applications were considered useful by 61% of the respondents. Only one teacher commented.

"A properly constructed inservice course where all the resources are available for acquisition plus further information on available resources would be a far better way of encouraging the introduction of New Zealand technology."

A change in the syllabus was considered by 51% as being an effective method of encouraging the use of more technological applications of physics in the classroom.

"The syllabus would need to change to provide time for this kind of approach."

"The only sure way to introduce anything is to put it in the exam."

"Greater emphasis in exams only if this is accompanied by available resources for the physics teacher."

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3 Respondents could choose more than one category.

A clear indication by physicists 30%, visits by science advisors 34%, and a greater emphasis on applications in examination questions 36%, were not considered to be such important factors in implementing change.

The comments tended to indicate that teacher support material was generally required for more technological applications to be introduced into the physics classroom. It appeared that as well as more emphasis in the syllabus for this approach there needed to be adequate resources that could be used directly in the classroom by the teacher rather than used solely by pupils.

Evaluation of Existing Resources (*Physics at Work in New Zealand*)

Teachers' reactions to existing resource material may indicate further why teachers generally do not introduce technological applications. Of the 207 who responded to the questionnaire, 112 had a copy of the resource book, *Physics at Work in New Zealand*. Table 32 indicates the way they used the book. For most, the book was used as a teacher reference (79%) with 35% having a personal copy. Six percent of the schools had a copy in the library and 3% had a class set.

Table 32.

Distribution of copies of *Physics at Work in New Zealand.*

	%
In the school library	6
As a class set	3
As a class textbook	1
For teacher reference	79
As a personal copy	35
Class reference	3
No response	3

The teachers' reactions to the resource book can be observed in Table 33. They considered the resource book to be reasonably useful (mean of 3.33). Those who did not regard it as useful (i.e. scored 1 or 2, 21%) commented on the syllabus and time constraints.

"Because time, nature of our kids etc, precludes too much emphasis with topics not directly examined by the syllabus."

"Because of the demands of the traditional syllabus."

Thirty-one percent of the teachers appeared to be neutral about its usefulness (i.e. scored a 3). Their comments covered a variety of reasons such as the problems of time and syllabus, the limited nature of its examples and students' apparent lack of interest in it.

"Students are not attracted to it."

Table 33. Teachers' reactions *Physics at Work in New Zealand.*

How useful do you consider it in your teaching? mean = 3.33

%

	1	2	3	4	5	
Not Useful	9	12	31	34	14	Useful

How would you rank the difficulty level of the examples in the book?
For teacher understanding. mean = 4.14

%

	1	2	3	4	5	
Difficult	1	1	22	42	43	Straightforward

For pupil understanding. mean = 2.8

%

	1	2	3	4	5	
Difficult	7	32	36	20	4	Straightforward

How well do the examples in the book relate to each topic in the syllabus? mean = 3.48

%

	1	2	3	4	5	
Don't relate	2	13	31	45	10	Relate well

How easily do the examples in the book fit into your lessons? mean = 2.93.

%

	1	2	3	4	5	
Not easy	11	23	30	33	3	Easy

Those who considered the book to be useful (i.e. scored 4 & 5, 48%) gave reasons such as its value as a source of relevant applications.

"Gives physics more relevance to the society we live in."

The book was considered to be easily understood by the teacher but could be difficult for pupil understanding. The teachers who indicated that the examples in the book related reasonably well to the syllabus still felt time was a major problem.

"Problem is finding time to make the operation clear."

There appeared less certainty on how easily the examples could be incorporated into physics lessons. Those who tended to be neutral about how well applications related to the syllabus commented on the time factor, the amount of extra preparation, and did not consider they fitted with the emphasis of school physics e.g. emphasis on theory. Again those who indicated that the applications did not relate to the syllabus repeated the constraints mentioned earlier.

The amount of modification perceived as being necessary to the book *Physics at Work in New Zealand* appeared to depend on the individual's view on the teaching and learning of school physics. Table 34 indicates the responses to the amount of modification required. Overall, teachers considered that some modifications were necessary.

Table 34

The modification required to *Physics at Work in New Zealand*.

	%					
Considerably	4	20	29	37	10	Not at all
	1	2	3	4	5	

Twenty-four percent indicated that the material had to be considerably modified. The comments indicated that (i) the material was not incorporated into lessons and (ii) it was considered too difficult to incorporate.

> "Not used in class. Not suitable for the development of physics concepts."
>
> "Most of my students will be following careers in medicine, teaching, nursing and at this stage are not interested in technological applications."

The group who indicated three on the scale tended to comment more on how they incorporated the examples into their lessons.

> "Put into my own and class language."
>
> "Often I will gloss over the material leaving out much/most of the matter."

By way of contrast, those who indicated a 4 or 5 were more positive about the introduction of technological applications, although some modification of the resources was still required.

> "It would be useful to have one or two open questions with each example."

The teachers who had a copy of the book *Physics at Work in New Zealand* indicated that they would like support material (Table 35) in the form of student workbooks 55%, students readers 68%, overhead projector transparencies 69%, and, the most popular, videotapes 80%.[4] The single most important resource desired was the videotapes 47% and overhead projector transparencies 27%. Overall, it appeared that many teachers have bought the book but its impact in the classroom has been limited. Resources need to be produced which can be used directly by the teacher and the students in the classroom.

Table 35. Teachers' interest in using support material based on examples from *Physics at Work in New Zealand*

	%	Most Important
Student readers	68	12%
Student workbook	55	14%
Videotapes	80	47%
O.H.P. Transparencies	69	27%

5.4 SUMMARY

The students who have been interviewed and surveyed (Chapters 3 and 4) appeared to be supportive of introducing technological applications into senior secondary school physics. This part of the study has been useful in exploring teachers' reactions to technological applications.

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4 Could choose more than one option and then indicate the single resource they would like.

Interviews

The teachers who were interviewed (12) all had similar approaches to the teaching of physics, they all followed a format of a lecture style introduction, occasional demonstration, theoretical problems and student experiments. The experiments they introduced tended to be validation of the theory taught, and precise instructions were given. The lessons were dominated by theory and the pressure of the syllabus and examinations exerted a major influence. The mathematical language of physics was emphasised. Technological applications were hardly used. Although the teachers perceived some benefit in the introduction of technological applications, they did not put this into practice because of the following factors; not enough time, too large a syllabus, their perceptions of school physics and the present examination structure. Their views of school physics appeared to be consistent with the responses of the students who were interviewed about school physics (see section 3.4).

Surveys

With the survey data, it was difficult to explore what the teachers actually did in their classrooms. However, the survey did provide some insights into teachers' opinions about the introduction of technological applications.

Generally they felt that technological applications would assist students to become more interested in physics and may even help in terms of relevance and understanding. However, they felt there were often insurmountable obstacles in that there was insufficient class time, the syllabus was already too large, the present emphasis on examination allowed for no distractions, technological applications were not emphasised in the syllabus, and that there was a lack of serviceable resources. In addition, many simply thought that pure physics alone should be taught. Many teachers were opposed to this approach and others lacked personal knowledge and confidence. As a result it appeared that it would be difficult to encourage the majority to introduce applications with their classes. Physics teachers generally did not introduce technological applications very often. It was suggested by the teachers that the provision of resources would be the most effective method of encouraging the use of technological applications. The resources should be ones that they could use directly in the classroom. However, from the teacher comments it would appear that until there is a change in the length and emphasis of the syllabus and examination structure, there is unlikely to be any change.

Although teachers have been keen to obtain previously produced resource material, its impact has been limited because of the aforementioned constraints. However, some teachers have found it useful in their classrooms. These teachers appeared to believe that applications did provide interest and relevance for the students.

CHAPTER 6

DEVELOPING A PHYSICS AND TECHNOLOGY PROGRAMME

6.1 OVERVIEW

The previous chapters have explored students' perceptions of physics, their reactions to the introduction of technological applications, student interest in physics and technology, and teachers' reactions to the introduction of technological applications. This chapter further examines aspects of physics teaching, particularly the introduction of technological applications (section 6.2), and develops a new perspective for the teaching and learning of school physics. This new perspective is applied to two teaching packages (section 6.3).

6.2 INVESTIGATING EXISTING TEACHING APPROACHES

6.2.1 Introduction

This section of the study was designed to explore what the students focused on in physics lessons, whether the focus was different for different physics lesson formats, and in particular what they could later recall of the lesson. It was not intended that this would be an experimental-control type investigation but rather a tentative exploration of students' responses to technological applications in the classroom.

Chapter 2 noted that there were at least two different approaches to the introduction of technological applications. The first involved teaching the scientific concept then introducing the technological application at the end of the lesson. Technological applications have traditionally been introduced after the teaching of the physics concepts and have consequently been used as examples. What students remembered from this traditional approach may give some indication of its effectiveness. The second approach was to start the lesson or topic with a technological device which illustrated a chosen scientific concept. This section investigates both approaches and assesses their potential for developing links between school physics and the students' existing knowledge.

Students' reactions to the possible introduction of technological applications were explored through classroom observation and student interviews. It was not the object of this study to review classroom based research. This has been investigated by a number of researchers. For example, Tawny (1976) recognised that the most valuable data can be informal and discussed evaluation in terms of the collection and use of information to make decisions about an educational programme. Renner, Abraham and Birnie (1985) used naturalistic research methods in selecting and interviewing a small sample of students about activities they had been exposed to in a physics classroom. Similar work has been carried out in science classrooms in New Zealand by Osborne *et al.* (1979) and Tasker and Osborne (1983).

6.2.2 Methodology

The classroom observation consisted of observing five (3 sixth and 2 seventh form) physics classes, at the same school. Each of these classes had the same teacher who used a variety of teaching strategies with all the classes. Having three classes at the one level and two at another meant that the same applications could be introduced in different ways at different times during the day, by the same teacher. It was hoped that this would limit the potential variables such as the time of the lesson, i.e. whether it was the first or last period, and also the different students involved. It was decided to interview the students in the classroom the day after a particular lesson. The students were generally interviewed individually but sometimes in groups of up to three students. The interviews tended to be informal. Both the lessons and informal interviews were audiotaped and later transcribed for analysis.

- Procedure

Over a period of 10 weeks the teacher agreed to adopt different approaches to the teaching of the physics and these would be recorded. The next day students were interviewed about the lesson. A very simple interview procedure was used. A foundation question was asked;

"Can you tell me what you did last lesson?"

"Can you tell me a little more about that, etc?"

The remainder of the interview (lasting 10-15 minutes) then probed that individual student's response. Every student in the five classes was interviewed at least once. The 10 week period was chosen to allow time for, firstly, establishing what students remembered from each type of lesson and, secondly, for the development of a rapport between the researcher, teacher and students, prior to the introduction of the two teaching packages.

- Background to the school

The school involved in these observations and interviews was a large co-educational school (1650+ students) situated in a metropolitan area. The teacher had 13 years teaching experience, had an honours degree in physics with a further degree in philosophy and education, and was considered by his peers to be an expert teacher. The researcher's observations and the teacher's comments showed that his typical lesson format was 'traditional', e.g. theory, problems, and some student experiments (one per topic). The teacher felt he had achieved a good teaching programme and method, but was sympathetic to the development of new approaches to the teaching of physics and to having an observer/researcher in and out of his classroom for almost six months. Apart from two Indians, the students were of European ethnic origin.

- Lesson structures

There were five different lesson structures used apart from those lessons where just theoretical problems were attempted or completely experimental lessons. The basic structure of the lessons are shown in Table 36.

Table 36: Five different lesson structures used in a physics classroom

TYPE 1 LESSON

Time allocated	Lesson structure
5%	Demonstration
60%	Theory[1]
10%	Demonstration
25%	Applications

TYPE 2 LESSON

Time allocated	Lesson structure
56%	Theory
16%	Demonstration
29%	Theory/problems

TYPE 3A LESSON

Time allocated	Lesson structure
40%	Theory
25%	Application (no introduction)
35%	Theory/Problems

TYPE 3B LESSON

Time allocated	Lesson structure
30%	Theory
35%	Application (with introduction)
35%	Theory/Problems

TYPE 4 LESSON

Time allocated	Lesson structure
20%	Application
46%	Theory/Discussion
34%	Theory/Problems

Each lesson structure was used with three to five separate classes. These different types of lessons came about in attempting to find the most effective way of introducing technological applications. It was decided not to use dramatic attention-getting applications but rather ones that were already available to physics teachers in textbooks or in the teacher resource book *Physics at Work in New Zealand*.

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1 Development of theory includes teacher questions, pupil answers, clarification and problems.

6.2.3 Classroom results

The student responses to type 1 lessons (applications were introduced at the end of the lesson) indicated that they considered it a typical lesson format. This was despite the introduction of medical technological applications, which the teacher stated he did not usually include. When asked what they had done the previous day the students tended to focus on the formulae the teacher had introduced even though it amounted to only about 20% of the theoretical development.

> "He differentiated the formula with mass and gave us acceleration, and velocity and force."
>
> "The centre of mass equations. Finding it....we had all the basic equations and we derived them from there."

Three students out of the eighteen interviewed the next day did remember the final demonstration (air table) after a lengthy discussion. None commented on the demonstrations at the beginning of the lesson (showing the centre of mass of different shaped objects).

> "...we did that demonstration on the air table."
>
> "It was interesting to see how it worked but it was not that important...he did not need to show it...it will not affect how well we do in the exam, having seen the air table."

None of the students commented on the applications that the teacher had introduced at the end of the lesson even though they amounted to 25% of the lesson time. The teacher commented that he was very surprised that the students had not recalled the applications as he thought they would be interested in them.

In the second type of lesson, a new physics concept (e.g. cross product to find the torque and 6th form optics) was introduced and then the teacher carried out a demonstration. The majority of the students could remember the theory (formulae) but had difficulty in applying it to the demonstrations (cross product to explore the torque in opening a door).

They appeared to relate their previous years' physics ideas (moments) to the demonstration rather that the new theory which was supposed to be an extension of those ideas. Their inability to link the theory to the demonstration meant they memorised a series of rules which they then applied inappropriately to the demonstration. This was discovered in the interviews when they were asked to explain the use of the theory and the demonstration.

> "If something is accelerating that way another is accelerating that way and you wanted to find the direction of the force you would multiply the acceleration together."

> "If you have a screw driver, the longer it is the easier it is to turn."

However they were able complete the theoretical problems that had been set. When asked if their inability to apply the theory to the demonstrations concerned them, they stated:

> "I like just remembering the formula because that is easier."

> "You do not have to understand anything you only have to know which number goes where."

> "The equations make it easier to work out rather than thinking about the actual situation."

However two of the students who were interviewed were able to relate the theory to the demonstration.

In the third type of lesson (type 3a) the technological applications were introduced as numerical examples of various concepts. There was no introduction or explanation of where and how the device was used, it was presented as a typical physics problem. The students tended not to remember the applications but rather just the theory.

"Just a typical physics lesson with the theory and problems."

"We just learnt how light passes through different lenses."

"We went over the formula and learnt that."

They were able to successfully carry out theoretical problems set by the teacher.

When the applications were introduced with some background information and class discussion in the middle of the lessons (type 3b), students remembered the applications after they had spoken about the theory or were asked if they were shown any uses for physics. These were the same applications that had been used in type 1 and 3a lessons. Fifty percent of the students appeared to find difficulty in remembering the applications.

"I do not know, we did not write it down so it could not have been that important."

"...but there is just so much other stuff to remember."

Others could remember more about the applications.

"We did Ohms law and the wind velocity thing..."

"We worked out the position of the light rays....oh that light scatter thing for looking at clouds...."

In the fourth type of lesson that was trialled the technological application was introduced at the beginning of the lesson and the theory was developed from the application. These were the same applications that had been introduced with other classes at different places in the lessons (types 1, 3a and 3b) so the applications themselves would not be considered too different. The theory was taught from the principles underlying the operation of the technological applications, background material was introduced and there was time for class discussion. The teacher commented on the class reaction:

"I felt that the class became very attentive, they appeared interested in the examples. I felt I had the whole class paying attention. It was a new way to introduce it, one that I had not used before and was not very confident about it. It seemed to work really well. It was good."

When the students were asked what they had done in that lesson they were able to talk more fully about the application and the theory. The explanations of both the theory and the applications were longer. The students were able to relate the theory to the applications and asked questions about them both in the interview and in the class.

"We did some examples of Ohm's law, how the wind speed thing works..."

"It has a resistor and the wind blows...the gas detector ...how it works."

"We saw where they use it...it makes it easier to learn."

"We saw how they count rain drops ...we learnt about the scattering of light and refraction through prisms."

6.2.4 Summary and conclusions

The observations and the interviews described in this section revealed there are some important criteria to be met if technological applications are to be remembered by the students. These may be summarised as:

1) Technological applications are not well remembered if they are introduced after all the formulae and equations had been developed. Students focused on the formulae.

2) Technological applications have to be introduced with an explanation of where and how they are used and they need to be directly related to the physics concepts that are being developed. When they were introduced without background information or in the form of an extended problem students tended not to remember them.

3) Technological applications must be chosen so that they are of interest to the students (as shown in chapter 4). Then students ask more about the device and want to learn more about the physics involved.

4) Technological applications tend to be remembered if the theory is developed from the applications.

Thus it appeared that if technological applications are introduced at the end of a lesson they are unlikely to change students' perceptions of physics (they still see school physics as being formulae) or to help in generating links between new constructions and existing ideas. The separate knowledge structure for physics may continue unchanged. However if the appropriate technological applications (relevant to students' existing knowledge) were introduced at the beginning of the lesson, the students attended to these and remembered them, linking them to the theory which was developed from the application. These appeared to help them understand more clearly some of the physical concepts introduced.

This was an initial study with a small experimental base and many variables. It may have been the novelty of the lesson format or that students were concentrating more fully at the beginning of the lesson that contributed to their positive response to the type four lessons. Students may have also recalled things that they thought the researcher wanted to hear or what they perceived physics to be. Other students thought that applications were not important when they had so much other information to remember.

6.3 TOWARDS A NEW PERSPECTIVE

6.3.1 Introduction

This section sets out to develop a teaching approach for the introduction of technological applications which is consistent with the ideas of the generative learning model. Section 6.3.2 discusses the rationale for progressing towards a new perspective for the teaching and learning of senior secondary school physics. The new perspective is outlined in section 6.3.3 with the complete teaching packages in appendix I.

6.3.2 Rationale for a new perspective

This study has progressed toward developing a new perspective for the teaching and learning of physics. Chapter 2 attempted to show that school physics has become divorced from the students' real world and the scientists' world. Claxton (1984) suggested that school physics in the United Kingdom had a linguistic, mathematical and experimental superstructure which is sometimes not intuitive and is not open to question. In New Zealand school physics has similarly emphasised the mathematical, experimental and philosophical aspects of the subject. This study has shown (Chapter 3) that school physics in New Zealand is perceived by the students as being difficult, unenjoyable, mathematical, of limited use and mainly to be studied as a prerequisite for careers or other subject areas. However students appeared interested in certain aspects of physics. Overseas studies (as noted in Chapter 2) and this study (section 3.8) indicated that senior secondary school students could benefit by the introduction of some technological applications in the teaching of physics. Chapter 4 indicated the type of applications that could be introduced into the senior school physics programme and the gender difference in interest.

In the generative learning model of teaching and learning (section 2.4) a key aspect of the learning process is the generation of links between the sensory input and the learner's existing knowledge. It was suggested that if a student is unable to link the idealised world of physics to existing knowledge structures within his/her memory store, the student is likely to develop a second and independent knowledge for physics. It was indicated that to provide links to the memory, the historical, technological and everyday aspects need to be integrated with the mathematical, experimental and philosophical aspects. Students are more likely to attend to a learning situation that is related to an aspect of their existing knowledge (which includes interests, career expectations, examination passes, etc, section 2.4.3). Given students' present negative perceptions of physics (section 3.4) and their declared gender-dependent interest in technological issues (Chapter 4), a technological based physics course consistent with the generative learning model would seem appropriate. Results from the previous section (Section 6.2) indicated that there were advantages in introducing technological applications at the beginning of the lesson. Thus. providing a technological focus which is perceived as being relevant by the students, it should enable students both to attend to the learning situation (engagement), and to generate more adequately links between constructions and existing ideas. The greater the number of links made, the more likely that a scientific idea will be remembered and make sense to the learner. Furthermore, an appropriate technological focus may mean that students integrate ideas of physics into their existing memory structures, so that school physics knowledge is no longer a separate knowledge.

6.3.3 A new perspective

A new perspective for the teaching and learning of senior secondary school physics was developed utilising the conclusions reached in the literature review (chapter 2) and the findings of chapters 3, 4, 5, 6.2. A classroom package was developed from the constructivistic learning philosophy and a particular New Zealand teaching sequence. Other teaching approaches for the introduction of technological applications have been discussed in Chapter 2 and by Cosgrove and Osborne (1985).

In compiling the teaching packages three particular aspects were considered; the constraints of the classroom, the type of technological applications that could be considered, and the format of the teaching packages.

Classroom constraints

One of the major constraints in developing the classroom materials was that at the end of the seventh form there is a national external examination. As was evident from Chapter 5 teachers felt that there was not enough time available and the syllabus was already too large for the introduction of technological applications. Thus the teaching package had to develop concepts required by the syllabus while not increasing the amount of time spent on the topic. Teachers and students also placed very great importance upon the examinations at the end of the year. The teaching sequence was also structured to allow the types of questions students wished to ask to be the focus of the lesson and also allow the sharing of ideas; a pattern of classroom activity basic to the interactive teaching approach of Biddulph and Osborne (1984).

Selecting the technological application

In many senior physics courses, students may have very limited or no existing ideas about certain concepts. As a consequence they have little or nothing in their memory store to link new ideas to. However it might be possible to identify technological applications which enable students to generate cognitive links, thus allowing new ideas to become part of the students' integrated memory.

The requirements of such technological applications can be summarised as follows:

1) Relevance in terms of human relationships and everyday aspects.

2) Related to the students' interests and existing knowledge with particular reference to gender differences (see Chapter 4).

3) Where possible a choice of applications (with the same physical principle) for study should be provided because of differences in existing knowledge.

4) The technological applications should be ones that can be introduced at the beginning of the lesson with background material and the physics concept directly accessible.

5) The device chosen should be one where simple experiments can be carried out to further explore and test students' ideas.

6) The technological applications should be ones that are able to form a theme for the next few lessons so that new ideas could be linked back to existing ideas and so further reinforce the physical concepts.

7) The applications should be ones that students can ask a variety of questions and explore more fully.

8) The applications should be ones where students' existing ideas can be explored and members of the class can share ideas.

Structure of the teaching units[2]

Each teaching sequence of the unit starts with the teacher introducing a theme or an actual technological device. The teaching sequence consists of five stages; (i) focusing, (ii) exploration, (iii) reporting, (iv) formalisation, (v) application. This is shown in Table 37.

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2 The teaching packages are found in appendix I.

Table 37: Teaching sequence with a technological focus.

Focusing stage: *This stage is designed to focus the students' attention on the learning situation. A context for learning is established (similar to Cosgrove and Osborne (1985) focus stage) in terms of a technological application, a social issue, etc, or an instance that relates to the students' existing knowledge. The teacher sets up a number of different situations so as to encourage the students to ask questions, put forward tentative statements, provide further information that they may have and discuss their ideas with other members of the class.*

Exploration stage: *This is a time for the students to carry out investigations, to try to answer questions they may have and further explore their tentative statements. These further investigations may be experimental, demonstrations, reading exercises, group and class discussion of various issues, comprehension exercises, technological and theoretical problems. The students explore in more detail how devices work and the physical principles behind their operation. Historical and everyday aspects are also examined.*

Reporting stage: *This involves students reporting back to the class the results of their investigations, discussing ideas and making summaries of the physical concepts involved.*

Formalisation stage: *This is when the teacher and the students use the information gained in the previous stages to develop physics concepts and write them in a formal physics manner.*

Application stage: *This may involve the student carrying out further investigations, attempting traditional school physics and other (technological) problems. This stage also includes other experimental, historical, philosophical, everyday and theoretical aspects of the physics concepts that have been developed.*

This structure is based on the generative learning model and also the idea of developing a more integrated knowledge structure of physics (mini-theories, see section 2.4). The aim of the technological applications and the lesson structure is to provide a framework into which students can fit new ideas and link them to other parts of their existing knowledge structure. In this way school physics knowledge is less likely to become a separate knowledge structure.

This format was utilised in developing two teaching units at the 7th form level. The topics chosen were electrical capacitance and the Doppler effect (both of which are normally taught in the 7th form). Each topic was distinct in that more student experiments could be carried out with electrical capacitance than the Doppler effect. Since students could not necessarily carry out as many classroom experiments with the Doppler effect and the technological devices involved where not directly accessible in the classroom a video was made. It showed technological applications in action and difficult experiments. The Doppler effect unit tended therefore to be more teacher dominated than the electrical capacitance unit.

6.3.4 Outline of the teaching units

- Outline of Electrical Capacitance Unit

The unit was designed to fit into the same time frame as the previous lessons on capacitance because of time and syllabus constraints (10 periods). The teaching package consisted of a teacher's guide, student reading material, models of technological devices, photographic slides, student experimental kits and student experiments. The unit was open-ended enough for the teacher to influence the presentation and the student notes. The unit was constructed around three lesson formats in which each emphasised different physical concepts. For each type, a technological theme or event was introduced which then became the focus of the next three or four lessons.

The first type of lesson started with students examining a camera flash gun unit, including its internal structure. Examination of the flash unit resulted in students asking questions and forming tentative ideas about flash gun units and capacitors. Next, students made models of flash gun units on circuit boards and were encouraged to explore and ask questions about capacitors, an activity which gave the students considerable time to test their own ideas and explore any further questions which arose out of their work. The students were then given the opportunity to pool their ideas and examine them for possible relationships. At this stage a summary of individual and group ideas was made by the whole class. A series of formulae were developed. Numerical and technological problems were then attempted.

The second type of lesson structure involved a central theme (for example, detecting changes in our environment) being associated with different technological applications. The students were able to choose the one that interested them and they then studied it in detail. The choices included medical, social and environmental issues. For example, earthquake monitors, baby breathing monitors, altitude monitors, and microphones. The students carried out investigations (including experiments) and presented reports to other class members. A series of formulae were developed. From this other technological applications were examined or used as technological problems. Typical school physics problems were also attempted.

The third type of lesson was based on a social concern. The issue of cot deaths was discussed at length by the whole class. This led to the detailed examination of a baby breathing monitor. The students carried out investigations using circuit boards and explored various physical relationships. They then combined their ideas in a class summary and developed physical formulae. Further applications were examined and problems undertaken.

- Outline of the Doppler effect unit

The unit was designed to fit at the end of the series of lessons on waves and to take only the normal amount of time spent on the Doppler effect. The unit that was presented to the teacher consisted of a teachers guide, a video of four technological applications and demonstrations, student reading and exercise material.

The unit was developed with the theme of 'Detecting moving objects'. The first lesson (focus phase) started with showing the video of the four technological devices that utilise the Doppler effect (Traffic microwave speed detector, blood flow meter, foetal heart beat monitor, and microwave burglar alarm) and the students discussed their ideas of how these devices might work. Students then explored (exploration phase) the properties of waves through discussions, demonstrations and further questioning. They also explored the changing frequency of waves. Exercises were undertaken to find out how these devices worked. The students chose which device they were most interested in learning about. They then reported back to the class and a general summary was developed. Other technological and numerical problems were attempted.

6.4 SUMMARY

In the initial studies (6.2) on the introduction of technological applications it was found that students would benefit more if the applications were introduced at the beginning of the lesson with background material of where they were used, who used them, etc, and the physics principle was developed from the device. Utilising this and the findings of the previous chapters, teaching units were constructed using the generative learning model as a basis. The teaching units consisted of five phases; focus, exploration, reporting, formalisation and application. These teaching approaches are trialled and evaluated in the next Chapter (7).

CHAPTER 7

EVALUATION OF THE NEW TEACHING APPROACHES

7.1 INTRODUCTION

This section reports on the evaluation of teacher and student reactions to the new teaching units (topics of capacitance and the Doppler effect developed in section 6.3) for senior secondary school physics. The evaluation consisted of four strategies. The first involved general classroom observation. The second involved the evaluator interviewing the teacher before, during and at the end of the teaching units. The third involved students being interviewed following the lessons and at the end of the teaching sequence. The fourth strategy took place four to six weeks later when the students were interviewed again to investigate their understanding and recall of the unit. Further less structured trials were carried out with another class in the same school and two other classes at a different school. A comparison was also made of students' reactions to the topic of capacitance taught in the usual manner and the new approach.

7.2 METHODOLOGY

7.2.1 Evaluation techniques

The sequence of evaluation procedures listed below were used with the two teaching units; Electrical Capacitance and the Doppler Effect.

(i) Classroom observation

Classroom observation techniques have already been briefly mentioned in this study (section 6.2.2) and have been used to evaluate other physics programmes (Renner, Abraham and Birnie, 1985). These techniques are used so that students are observed in their natural environment (Entwistle, Hanley and Hounsell, 1979). While the technique may not allow for experimental comparisons of different teaching strategies under controlled conditions (Cohen and Manion, 1980), classroom based research has become an accepted method of providing information about the learner (as reviewed by Tasker and Osborne, 1983).

An audio-tape recorder was used to record teacher-class interactions. Notes were also taken of the lesson for later discussion with the teacher.

(ii) Teacher interviews

The rationale of using interviews has already been discussed in section 3.2.1. The teacher was interviewed before the sequence of lessons, after each lesson, and at the completion of the teaching sequence.

(iii) Student interviews

The students were interviewed after the lessons, usually the next day to obtain their views of the lesson and to find out what they recalled from the previous lesson or lessons. Interviews of various kinds had been carried out by the evaluator in these classes with several different topics during the year (see section 6.2) so that the students would not have considered this activity unusual.

(iv) Semantic differential probe

Individual student interviews using a semantic differential type scale (Osborne. 1976) as a probe were carried out as a way of recording student perceptions of the unit. This type of evaluation has been reviewed in chapter 3.2. The scale consisted of 16 bipolar adjectives developed by Osborne (1976) to evaluate new courses at university. The students were asked to complete the first scale a week before the trial began and the results of this first procedure were compared with similar scales used in the study on students' perceptions of physics (section 3.4.2) to check for reliability and stability. (The scale that was used can be observed in Appendix J). At the end of the trial unit a similar scale was filled in by the students to explore their reactions to the new teaching approach. The students were interviewed individually with both completed scales before them to probe the reasons for their responses. The emphasis of this evaluation technique was on the student comments rather than the statistical analysis of the responses.

(v) Further interviews

The final component of the evaluation procedure took place four to six weeks after the completion of the unit. Students were again interviewed to explore what they recalled about the unit.

These procedures (iii-iv) were carried out at the trial school and also at a school that had taught capacitance in a more traditional manner.

7.2.2 Background of the teacher and school.

The school and the teacher used were the same as those discussed in section 6.2. The classes chosen for trialling the new approaches were taught by their usual physics teacher. The students were 7th formers and all of European ethnic origin. The classes were not streamed and were of mixed ability. Two (33 students) of the three 7th form classes were used in the trial. Originally it was intended to use the third class as a control, however the teacher felt this would be unfair, since to him the trial units were better than the traditional approach of teaching these topics. The other class would study these topics later in the year. As the teacher stated:

> "Although it might have been better for research purposes, when I looked at the new material and thought about it I decided that it had to be better than the old approach. I did not want any of my classes to have something other than the best I could offer. I felt that I would be disadvantaging them in terms of interest, motivation and in terms of getting the concepts across."

The teacher did teach the third class by the new approach later in the year and this was used as a further trial.

7.3 EVALUATION OF THE ELECTRICAL CAPACITANCE UNIT

The general outline of the unit has been discussed in section 6.4. The evaluation will be reported in terms of a general overview, teacher comments and student reactions, and what students recalled from the unit.

7.3.1 General overview of the lessons

Observations of the first phase of lessons (exploration of a camera flash gun) indicated that the students were involved in the activities and were stimulated by them. For example in the first lesson, where the camera flash gun was demonstrated (focusing stage), the students produced thirty questions and tentative statements about flash gun units and capacitors. The students also created analogies of how a capacitor might work. The experimental stage provided time and experiences for the students to test out their own ideas (exploration stage). (Some students became so engrossed in exploring their ideas they worked through the lesson breaks). Three of the four groups tried out different experimental arrangements to test out their ideas. The teacher commented on this:

> "They were really latching into this stuff, one (student) was using an ammeter to measure how bright the bulb was really...one of the others asked if I had a light meter...I came to a group they were finding they could turn off the power pack and still charge up the capacitor and they came up with the idea that capacitors were in the power pack...others stacked up capacitors or put them in series."

At the reporting stage the students came up with interesting ideas and when questioned in class and in the interviews the students appeared to have formulated helpful ideas about how capacitors worked.

> "They obviously knew the facts and the way they were telling me suggested that they regarded the facts as being particularly basic." [teacher]

> "They build up charge and they release it ...it only goes up to a certain level and it will not go above that level and that depends

on the size of the capacitor...also possible to hold its charge after it has been disconnected." [student]

At the end of the first phase of lessons the students appeared to be reasonably enthusiastic, however a few in the class just wanted to be given the `right answer'.

The second phase of lessons (the theme of detecting changes in the environment) was where the students could choose a technological device which interested them (focusing stage) and study it in more detail (exploration stage).

"It was good they could choose their own thing and were able to choose something they were interested in and that committed them more to actually doing it which is good." [Teacher]

In the reporting stage it was apparent that most of the class had understood the principle behind the devices and enjoyed having the choice of device to investigate.

"It was good, you can see some result of the physics...people can measure earthquakes...when it is going to happen...it was something that was quite interesting." [Student]

"...well like how when the plates are closer together the capacitance is larger...it was good fun learning about volcanic eruption detectors...it was different from the normal type of assignments we are given." [Student]

The third phase of lessons involved the social issue of cot deaths. Most students became involved in the class discussion of cot deaths (focusing stage). Two points of interest were (a) three boys who in the past had appeared bored with physics became very involved, (b) the observation that girls began asking more questions of a technological nature.

"How is the delay time on the mattress related to the size of the capacitor?"

The students responded well to the issues and indications were that they had learnt a considerable amount of physics from the technological devices involved (exploration stages).

"I think it would be great to learn physics this way...you are sort of given practical examples along with it. It's a lot easier to remember."

"You can understand the theory because it is more of a device used in the real world."

Students were able to give detailed descriptions (reporting stage) of the relevant physics involved, such as how the mattress worked.

Overall, the students found working things out for themselves enjoyable, they developed physics concepts and appeared to become more involved in the lessons.

"It gets a lot more class involvement that way, it's really good."

[student]

One group of students were apprehensive about using this approach all year.

"I think it would not be good to do this all year because you might make a mistake and once you have established a mistake it's hard to correct it."

Three boys indicated that they did not enjoy this approach.

"He (teacher) seems to be brushing over it a bit. This is a pretty difficult subject and he is treating it a bit lightly."

"This gives us a view out side but we are talking about a little device. I think of the formulae and stuff...I think it's a waste of time."

As a result of this trial aspects emerged that need to be changed. From the teachers and observers point of view these were more management and technical problems rather than difficulties with the underlying philosophy.

"One of the incredible things about it is that for me this has really been a new approach...given the fact that I am really a beginner it has gone across really well, but it can certainly be fine tuned...I would not change a lot really." [teacher]

"I was not actually sure what I was suppose to do with this piece of work. Although it was interesting reading about it." [student]

7.3.2 Teacher comments

The teacher comments can be summarised as follows:

1) Strong and sustained interest in the class

"I thought the approach was very good in a number of aspects. I firstly felt that the class was very interested in what was going on, particularly interested and one group were so enthusiastic that it was unreal. They are normally a pretty unruly sort of bunch...incredibly on task and came up with all sorts of different ideas."

2) Greater student involvement

"A typical student who found physics boring ... showed his interest by delivering a lot of answers and coming up with questions of his own."

"... students did seem to learn a lot and it was backed up by a fair bit of understanding."

3) Increased learning in experimental work

"I think they got a lot of stuff out of it. It was good wandering around and hearing people discuss their ideas about capacitors .. I got the impression they had learnt a lot."

"They really did get the ideas ... they enjoyed getting them too."

4) Interest in individual work

"They really were interested in their individual activities ... They really seemed to understand what they were talking about... they had to find things out for themselves."

5) Enhanced understanding

"Increased grass roots understanding. They really have grasped the basics and were not getting lost in a whole pile of formulae... they were incredibly enthusiastic ... they really came back with lots of ideas."

These views were supported later when the students completed a standard class test for this topic which had been used in previous years. The two 1986 classes involved in the trial had through the year scored consistently lower in all tests compared to the 1985 class. Question types were similar to those found in the external examination. In the test on capacitance the 1986 classes scored higher than the 1985 class. When commenting on a standard assignment the teacher stated:

"Those marks are really very good, possibly the best ever on that assignment."

6) Marked modification of teaching strategy

"I think I am finding I can get along without getting into really gory derivation from Gauss' law or stored energy."

"... I would like to teach other things this way too. I am going to attempt this approach with the topic of waves ... I would be keen to try some more and my class will be upset if I don't which could be a problem."

7) No extra time was taken

"I think that we have got through it in 10 periods, that is the time I have spent on it before. I think that they have learnt more by doing it this way in terms of genuine understanding than they have usually done in the past. As well as probably learning more I feel they are a lot more enthusiastic... They are more enthusiastic about physics in general.

The teacher, like the researcher, felt that only a few students may have been disadvantaged or disliked the approach.

"There might be a few individual people who have not found it to their liking ... they might perceive physics as being fairly cut and dried, tied down with formulae and they feel a bit insecure if they do not get that."

"At the bottom end of the scale it has been radically better. I think it has really gathered in those people ... really cottoned onto the ideas and really presented some brilliant stuff."

7.3.3 Student reactions

The majority of comments made by the students indicated that they were interested in learning about technological devices and that these devices helped them to remember some physics concepts. The students reported:

1) Interest in technological devices

"You can understand the theory because it is more of a device used in the real world....I did the thing on volcanoes... it was good it showed the inverse thing, capacitance is proportional to distance ... it was good finding that I could do it."

"It's interesting seeing how physics can apply in everyday life and you can remember it better."

2) Links to everyday events

"It was quite interesting because you can relate it back to something that you have seen happen or know something, it's a real situation rather than a theoretical thing ... you can relate it better."

"It was easier to retain because it was based on practical bases. It had practical ideas behind it which we were able to relate too. As soon as I think of capacitance I think of monitors in the hospital. It's the first thing I think of and everything else is related to that."

"More interesting because you can see the result of physics."

3) Useful knowledge

"It's good learning practical uses. It's good finding it's so simple really ... Its use in society."

4) Links between technological devices and physics concepts

"The apnoea mattress for hospitals ... we learnt how they work... You have got 10 different sections and all these tubes going into a central control area which you have got a thermistor which is a special type of resistor which the air flows through it and it cools down and the resistance gets higher. It is connected to an alarm unit which has a capacitor and if the baby stops moving then the resistor gets warmer and so the resistance decreases and thus the capacitor charges more quickly and if it gets over a certain voltage level the alarm will sound."

5) <u>Experimental based programme</u>

"I think it's good when you are not just told everything and you get a chance to figure it out for yourself as well."

It's good having an experiment where you do not have to worry so much about the getting of results and getting things right. It's more learning by doing."

6) <u>They liked the choice provided</u>

"That was quite fun. You got to do your own thing."

7) <u>Some recognised two sorts of physics</u>

"I've seen bursary papers and this stuff is not in the examination."

"This is not going to help me get good marks."

The interviews with the students in the classroom revealed that they remembered the technological applications and more importantly they linked the physics ideas to them. They generally appeared to enjoy the lessons. Students were now willing to speak at length about the physics lessons, whereas before this unit their replies had been short and concentrated on the formulae introduced in the lessons.

- Semantic differential scale

A week before the start of the trial unit the students were requested to complete a semantic differential scale about how they felt about school physics. At the completion of the trial unit a similar scale was filled in by the students to record their reactions to the capacitance unit. This data was used as an interview probe to explore students' responses to the unit. The first survey produced typical results for New Zealand 7th form physics students (see section 3.4.2). Thirty students completed both forms and twenty of these were interviewed. The results for the 30 students can be seen in Figure 5 and the reasons for the change are in Table 38. The profile (Figure 5) shows the mean responses for traditional physics lessons and that of the capacitance unit. The changes were analysed[1] using a sign test for non-parametric data (Table 59) and a two tailed t-test (Table 55) (Ferguson, 1971; Osborne, 1976; Walker and Lev, 1969).

As evidenced by Figure 5, the student comments and the statistical analysis (Tables 38, 55, 59) suggested that, compared to the usual style of teaching, the trial unit was considered to be significantly (1% level) more: interesting, easy and straightforward with a technological bias. The unit was perceived as more enjoyable and relevant to everyday life (5% level). It was also considered to be (1% level) less mathematical and have fewer calculations. However, the students did consider that the unit was less relevant than physics generally for career purposes.

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1 Full analysis and tables of results and significant differences noted in appendix K.

Figure 5

Capacitance unit and traditional physics mean score profiles. (N=30)

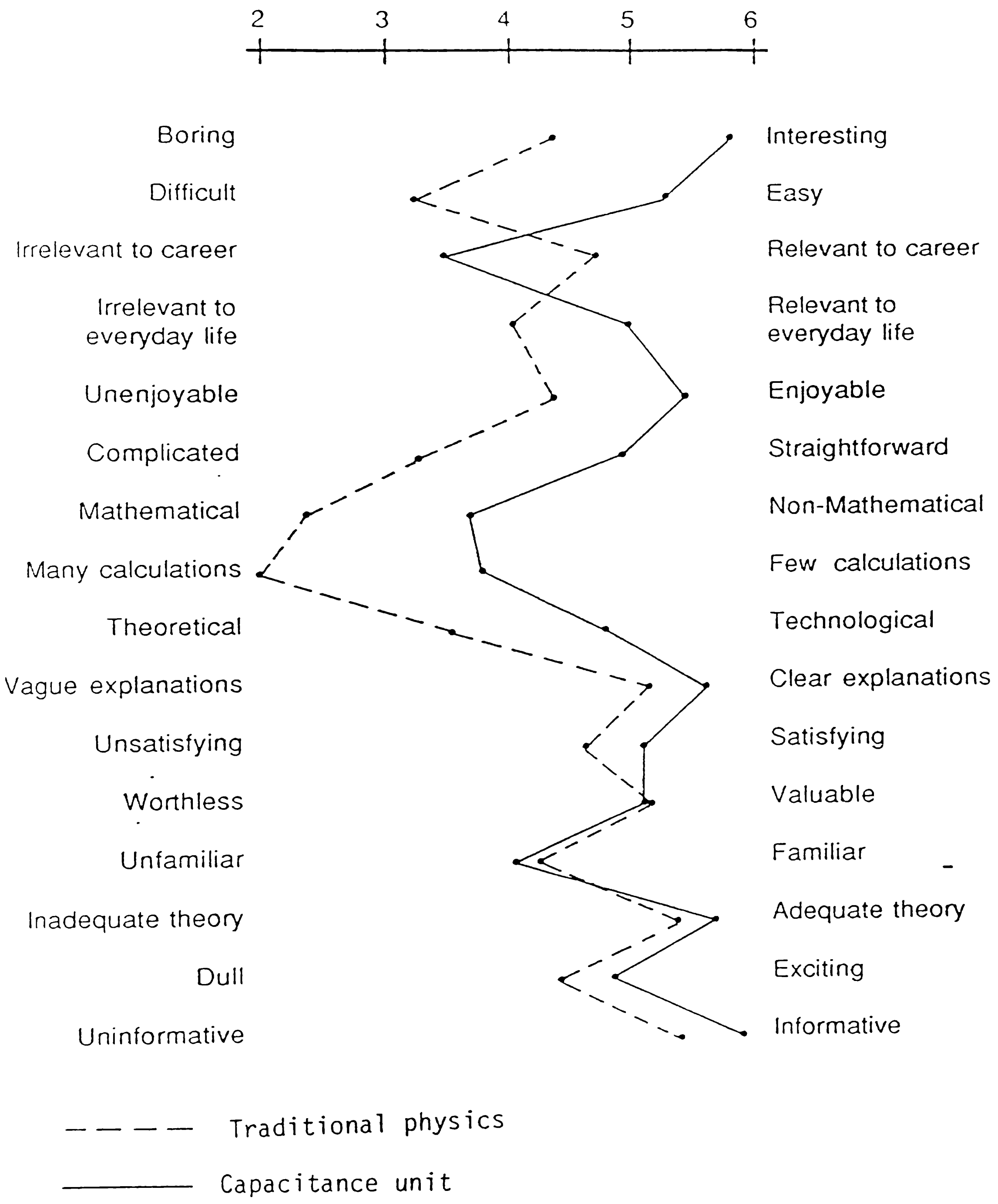

Table 38. Student responses to the capacitance unit using the semantic differential scales. (N=30)

Interesting: *(25 more positive, 4 more negative)*[2] **

"They were more to do with everyday life ... like[3] *the cot death machine ... it helps a lot.*

"It held my attention better because we did things like the baby breathing."

"I found it more interesting because you had to think about it, not just given the information."

Easy: *(27 more positive, 1 more negative)* **

"I could actually picture it."

"Found it out for ourselves."

"It was the different way of approaching the problem."

Irrelevant to Career: *(5 more positive, 21 more negative)* **

"Physics in general is relevant but capacitors wouldn't come into it."

Relevant to everyday life: *(18 more positive, 4 more negative)***

"It was the breathing mattress seeing how those things worked."

"Emphasis on the uses of capacitance."

Enjoyable: *(20 more positive, 4 more negative)* *

"Enjoyable because of its relevance."

"I guess discussing it in class makes it better."

"It has been a fun time."

Straightforward: *(20 more positive, 3 more negative)* **

"There were not so many formulae ... in this case your basic knowledge brings out the formula so you can do it yourself."

Non-mathematical: *(24 more positive, 3 more negative)* **

"It was more thinking about it then trying to reach a formula."

Few Calculations: *(25 more positive, 1 more negative)* **

"They are still there but I did not find them

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2 Only those students whose response changed are recorded.

3 These comments are representative rather than idiosyncrasies.

as difficult."

"We sort of came up with the formulae ourselves."

Technological: *(19 more positive, 1 more negative) ***

"The applications of it were good ... if you do not know how it applies to things it is much harder to understand."

"You can see it in use."

Clear explanations: *(17 more positive, 8 more negative)*

"Very good the best they have been for ages."

"I seemed to understand them probably because could see what was happening."

"We had to work some of them out ourselves."

Satisfying: *(16 more positive, 10 more negative)*

"I had increased interest but sometimes you did not know if what you were doing was right."

"You get a better understanding of how it works."

Valuable: *(11 more positive, 13 more negative)*

"Valuable information for career or something."

"Marked it the same as career."

"You wanted to learn more about it."

Familiar: *(8 more positive, 10 more negative)*

"It is still unfamiliar sort of work."

"I did not know a lot about it before."

Adequate theory: *(10 more positive, 8 more negative)*

"You have always got everything you needed."

"We did not actually get as many theory notes."

Exciting: *(11 more positive, 4 more negative)*

"... the cot deaths made it quite interesting."

"I like stuff more directed toward the exam."

Informative: *(16 more positive, 5 more negative)*

"It is interesting when I can relate it to things."

"In the sense that you are using the medical area."

** *Significant at the 1% level using the two tailed t-test and the sign test.*

* *Significant at the 5% level.*

It is suggested that the reasons for the changes in the profiles result from the teaching unit that was introduced. The major factors involved appear to be: introducing technological applications that students were interested in and could relate too, the individual projects, students finding out the information for themselves, class and group discussions, developing physical concepts from the applications, experiments and other investigations.

Only four students did not find the unit more interesting and enjoyable. The reasons given were:

"It moved a bit slow."

"Not interested in how things work, I just want to go to medical school."

Students were also asked during the interviews with the two scales what they thought about when the word capacitance was mentioned. The replies were centred around the applications, usually mentioning a few of them, and the physical principles involved.

"Generally more interesting, more practical, everyday use... Cot deaths and mattress to see if the baby is breathing. Earthquake warnings and condensor microphones. The distance between two plates... The charging up and discharging, different charge rates and the formulae involved."

"Stored energy ... Things like uses for measuring quakes, altitude, the breath of the baby related to cot deaths ... It made it better I suppose ... just practical sort of situations."

- Interviews 4-6 weeks later

Fifteen students were interviewed five weeks after the completion of the unit. The students were asked what they thought about when the word capacitance was mentioned.

"Cot deaths and the altimeter thing, barometers. Anywhere you can adapt the problem to two plates moving, and changing capacitance .... Like the flash gun where it stores up energy."

Some students who gave quite a long description of capacitors were asked why they had remembered so much.

"We did a lot of work ourselves which helped it to stick and it could be related to everyday life so that helped.... it was a lot more interesting."

"It was about the uses and that sort of thing was quite interesting...How they stop cot deaths was quite interesting... that was easy really."

They (technological applications) seemed everyday ... you use them without knowing about them ... you do not remember the formula you remember the concepts ... it actually stuck seeing what happened."

The students appeared to remember the technological applications first and then link the concepts and the formulae. Typical of the replies were:

"Cot deaths and the formulae involved..."

"Flash gun and the charging and discharging..."

"....physics ideas linked together by real things."

- Comparative study

To investigate whether students generally find the topic of capacitance more interesting than other physics topics, studies were carried out at a school where the topic of capacitance was studied in a more traditional manner. The semantic differential scales were again used before and after the capacitance topic, in conjunction with other student interviews. The scales revealed the traditional perceptions of physics (see Table 57). The scales showed the lessons on capacitance were perceived to be similar to their previous physics lessons (Table 58).

"Just the usual kind of physics lesson."

Students at this traditional school tended to remember some of the formulae involved in the topic of capacitance.

"Charge storage. I do not really remember any formula,
may be Q=CV."

"Capacitance increases with surface area overlap, decrease in the distance between the plates."

Only three of the twenty students were able to state where capacitors could be used.

"Variable capacitors in radios."

"Stereos might have them."

7.3.4 Summary

The evaluation of the capacitance unit showed students became more involved in their lessons, found the lessons interesting, easy to understand, enjoyable, non-mathematical, technological rather than theoretical, more straightforward and relevant to everyday life. They developed a satisfactory understanding of where physics principles were used in the real world and made links between technological applications and physics principles. As a consequence the students were able to talk more freely about capacitance and its uses. In contrast students taught in the more traditional manner had a narrower view of physics concentrating mainly on the formulae involved. One of the major advantages of the new approach was those students who had been bored with physics previously, became interested and increased their contributions to classroom interactions. Another advantage was that first hand experience with examples of technology gave students more confidence to attempt traditional physics problems and to achieve better results than expected. There were a few students who did not enjoy the approach.

7.4. EVALUATION OF THE DOPPLER EFFECT UNIT

The evaluation of the teaching unit on the Doppler effect was analysed in a similar way to the capacitance unit. It will be reported in terms of a general overview, teacher comments and student reactions. The Doppler effect unit only took four - five teaching periods. Three 7th form classes (52 students) were involved in this trial.

7.4.1 General overview of the lessons

The unit was taught to all three 7th form physics classes by the teacher at the trial school. A video was used to illustrate the technological applications and various experiments that could not be easily observed without the use of slow motion or diagrams. One of the factors that the students responded well to in the capacitance unit was the fact that they could explore and carry out experiments for themselves. The Doppler effect unit offered an opportunity to find out if technological applications would still have the same effect on student learning if there were not so many experiments.

Four applications of the Doppler effect were all shown on video: traffic department speed detectors, foetal heart beat monitor, blood flow measurements and microwave burglar alarm.

> "I think the video to start the lesson off with the four applications is excellent and here you are faced with actually bringing a 3-D Doppler effect into the classroom." [teacher]

The students were introduced to the theme of 'Detecting moving objects' (focus stage) and were asked 'how do these devices pick up the movement of objects?' In the first lesson the teacher provided little introduction or time for the students to ask questions. Despite this students appeared interested in the devices. After discussion with the teacher this situation was altered for the other two classes and students were able to direct the lesson more with their questions. This led to considerable use being made of their own ideas of how these devices might work.

> "The students are asking questions they are interested in which is excellent, because if someone asks a question they are ready to learn the answer." [teacher]

From the students discussion and questions it was evident that many had a view of how the devices might work. For example:

> "This is just my theory, the waves are sent out and they hit an object, a car moving and it sends back this message that there is an object there and the distance gets smaller and they work out the time it takes for the distance to get smaller."
>
> [student]

The next two lessons attempted to answer the students questions and help them formulate tentative statements about waves (exploration stage). This was achieved by having a ripple tank in the class and by showing the experimental aspects of the video.

> "It was good testing out their ideas ... that was pretty valuable really and again it was related to everyday life." [teacher]

The students themselves introduced the idea of red shift. At times the more able students tended to dominate the discussion but one of the 'less able' students asked:

> "If the waves are reflecting off the moving object does that then act as a moving source? Would the waves reflect off the object and there be a change in frequency?"

This statement triggered the students to use the information about waves to try to find out how the technological devices worked. The wave property ideas became more fully developed and there was noticeable classroom participation by the girls.

> "That was amazing because at the end of the first term she got an exam mark which she was not too happy with and she was definitely concerned as to whether she should drop physics ... she gave an excellent explanation on what was occurring. That was incredibly impressive." [teacher]

The students responded well to the assignment sheets and the video on the moving reflector. Both of these helped solve problems without relying on complicated formulae (reporting and formalisation stages).

> "I noticed a lot of kids were able to solve Doppler shift problems without referring to the notes at all ... I've noticed a big change in that area actually where they tend to use the principle rather than the formulae." [teacher]

Students were motivated to attempt the problems on the activity sheets as they helped answer the questions they had about the devices.

"It was good being able to link it back it how those devices worked." [student]

Two of the more able boys in one class only became attentive whenever formulae were put on the board. However it did appear most students had responded well to the unit.

The Unit on the Doppler Effect did not receive as such a positive response from the students as did the Capacitance Unit. The teacher provided three reasons for this:

"1) Possibly because the capacitance unit came first it was a big jump from what we had been doing before and they had 10-11 lessons on that.

2) More hands on stuff ... the actual circuit board appealed to people I think.

3) I think I presented capacitance in a more coherent fashion ... I had more time to sort capacitance out...."

The designer of the teaching package felt he did not provide as clear information or spend as much time with the teacher as with the previous package.

"I still think it was pretty successful actually. I think if I tidied up the presentation it would be an excellent package and certainly one I would use again." [teacher]

7.4.2 Teacher comments

The teacher reported:

1) The students were interested and motivated

> "The examples covered a fair range of stuff and I think most of the people were interested in that."
>
> "They are really getting interested and motivated."

2) The students asked and wanted answered a lot of relevant questions

> "It was great the way the students responded and asked a lot of questions. They really did want to find out how the devices worked."

3) Students changed their views how the technological devices worked

> "It was probably very good they were able to change their minds about the microwave detector... I think in the past we have studied the Doppler effect and they still think that it was done by measuring distances."

4) Enhanced understanding

> "I have found it is possible to actually spend quite a bit of time seemingly to not make much progress in theoretical terms because you are spending a lot of time looking at some application. All of a sudden you find the students have picked up a lot of the fundamental concepts and once they have really grasped those you can make very quick progress through the rest of the stuff."

5) Modified approach to teaching

"I think here I have got a new approach which I feel happier about and one which I think the students feel happier about and feel they learn more as opposed to number crunching. So I am really keen to modify all my teaching to along these lines."

7.4.3 Student reactions

Although there were no student practical experiments (one of the apparent strengths of the capacitance unit) the students were still keen to carry out reading and calculation investigations and were involved in the teacher demonstrations.

The students reported:

1) Interest in technological devices

"I am curious how the cops pick up whether you are speeding or not."

"I find it quite interesting. I never thought anything like this could exist (foetal heart beat monitor). ...I always wondered why the cars when they went past, why they start with a high pitch then go away."

2) Links to the everyday world

"It is good.... you can think oh so that is how they work. Normally you just have to accept things... It makes you think about things."

"It is a lot more enjoyable. You just do not get handed out sheets, whereas we learnt how the microwave detector worked. We saw the video about practical ideas and their use."

"Stuff like this puts physics into context ... you can see what it might be used for. It shows that it is not another topic, it shows that somebody might use it."

3) <u>Liked the choice provided</u>

"I was more interested in finding out about that traffic thing than the blood rate thing."

4) <u>Liked the use of the video</u>

"The video helped to show it better, it was really good."

"With different learning mediums you learn a lot more."

5) <u>Liked being able to explore how devices work</u>

"I found it good when the whole class worked it out ... He (teacher) never told us how to do it. I probably did not contribute that much but it was a good feeling, to work it out for yourself."

"It is good to do things like this and work out how actual devices work rather than just sort of doing problems that have got numbers because you do not know where they come from."

6) <u>Easier to understand</u>

"It is easier to understand when you are talking about examples that you know about like that and then the more interesting it is. It actually makes it easier to remember it because it is something that we know about."

- Semantic differential scale

The semantic differential scale was again used as a probe for exploring if the students perceived the new unit to be different from their existing physics lessons. The evaluation strategy was the same as was used for the Capacitance Unit. A total of 28 students completed both the before and after scales. The 'before' scale was the one that had been filled out previously by the students prior to the capacitance unit. Sixteen of these students were then interviewed to explore the reasons for their responses. These procedures meant the amount of change could be shown as well as the reasons for that change. The profile of the mean responses is shown in Figure 6[4] and Table 56 provides the actual means. The number of the students who showed any change and the reasons for those changes are shown in Table 39.

Thus the Doppler unit was considered more interesting, easy, relevant to everyday life, enjoyable, technological, and to have fewer calculations (all significant at the 1% level). The reasons for the changes, as shown in Fig 6 and Tables 39, 56, 59 were related to the approach that was introduced. The major factors involved were: technological applications that students were interested in, finding out how they worked, the choice provided, the individual investigations, class discussion of ideas, student questions and the developing of the theory from the applications. Both teacher and student comments indicated that the students developed more confidence to attempt traditional school physics problems. There was little

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4 The table of means and calculation of significant differences are shown in Appendix K, Tables 56 and 59.

Figure 6

Doppler effect unit and traditional physics mean score profiles. (N=28)

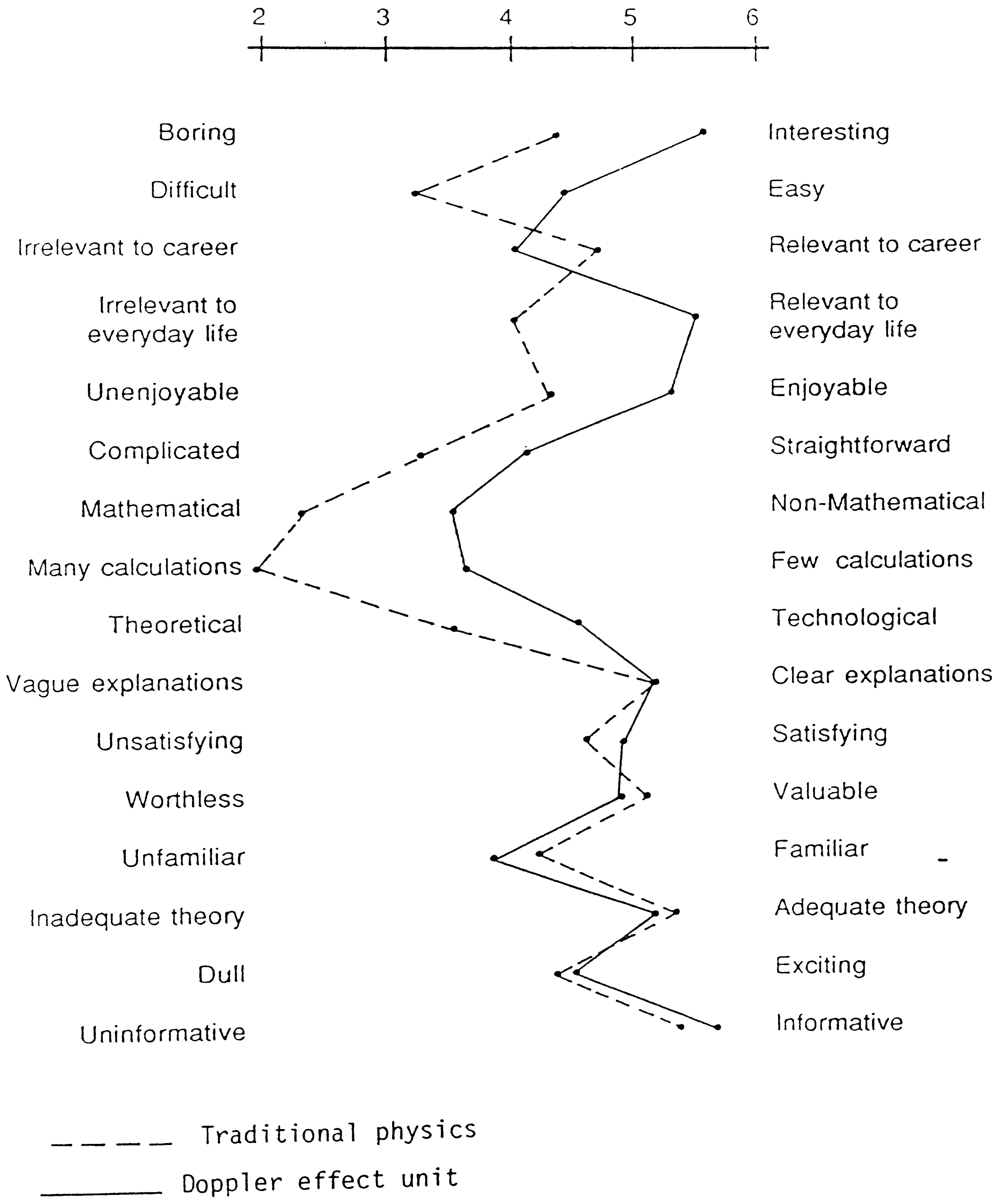

Table 39. Students' responses to the Doppler effect unit using a semantic differential scale. (N=28)

Interesting: *(17 more positive, 1 more negative)*[5] **

"Very interesting it relates to what we are dealing[6] *with. It is good to understand how the cops operate."*

"I think it is interesting because it has a lot to do with real life."

Easy: *(21 more positive, 3 more negative)* **

"This was easier than most physics. You could see it."

"If I was just doing problems I would have found it difficult. The projects about practical applications help, because suddenly you realize I thought it worked that way."

Irrelevant to career: *(8 more positive, 13 more negative)*

"No effect on my career."

Relevant to everyday life: *(23 more positive)* **

"Because of all the examples he gave us."

Enjoyable: *(16 more positive, 1 more negative)* **

"Because we were finding out how it actually works."

"Because it was related to things in general."

Straightforward: *(13 more positive, 5 more negative)*

"Easy to understand but complicated in working out the problems."

Non-mathematical: *(16 more positive, 5 more negative)*

"Suppose it is (mathematical), but you actually see it work and it does work."

Fewer calculations: *(23 more positive, 2 more negative)* **

"You don't need a lot of calculations to make it work or understand it."

Technological: *(18 more positive, 2 more negative)* **

"It was more relevant because you could see its application and find out why it worked."

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5 , Only those students whose response changed are recorded

6 These comments are representative rather than idiosyncrasies

"The use of the microwave and the medical stuff."

Clear explanations: *(9 more positive, 11 more negative)*

"At times he could have told us the answer it can get pretty frustrating."

Satisfying: *(11 more positive, 7 more negative)*

"It is interesting to find out about those things."

"I just don't like getting things wrong."

Valuable: *(8 more positive, 10 more negative)*

"Depends on what I am going to do but it is just good general knowledge."

"Relevant to everyday life and career."

Familiar: *(8 more positive, 9 more negative)*

"I did not know anything about the Doppler effect."

Adequate theory: *(10 more positive, 11 more negative)*

"I did not think there was enough theory ... we taught ourselves."

"Adequate to do the problems."

Exciting: *(10 more positive, 8 more negative)*

"Not exciting but I cannot say it was dull."

"You see a practical use so it is slightly more exciting."

Informative: (12 more positive, 3 more negative)

"Very informative. We had a video that discussed discussed different situations."

"I found out a few things I did not know before."

** *Significant at the 1% level using the two tailed t-test and the sign test.*

* *Significant at the 5% level.*

change for those students who were already doing well in physics. However, those students who were struggling and those who had appeared bored with physics became more interested and increased their contribution to classroom interactions. The students suggested that in this unit the explanations may not have been clear as they might have been. At the end of the teaching sequence the students appeared to have an understanding of how the devices worked and an appreciation of the physics involved.

- Student comments 8 weeks later

Eight weeks after the completion of the unit the students (44) were asked to write about the Doppler effect. Those students (6) who were concentrating on the scholarship examination tended to write about the principles and formulae involved and used examples of moving car horns rather than other technological devices. The other students (38) wrote on average 120 words on the Doppler effect. They included diagrams, formulae and the technological uses. Eighty four percent of these students mentioned at least the example of the microwave speed detectors used by the traffic department (71% of the students studied the microwave option for the individual study). Only one student reverted back to her original understanding of the way the microwave detector worked. Most students described in detail the principles involved in the devices and illustrated these with diagrams of both the principles and devices. This reinforced the teachers claim that the students were solving school physics problems from the principles rather than directly from the formulae. One student who stated that he could not remember the formulae was able to describe how the microwave detector worked and the principles involved.

7.5 FURTHER TRIALS

Further trials of the electrical capacitance material were conducted with another class at the trial school, whose students the teacher perceived as being more achievement-motivated, and two other 7th form classes in another school taught by different teachers. In this report of the evaluation the teachers', students' and evaluator's comments will be reported as general comments.

7.5.1 General Comments

An important aspect of the introduction of the unit in the other class and the other schools was the way in which some of the more able students responded. Some who were generally considered to be high achievers did not react very positively to the unit. It was observed in one class that four of these students only became attentive when the formulae were being introduced. The teacher commented:

> "In the practical work one or two seemed to think it was beneath their dignity to do, especially one very able student ... it was interesting that he was putting up some invalid hypothesis ... but was reluctant to getting around to measuring that and finding out they were wrong."

This teacher also commented that:

> "Overall the standard is high academically. There is probably more of a gearing towards passing exams compared with the other classes. ...so I guess there was a certain element of I'm O.K and physics is O.K so I'm happy just getting the formulae."

Not suprisingly students who have been successful in learning physics in the way it has been traditionally taught might be resistant to change.

"It seemed to go too slowly. If they just tell me what I have to learn and I will learn it for the exam." [student]

"You do not need this stuff (technological applications) to get into medical school." [student]

"It would be much better if they just told us the answers."

A second teacher also commented that this approach may not be popular with some of the more academically inclined students.

"They want short cuts. Tell me what I've got to know and I will learn it. They are very exam oriented people. They want quick answers to everything."

A third teacher commented that she had a small group of students who appeared concerned about the initial lack of equations and the emphasis on other issues.

"What has cot deaths got to do with physics? We spent a whole period discussing that." [student]

However the three teachers agreed that this type of student was not disadvantaged by the alternative approach.

"I think they learnt more than they think they did."

"Even these students seemed to have a clearer understanding of what was going on ... they actually did extra research and had gone definitely beyond the unit."

The three teachers commented that the approach appeared to be successful for the majority of the students.

"The change of approach may have given them a new lease of life."

"I think they enjoyed it ... they saw that there was some point to it."

"The girls have been the least confident but they have really improved."

Such students were interested in the technological applications, asked plenty of questions and provided tentative statements in the lessons. In these classes many students responded well to the investigations where they were able to explore their own ideas and questions. They also enjoyed having the choice in what they could study further.

"It was more interesting than other parts of physics because you got to do your own thing."

"We learnt a lot more because we did it ourselves."

However some students suggested that they would have liked further guidance during the individual and group investigations.

"We did things on our own and it would be nice to know if we were doing it right."

The majority of the students indicated that they felt they could **contribute more in class.**

"I could use some of my own ideas."

"I found I could contribute a lot more in class."

The students were **interested in the technological devices** and perceived this topic as being different from others they had studied in the past.

"It was a lot different from normal physics. We are not just dealing with formulae but found out how things worked. That was the best part."

"It was good finding out how things worked."

It was suggested by the students that this approach **helped in the** learning of physics.

"Capacitance was one of the better ones to learn because you could see things....and how you could use them."

"The applications made it stick more."

The students appreciated that they were shown some reason for learning physics.

"This is the first time there was some reason for it. You enjoy it a bit more if there is a reason for it."

"It was a lot more relevant having something like the toaster timer."

The teachers who had not used this unit previously were positive about the approach.

"The unit was well put together ... it was easy to use and I was able to bend it to suit my own teaching style ... I think the students enjoyed it, they saw some point to it. This approach increases the amount of understanding ... When I do it again I will do it better ... there are no real criticisms. I like it ... it is the way we should do most things."

7.5.2 Summary

These further trials showed that similar responses to those obtained from the initial trials could be obtained from other schools. They also showed that those students who were already successful in physics or were concentrating on the examinations may not be so positive about the approach. This factor was not so obvious in the initial trials due to the nature of the classes. The girls responded well to the new approaches in all the trials. The majority of students indicated that they were interested in technological applications, learnt more physics, could contribute more in class, carry out their own investigations and saw more reason for learning physics.

7.6 GENERAL SUMMARY

It would appear that the introduction of an appropriate technological focus within a framework of activities based on the ideas of the generative learning model, can enhance the learning of senior secondary school physics. The majority of the students became involved in their lessons, were more likely to share ideas and to carry out their own investigations. Students also found the lessons interesting, easier to understand, enjoyable, non-mathematical, more technological, straightforward and relevant to everyday life. They found the physics concepts easier to remember and were able to relate to both school physics and technological problems. Furthermore students who had appeared bored with physics became more interested and increased their contributions to classroom interactions. There were other positive features; for example, first hand experience with examples of technological applications gave the students more confidence to attempt traditional school physics problems. However not all students responded favourably, particularly those who were more concerned about the formulae and answering theoretical problems.

CHAPTER 8

SUMMARY, CONCLUSIONS AND IMPLICATIONS

8.1 INTRODUCTION

This study explored students' and teachers' perceptions of the teaching and learning of school physics and the introduction of technological applications. This section contains summaries and conclusions and compares the ideas of the generative learning model and mini-theories with the findings of the study. Finally, implications for curricula, the classroom, and further research are considered.

The summaries of the findings of the five phases of the research were documented in sections; 3.9, 4.5, 5.5, 6.4, and 7.6.

8.2 SUMMARIES AND COMMENTS

The physics curricula taught in New Zealand senior secondary school classes emphasise the theoretical,experimental and philosophical aspects of the subject. This has resulted in students generally perceiving physics as being the least enjoyable subject, very mathematical and the most difficult. They also felt the least confident in physics. Students however showed interest in the subject, particularly the experimental aspects. The students ascribed these perceptions to the apparent lack of relevance, the influence of the teacher, the mathematics and the formulae involved, the abstractions, and the apparently limited application of the subject. They viewed school physics from a mathematical perspective and this influenced how useful they saw physics in their intended careers. Compared with the boys, sixth form girls perceived physics as being less relevant to their intended careers and more difficult. As the level of physics increased so did the apparent level of complexity, e.g. more vague, complex, difficult, theoretical. For many the usefulness of physics was seen in terms of solving mathematical equations. The findings supported the views of Claxton (1984) that physics taught in a theoretical manner results in students seeing physics in isolation from the rest of their world. New Zealand students' views were consistent with those of physics students from other western countries (section 2.2).

The majority of students opted for physics at school because of their intended career and an initial interest in aspects of physics. There were significant gender differences in career choice, girls being more interested in medical/biological science careers and boys more interested in technical careers.

The findings were also consistent with the main features of the generative learning model, i.e. if historical, technological and everyday aspects are not included in physics lessons, and if links are not made to students' ideas about their world, then students will have a distorted and isolated view of physics. They may have difficulties in learning, and may develop a compartmentalised knowledge structure. However, students appeared to accept this situation because they were told it was necessary and it was appropriate for examination purposes.

If students find that school physics is isolated from their world then the appropriateness of the curriculum needs to be examined. Also, a realistic context for learning needs to be provided. Technological applications which students can relate to, and are interested in, may provide a vehicle for learning physics. It was shown in Chapter 3 that students would respond positively to the introduction of technological applications, particularly medical applications of physics. Preliminary trials revealed that those who were shown applications could remember them and were positive about physics in general.

Students interest in physics and technology can be summarised as follows (Chapter 4):

(1) students were generally interested in those technological applications they saw as directly involving people.

(2) students,particularly girls, preferred those examples which were medical applications.

(3) students (particularly boys) were interested in modern technological devices

(4) students were also interested in technological devices within their environment, e.g. home, school, society.

(5) students were not interested in domestic applications, apart from new technology, e.g. microwave ovens.

(6) students were not interested in remote industrial applications.

(7) students generally were not interested in 'school physics' activities.

(8) boys were more interested than girls in the more technical aspects of devices, especially how they operate and their

use of electronics.

(9) students were interested in those devices which correspond to their intended careers and anticipated needs.

This aspect of the study provided useful guidelines on the type of applications students may attend to in a physics classroom.

In one of the resources produced for New Zealand schools (*Physics at Work in New Zealand*; Jones, 1982a) many of the applications were industrial examples, yet many of the students did not appear to relate to these. Examples used in present physics courses emphasise the interests of the boys. However, in the development of the physics teaching programmes the gender learning differences need to be taken into consideration. This may involve choosing examples where different aspects of the device can be emphasised. For example, concerning medical applications, girls are interested in the human aspects whereas boys are interested in the electronics of devices or how they work. Another alternative is to provide a choice of examples which illustrate the same principle in different devices. Other approaches might be to emphasise the human aspects of the technological application, how the applications relate to the environment, to the country's economy, where they are used, and how they relate to the students' lives.

The study revealed how teachers approached the teaching of senior secondary school physics in New Zealand (Chapter 5). Physics teachers generally have a transmission view of teaching and learning (Watts and Bell, 1984). The teachers' lesson structure was consistent with this view, i.e. a lecture style introduction, with perhaps a demonstration, theoretical problems and occasionally a student experiment. The teachers followed the prescription and the textbooks very closely with the external examinations exerting a major influence. The emphasis was on the the physics concepts and the mathematical language. Student experiments validated a theoretical concept and precise instructions were given. Fensham (1985) noted that this emphasis has resulted in the learning of concepts taking so much time that the excitement of contemporary science and social issues are often overlooked and omitted. The overloaded syllabus was one of the reasons teachers gave for not introducing technological applications. The reasons were (i) time constraints, (ii) too large a syllabus, (iii) teachers' perceptions of school physics, (iv) the examination structure,(v) lack of classroom ready resource material, (vi) lack of personal knowledge. However some teachers did consider that technological applications would help students become more interested in physics and may even help in terms of relevance and understanding, but they felt there were too many constraints.

An informal naturalistic correlation between the interviewed teachers comments (section 5.2) and the students' statements (section 3.4) revealed that students' views of physics were consistent with the way their teachers approached physics teaching. For example, one teacher stated that he had to spend considerable time teaching mathematics in physics, as he thought this was a problem area. All his students who were interviewed responded that physics was mathematics. Many teachers emphasised that school physics was a theoretical subject and this was repeated by the students. Fox (1983) suggested that when there is an overloaded syllabus and where the emphasis in the examination is on the recall of facts, this resulted in surface learning. It was also consistent with simplistic theories of teaching, that is, the straightforward transfer of knowledge, e.g "I taught them so they should know it."

It was analysed in Chapter 6 what students focused on in physics lessons. If students perceived physics as mainly formulae and mathematical manipulation then that appeared to be their focus in the lessons. Technological applications could not be introduced at just any point in the lesson if they were to be remembered by the students. The best student response came when the applications were introduced at the beginning of the lesson, when background information about where they were used, and who used them, was provided, and in cases where the physical principle involved could be taught directly from the device.

Trial units were developed based on the generative learning model and the findings of this study; namely students' present views of physics and their reaction to the inclusion of applications, noting their interests and providing choice of activities, developing resource packages as suggested by the teachers, limiting the extra time involved in the introduction of applications, introducing technological applications as a theme, and providing experiments and individual study packages.

The generative learning model provided a realistic framework for the trial units. These consisted of five phases; focusing, exploration, reporting, formalisation, application.

The teaching package resulted in the teacher in the initial trials being very positive about the approach and attempting to develop other topics along similar lines. Teachers in further trials also reacted positively to the approach.

The students acquired an integrated view of the topics of capacitance and the Doppler effect. They could describe applications, relate them to their world and solve typical school physics problems involving those concepts.

Compared with the previous teaching programmes both teaching packages were considered by the students to be more interesting, easier, relevant to everyday life, enjoyable, technological, and to have fewer calculations and be less mathematical. The major components responsible for these changes appeared to be; technological applications which students were interested in and could relate to, the experiments, the individual projects, the class discussion, finding out for themselves and developing the concepts from the applications and investigations. They were also more confident in attempting traditional problems. The largest change was in those students who were bored or struggling with school physics. There were a few students who did not react positively to this approach. They were already successful in existing physics lessons, expected well-structured lessons and a good set of notes.

8.3 GENERATIVE LEARNING MODEL AND MINI-THEORIES

8.3.1 The trialled teaching approaches and the Generative Learning Model

The technological applications introduced as the theme for a lesson or a series of lessons appeared to be successful in terms of the generative learning model.

The introduction of the appropriate technological application (i.e. one relevant to students' existing knowledge) helped students attend to the learning situation and utilise their existing ideas, i.e. it was engaging. They stated that it was relevant and interesting. The technological applications helped the students to generate links between the selected input and their existing knowledge. The students commented that the applications helped them to learn and remember the physical concepts and also gave them confidence. The applications provided a framework on which they could construct physical concepts. Students were able to test out the constructions they had made through questions, tentative statements and their own investigations. In terms of the generative learning model the most important aspect appeared to be the generation of links between different aspects of existing knowledge and new information, thereby integrating the physics concepts with other knowledge structures. The generative learning model also explained why some students were not so positive about the teaching approach. If their existing knowledge of school physics only related to the formulae and learning the physical concepts, then that is what they selected in the physics lesson.

8.3.2 The trialled teaching approaches and mini-theories[1]

Mini-theories may also account for physics students reactions when the trial units were introduced. Mini-theories represent a belief that our knowledge is modularised (Claxton, 1984, 1985). These modules can be represented as programmes which are packages of processes which determine the way we react to, feel about, perceive, have opinions about, and learn from phenomena within a particular domain. These

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1 This section resulted from discussion with Dr Guy Claxton, Kings College KQC, University of London.

packages will in general determine a stance, mood, point of view and attitudes towards the phenomena. Programmes are therefore linked to a specification of when they are able to be used, and what they are to be used for. The signal that a programme is to be used is called a cue, and what it is to be used for is called a goal. A particular combination of a cue and goal pair results in a specific action. The action may be internal or external. A cue-goal action pair becomes active wherever its condition is satisfied by the data base. The data base is long-term memory or existing knowledge through which all independent cue-goal pairs are filtered.

It is proposed that in a situation where we are required to work or react or respond, we actually initiate a process involving the selection of the appropriate programme based on the currently available stack of goals (within existing knowledge) and the selected features of the environment. Next, the selective description of the environment and the stack of goals interact with each other so that a range of possibilities is selected from the environment. This leads to a focusing, selection, narrowing and perhaps reordering of the goals. Certain options become highlighted because the goals are considered obtainable. This process then works in reverse, so that the narrowed, highlighted set of obtainable goals determines what is perceived from the environment. The associated action now becomes available for application, to add to, modify or otherwise manipulate the information already present in the existing memory or knowledge store.

Relevance is the way in which significance is assigned to things in the environment as a function of the set of goals stored internally. Relevance can only be expressed in terms of the students' existing goals and therefore can not be taught. Teachers can only make a lesson relevant by relating it to the students' existing knowledge.

To explore these ideas further the example of a typical physics student from this study was examined:
When an average student walks into a physics classroom, what is perceived from the environment will depend on the student's existing knowledge of physics lessons and what the student's current goals are. The student will try to relate the many cues, such as teacher, formulae, apparatus etc., to the stack of goals, such as,`help me to understand my world', `relate to my peers', `pass exams', etc. The matching of a cue-set with a particular goal-set dictates which programme will be used. From prior experience the student perceives that the physics cue, i.e. what he or she perceives as being physics, does not relate to many of his or her existing goals. In this case only certain goals will be highlighted as being obtainable. For example,consider the student who needs a pass in school physics for career reasons. The goals influence the cues selected from the environment. Other goals will be placed lower in the order because they are perceived as being unobtainable. With specific cues matching specific goals the programme called `school physics' will run. This programme will contain certain perceptions and feelings of physics, how to learn and what to learn, what is perceived as being a `physics' lesson and what is not, how to react to the teacher, etc. With this programme running certain phenomena during the class will be selectively attended to and others will be rejected. If the student's highlighted goal is solving exam questions dominated by formulae, that is what the student may focus on exclusively. If, however, the cues do not relate to any of the student's range of goals, then a different programme may be started such as `mucking about', `getting approval

from peers', `making fun out of the teachers' comments', or `establishing my reputation as a rebel',(i.e.one of the self-esteem programmes). The selection of one of these programmes determines on which disk is going to be stored the data being presented. If physics is perceived as being difficult, that there is just too much to understand and that it does not fit in with the student's existing knowledge, then the student is likely to learn by rote and soon forget since the new experiences can not be integrated into other knowledge structures.

Physics lessons often follow the order; theory, practical, and then the introduction of technological applications of the theoretical principle at the end. However, in this situation students have tended to remember the formulae and not the applications. In terms of the cue-goal model this situation could be anticipated. The cues at the beginning of the lesson have meant that the `school physics' programme has been loaded by the students. This programme includes students' perceptions about physics and what aspects of a lesson are important. If physics is perceived as being mathematical and of little relevance to the 'real world' then this new information about applications may not fit into the already running programme and therefore will tend to be rejected. The students will not select the cues of technological applications because they have already selected goals like remembering the formulae, or passing the exams. Thus it may be better to introduce technological applications at the beginning of the lesson to try and disrupt the student's expectations. This disruption means that other goals might be considered obtainable and thus other programmes may be run. However there is a pro and a con for the early introduction of technological applications. The pro is that resources and interests which relate to the students' existing ideas are made available in the classroom. This may involve more students talking about and using their ideas. The con is that the students may become confused. The boundaries may be blurred between the domains of school physics and real life. The students may have difficulty deciding which programme to activate. It becomes difficult for them to learn what the teacher intends. They may load the 'everyday life' or 'general discussion' programme and relish chatting about ideas but fail to learn any physics.

Perhaps students show interest in technological applications because they can talk about them. For example, they know that they will not have to a build foetal heart-beat monitor, but it might be desirable to know how it works. Examples of this occurred when students were asked why they considered a particular technological device interesting.

> "It makes you feel brainy just knowing about it."
> "So you can tell other people how it works."
> "So I can tell my father who is an electrician."

The introduction of technological applications can be used as a case study for exploring the idea of 'cue plus goal equals action' and the running of the appropriate programme. To investigate this further the different types of students in a typical senior secondary school physics class need to be identified. Five of the many groups of students within a physics class have been described in this study. These groups are only roles in physics. The first group are academically purposeful students. These students are happy with the existing physics lessons, they are successful, enjoying the mathematical aspects, and are impatient to learn what is required for the examinations. They may be studying physics because of interest or career reasons. The second group take a practical interest in things such as astronomy, electronics, computers, etc. but are also academically able. The third group of students would like to be good at physics, but are struggling with it and probably need a new learning strategy for physics. This group, the great majority, tend to be studying physics because of career reasons. The fourth group of students are interested in motor bikes, some electronics, and are interested in aspects of physics but are not as academically able as the previous groups. The fifth are those students, who may have chosen physics arbitrarily or are filling in time.

Using the cue-goal model of learning each one of these groups will be examined as to how they react to the teaching and learning of physics and the introduction of technological applications.

The academically inclined students have already been successful with existing physics lessons. These students, may concentrate on the type of material that will be in examinations and material they are already confident with. Their goal is to pass exams and to get through the material quickly. A cyclical process selects what cues they respond to. Their determination to meet these goals in physics lessons eclipses their everyday interest in understanding phenomena. Thus they may switch off when applications are introduced. Alternatively, they may try to fit the applications into the present school physics programme, perceive a mismatch and reject them after a short time or store them in a peripheral and unintegrated fashion.

For example:

"This (technological application) is not in the exam."

"It was boring, we just talked about a whole lot of things."

"This is not real physics.

(After technological applications had been introduced) "All we did yesterday was the derivation of the formulae."

In one class students in this category only responded to the formulae. Others felt that the lessons had moved too slowly and they were not given the 'right' answers. Some appeared interested in technological applications for a while then became impatient to 'get on with it' i.e. getting down to the real formulae.

The second group may have a wide range of physics type goals but only one goal (exam success) which has been activated by past physics lessons. Their other 'physics' goals have been given lower priority in school because of the lack of cues within the environment. When technological applications are introduced these goals are given higher priorities. However, this may result in 'outside the classroom' programmes being run, with the student still running a separate physics programme when the standard physics lesson appears again. Alternatively the 'technology outside the classroom' programme starts communicating with the 'school physics' programme and information may be transferred from one to the other to enhance the use of both programmes. If this type of student is more interested in advanced electronics etc. he or she may still keep running the 'school physics' programme if the application is considered simple or mundane.

"I'm not interested in that (foetal heart beat monitor) but the complex electronics might be interesting."

Or in the actual physics lessons

"They (applications) are not worth remembering really."

The third group of students are average at physics. They would like to be better and need to develop a new strategy for learning the subject. The introduction of the appropriate technological applications may be the most beneficial for these people. As was seen earlier when discussing the average student, when the 'school physics' programme is run it satisfies the cues in the environment and the goals of the student, e.g. passing exams. By introducing technological applications at the beginning of the lessons, the third group of students may not switch straight into their 'school physics' programme with its numerous negative affective factors. The range of possible goals may be increased to include, 'help me to make better sense of my world', 'indicates how physics is used', 'shows how physics is used in my chosen career', 'relates to my interests', 'relates to what I already know'. Since a number of goals are available the number of cues is also increased. Instead of the 'school physics' programme being run, an alternative disk may be run such as 'general discussion' programme where students are encouraged to discuss their ideas. The 'real world' programme and the 'school physics' programme may start to link together to formulate a new programme. Hence the introduction of technological applications increases the number of obtainable goals. If the students are having difficulty running the 'school physics' programme the technological applications. with their larger range of goals, may help the students format a new programme which will be easier to store new physics ideas. In other words the technological applications provide the framework for physics ideas:

"It was good being able to link the physics ideas to something useful."

The technological applications may help students <u>attend</u> to the learning situation because there are a larger number of obtainable goals and therefore through the cyclical process there are more cues.

"You sort of paid attention more."

Technological applications may also help in the retrieval of information. For example, thinking about cot deaths and apnoea mattresses may link them to the physics ideas:

"I could remember it because you just had to think of the baby mattress thing."

If this new programme has 'real world' or 'useful for later life' aspects as well as 'school physics' aspects then it may be easier for this new programme to communicate with other programmes within the students' cognitive structure. By being able to switch in the 'lay science' (Claxton, 1984) programme students are more able to bring to physics lessons their existing ideas about how the world operates and have these ideas challenged and developed. The introduction of technological applications and discussion about them would appear to be most beneficial for this group.

Almost a subset of this group is the fourth group. These are people who when in the 'general discussion' mode bring a lot of good ideas to the classroom. These students are basically interested in how devices work. They may enjoy the discussion and learning about this topic but only get a general idea of the devices or just a `working' knowledge, in other words remain in `general discussion' mode, and not learn any physics. The 'school physics' programme still runs. The alternative (as for the third group) is that the technological applications help these students attend to the learning situation, and their existing knowledge is utilised because the number of obtainable goals has increased. A new programme may be formatted.

The final group is those students who are filling in time. They may switch in the 'general discussion' programme which utilises their discussion skills and existing knowledge or they may continue to remain switched off. If they switch in the 'general discussion' programme then there are two options. Either they discuss the technological device in a very general sense and then switch off or they format a new programme of technological applications and physics.

This model of the cue plus the goal formulating an action and the running of a specific program may be useful in predicting novel classroom outcomes. The reaction of the students to the introduction of technological applications in physics lessons appears to be consistent with the underlying ideas behind this model.

8.4 IMPLICATIONS

8.4.1 Implications for the curriculum

This study has revealed that when the theoretical, experimental and philosophical aspects of physics are dominant in an overloaded curriculum then students tend to develop a somewhat isolated and distorted view of the subject. The emphasis tends to be on the transfer of concepts (transmission teaching) which may result in learning difficulties for most students (Fensham, 1985). The present curriculum may provide a good basis for future learning of physics but there are inadequate links provided between the principles taught and how these principles might apply to the world of the student.

In a constructivist view of learning the curriculum should take account of the students' total existing knowledge, i.e. their interests, intended careers, etc, not just their assumed level of conceptual knowledge. School physics needs to become more learner centred and curriculum materials should respond to the needs of all students who are studying physics, not merely those who are continuing to university. To this end topics which relate to students' existing knowledge need to be incorporated and ways of relating the topics to the students should be found, e.g. technological devices, social issues, historical or scientific perspectives. Different teaching and learning strategies that generate links between the sensory input and the learner's existing knowledge need to be developed. In this way the 6th and 7th form physics course could be relevant for those continuing the study to tertiary level and those terminating the study of physics at school. This study revealed positive responses from both teachers and students when a range of approaches and activities were provided. If school physics is to become more attractive to students then the curriculum must be broadened to emphasise not only the theoretical, experimental and philosophical aspects but also the historical, technological and everyday aspects (Osborne and Wittrock, 1985). As this study has shown, when these aspects were incorporated in a framework centred around the generative learning model then there was a positive response from the majority of students and teachers.

Where technological applications come in the lesson structure is important. Teachers' material must provide information on how to approach the teaching of technological applications in a framework of the generative learning model. In the past teachers have been keen to obtain resource material of applications of physics for use in the classroom but its impact has been limited.

If effective physics teaching is to be encouraged then the views of teaching, the role of the teacher and the curriculum should reflect a constructivist view of learning. Available textbooks and examinations also greatly influence what is taught. Textbooks are required that communicate a constructivists perspective of learning. The production of teacher/student guide notes in textbook form, which emphasise just the idealised theoretical aspects, will do little to change students' present perceptions of physics.

8.4.2. Implications for the classroom

This research has illustrated that physics concepts can be introduced to the majority of students in a manner which is relevant to them. The learning involved was characterised by active, constructive and interactive processes (compare Bell, 1985). The key aspect in this is the generation of links between the stimuli and the learners' existing knowledge. This means that topics have to be introduced in such a way so that they relate to the students' existing knowledge and therefore the students attend to the learning situation.

In this study one aspect of existing knowledge, students' interests in technological applications, have been examined. Attention gaining (in terms of generative learning model) activities were introduced; for example, challenging situations, appeal to student interest and future careers, experiments, individual investigations, problem solving, etc. New ideas were being related to the relevant frameworks held by the learner. These activities were more than just providing students with laboratory experience prior to the interaction with the teacher (Renner, 1982; Renner, Abraham and Birnie, 1985). Instead the activities, including laboratory experiences were linked to the technological world of the student and therefore to aspects of their existing knowledge.

The teacher therefore plays a different role from the traditional transmission style. He or she becomes a facilitator and enabler providing information and experiences which will enable students to bridge the gap between sensory input and existing knowledge i.e. providing experiences about which students can ask questions, construct ideas and have these constructions challenged by others and through experiments. The students are provided with a choice of what they would like to learn about that is related to an aspect of their existing knowledge.

In this study the new physics concepts have been embedded in a particular technological theme which students have explored and used to help them construct the physical concept. The result was an integrated knowledge structure, rather than one which was fragmented and isolated from the students' world.

8.4.3 Implications for further research

This study has shown some positive learning outcomes if the relevant links are made to the learner's existing knowledge, thus making school physics more relevant. Technological applications in physics lessons may be only one method of creating these links. Further research could explore the impact of other methods of improving attention and generating links. Other aspects of students' interests and existing knowledge could be explored e.g. conceptual, historical, life of scientists, social issues, cultural, and everyday aspects within a constructivist tradition.

This research has illustrated that a technological approach based on the generative learning model resulted in increased understanding and interest for the majority of students for two short topics. The novelty of the new experiences may have created some of the positive responses. A longer-term study would measure the full effectiveness of this approach. This technological approach may not be suitable for all topics either. A long term classroom evaluation using other topics such as magnetism, electricity, waves and mechanics could further explore both these issues.

One issue that this study has briefly examined is that of gender differences. Most girls in 7th form physics are already interested in aspects of physics and there were so few of them in this study that it was difficult to evaluate gender differences for this alternative teaching approach. Newman's (1987) study has hinted that girls may react more positively than boys. However the small nature of this and Newman's study means that gender differences for this type of teaching approach may not be fully explained. This could be further examined in larger studies using the same teaching units and perhaps with trials in single sex schools.

This study examined in detail how only one teacher changed his approaches to teaching physics. He was an experienced teacher who felt that he had achieved good results in the teaching of physics, however he felt that his teaching could improve. He saw that the technological approach worked, it was beneficial to his teaching and there were also dramatic changes in the students' responses to the lessons. Further research could be undertaken to examine the factors that are involved in a teacher accepting and developing new approaches based on the constructivist tradition. The documentation of successes and difficulties in developing alternative teaching approaches in the senior secondary school could also be explored.

Further research could examine if the findings of this study are applicable in other subject areas, and at different school levels. Could the teaching model (technological focus) developed in this study be used with primary science, form 1-5 science, or at the tertiary level?

There is the problem of how to make teachers aware of technological applications and how to implement them effectively in their teaching. In the past provision of teacher resource material appeared to have minimal effect. The development and evaluation of in-service courses for physics teachers to learn and construct different teaching strategies based on the constructivist tradition could be explored.

The generative learning model provided a useful framework for developing a teaching approach based on technological applications.

It does not however place much emphasis on the affective side of learning. The influence of affective factors, such as, enjoyment, interest, confidence, motivation, on the learning of physics could be examined from a constructivist tradition.

Overall this study has identified the students' and teachers' perceptions of school physics and indicated how these might be changed by introducing appropriate technological applications within a framework based on the generative learning model.

APPENDIX A: SURVEY TO 6TH AND 7TH FORM PHYSICS STUDENTS

(Print size reduced to 90%)

SCHOOL AND CAREER SURVEY

SECTION A

NAME: ______________________

1. SEX Female ( ) Male ( )

2. Do you attend a single-sex or mixed school this year?

   Single-sex ( ) Mixed ( )

3. List the subjects you are taking this year, 1985, in the appropriate columns below:

6th Form	7th Form
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	

4. Thinking about the subjects that you have studied this year how would you rank them in order of enjoyment (i.e. the most enjoyable at the top and the least enjoyable at the bottom).

____

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____

____

5. Rank the subjects you studied this year in order of <u>interest</u> (most interesting at the top and the least interesting at the bottom).

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____

6. Rank the subjects you have studied this year in order of <u>confidence to do well.</u>

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____

7. Rank the subjects you have studied this year in order of <u>difficulty</u> (i.e. the <u>most</u> difficult at the top and the <u>least</u> difficult at the bottom).

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<u>SECTION B</u> (This section deals more specifically with physics)

8. The following is a list of possible reasons for studying physics. Tick the boxes which best apply to you.

I am interested in physics	( )
I found physics interesting last year	( )
I enjoy doing practical laboratory work	( )
I need physics for everyday life	( )
I need physics for my career	( )
I was advised by my parents to take physics	( )

I am likely to score high marks in physics ( )

My friends are taking physics ( )

I was advised by my teachers to take physics ( )

I like the teacher ( )

I had to take physics because of the timetable ( )

I needed another subject ( )

It was recommended to me by a student who had previously taken the course ( )

I enjoyed the physics I did last year ( )

I did well in the physics I did last year ( )

Any other reasons (please specify) ______________________

Now go back and put a second tick in the box ( ), beside the one reason you think is most important.

9.(a) What is your proposed destination for next year, e.g. Technical Institute, Job, University, School etc.

____

9.(b) Have you chosen a career? Yes ( ) Go to Question 10.
No ( ) Go to Question 11.

10. What career have you chosen? ______________________
Go to Question 12.

11. Name the career area in which you are most interested?

____

12. Is a pass in U.E. or U.B. physics required for your career? Yes ( )
No ( )

13. Rank the subjects, you studied this year in order of usefulness for your chosen career (i.e. the most useful at the top and least useful at the bottom).

____

____

____

____

____

14. How important do you consider a knowledge of physics to be for that career. Please indicate with a tick how important or unimportant physics is to your chosen career

Unimportant						Important

15. Why is physics important or unimportant for your chosen career?

____

____

____

SECTION C

16. How do you feel about the physics course this year. Please indicate along the scale.

Boring	:___:___:___:___:___:___:___:	Interesting
Difficult	:___:___:___:___:___:___:___:	Easy
Irrelevant to career	:___:___:___:___:___:___:___:	Relevant to career
Irrelevant to everyday life	:___:___:___:___:___:___:___:	Relevant to everyday life
Unenjoyable	:___:___:___:___:___:___:___:	Enjoyable
Straightforward	:___:___:___:___:___:___:___:	Complicated
Non-mathematical	:___:___:___:___:___:___:___:	Mathematical
Few Calculations	:___:___:___:___:___:___:___:	Many Calculations
Technological	:___:___:___:___:___:___:___:	Theoretical
Clear explanations	:___:___:___:___:___:___:___:	Vague explanations

APPENDIX B: TECHNOLOGICAL EXAMPLES USED IN 7TH FORM INTERVIEWS

(Diagrams and print size reduced to 75-86%)

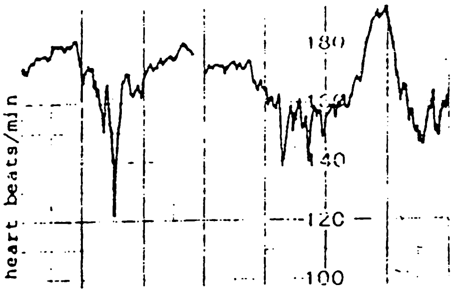
MEASURING FOETAL HEART BEAT

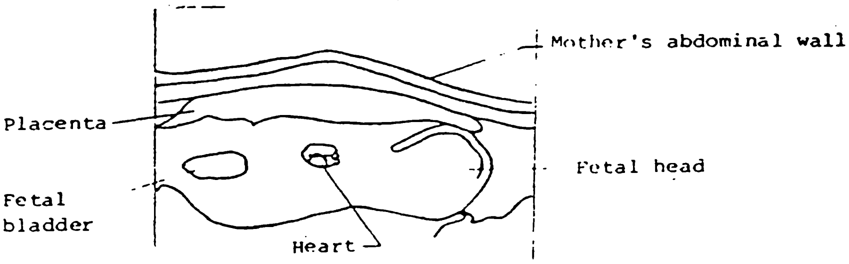
This is an example of how sound waves change in frequency when they are reflected off a moving object (Doppler effect). The heart walls expand and contract so a reflected beam changes in frequency. Prior to the commencement of labour a probe is used to check that the heart is still beating and to monitor it through labour. The frequency of the sound wave is about 5MHz. The device is placed directly in line with the heart. The heart walls have an average velocity of $0.075ms^{-1}$ and the velocity of the ultrasound wave is $1500ms^{-1}$

$$\Delta f = \frac{2fv}{c}$$

$$\Delta f = \frac{2 \times 0.075 \times 5 \times 10^{-6}}{1500}$$

$$= 500Hz$$

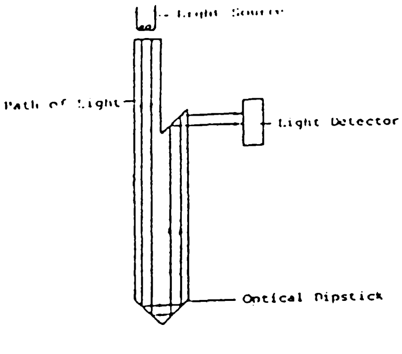




OPTOELECTRONIC LEVEL INDICATOR

An optical dipstick is a perspex rod with a prism shaped end.

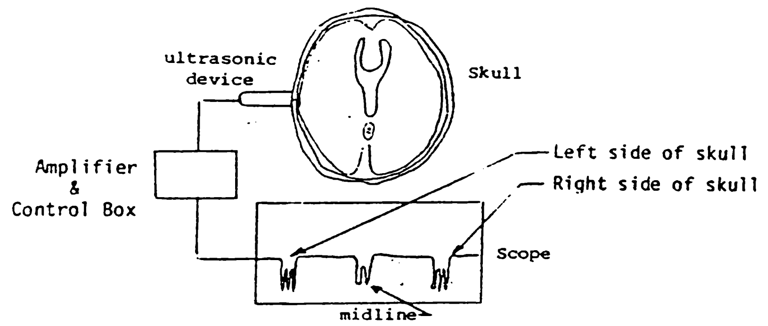
The light source sends a beam of light down the rod which is internally reflected in the prism. When the end is placed in a liquid the beam of light is no longer reflected so less light reaches the photodetector.



DETECTION OF CEREBRAL BLEEDING

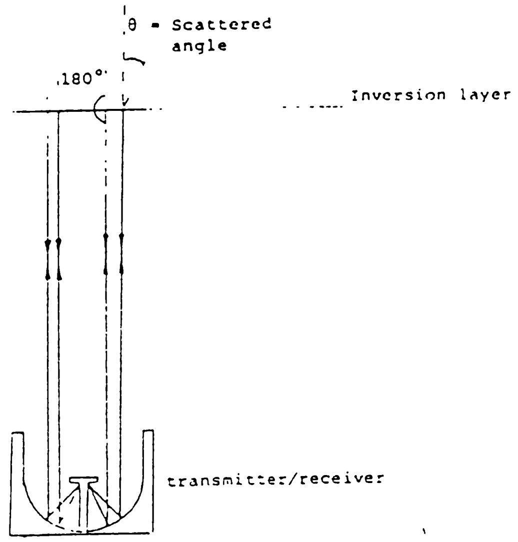
Compression waves are partially transmitted and reflected at different boundaries of tissue density.

A pulse of sound is sent out of the device which is reflected from any interface and the echo is picked up. A simple display can be used to detect bleeding in the brain. The brain has a midline which provides an echo when ultrasound is used. If pressure builds up on one side of the brain the midline will shift away from the middle of the scope.



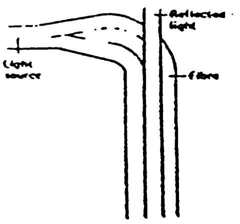
DETECTION OF INVERSION LAYERS

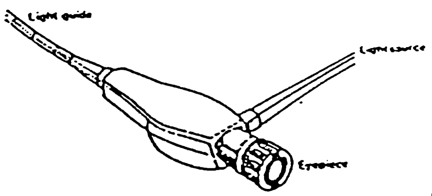
Sound waves will reflect off different temperature layers of air in the atmosphere. A parabolic reflector changes diverging rays into parallel rays. This device can be used to detect the height of the inversion layers of air which cause frosts. In areas where there are a large number of orchards these inversion layers need to be detected and broken up by helicopters or windmills.

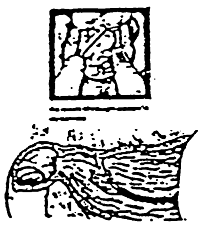


FIBRE OPTICS

Fibre optics allows light to travell down glass or plastic fibres. This enables light to be bent and illuminate such places as the stomach. The reflected light is returned via light pipes to an eyepiece.







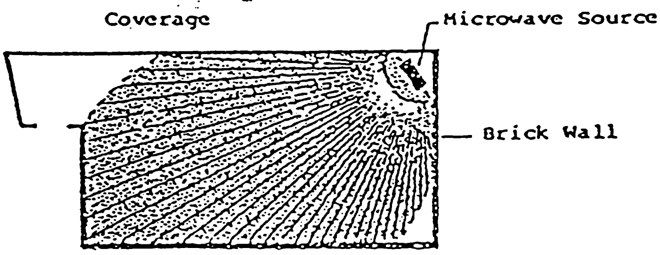
BURGLAR ALARM

This is an example of how the Doppler effect is used to detect intruders. Stationary objects reflect micro **waves back at the same frequency as was transmitted. If there is a moving intruder in the room the waves that are reflected back undergo a frequency change. The device is very sensitive and can pick up very small movements.**

$$\Delta f = \frac{2vf}{c}$$

$$\frac{2 \times 0.5 \times 10^{-10}}{3 \times 10^{-8}}$$

=33 Hz.



BIOMAGNETISM

This is an example of electric fields producing magnetic fields.

The transmission of electochemical impulses along nerves gives rises to small electrical currents. These small electric currents give rise to small magnetic fields.

In the region of the heart there are many nerves and electrical impulses which produce a detectable magnetic field. The size of the magnetic field is between 10^{-12} to 10^{-11} Tesla. The magnetic field produced in the brain is 10^{-14} Tesla. The earth's magnetic field is 5×10^{-5} T and a building is 10^{-8} T.

APPENDIX C: SEMANTIC DIFFERENTIAL RESULTS OF 6TH AND 7TH FORM SURVEYS

Table 40: How senior secondary school physics students feel about the physics course

		6th form N=426	7th form N=168	S.E. 6th form	S.E. 7th form
Boring	- Interesting	4.50	4.34	0.07	0.12
Difficult	- Easy	3.01	2.40	0.06	0.08
Irrelevant to Career	- Relevant to Career	4.85	4.88	0.09	0.16
Irrelevant to everyday life	- Relevant to everyday life	3.80	3.57	0.08	0.11
Unenjoyable	- Enjoyable	4.25	4.19	0.07	0.11
Straight forward	- Complicated	3.16	2.66	0.07	0.10
Non-mathe-matical	- Mathematical	2.19	2.24	0.05	0.07
Few Calculations	- Many Calculations	2.1	2.2	0.05	0.08
Technological	- Theoretical	2.92	2.85	0.06	0.09
Clear Explanations	- Vague Explanations	3.94	3.46	0.08	0.13

S.E. Standard error of the mean

Table 41:How sixth form physics students feel about the physics course.

6th FORM		Mean N=425	S.E.	$Mean_B$ N=296	$Mean_G$ N=127	$S.E._B$	$S.E._G$
Boring	- Interesting	4.50	0.07	4.50	4.61	0.09	0.14
Difficult	- Easy	3.01	0.06	3.27	2.70	0.08	0.10
Irrelevant to Career	- Relevant to Career	4.85	0.09	4.98	4.53	0.11	0.16
Irrelevant to everyday life	- Relevant to everyday life	3.80	0.08	3.80	3.68	0.09	0.14
Unenjoyable	- Enjoyable	4.25	0.07	4.40	4.16	0.08	0.12
Straight forward	- Complicated	3.16	0.07	3.18	2.98	0.08	0.13
Non-mathe-matical	- Mathematical	2.19	0.05	2.20	2.03	0.06	0.08
Few Calculations	- Many Calculations	2.10	0.05	2.09	1.97	0.05	0.07
Technological	- Theoretical	2.92	0.06	2.92	2.92	0.07	0.11
Clear Explanations	- Vague Explanations	3.94	0.08	3.94	3.90	0.10	0.14

S.E. Standard error of the mean

Table 42: How seventh form physics students feel about the physics course.

7th FORM		Mean N=168	S.E.	$Mean_B$ N=118	$Mean_G$ N=50	$S.E._B$	$S.E._G$
Boring	- Interesting	4.34	0.12	4.48	4.08	0.15	0.25
Difficult	- Easy	2.40	0.08	2.65	2.42	0.09	0.18
Irrelevant to Career	- Relevant to Career	4.88	0.16	4.89	4.82	0.20	0.29
Irrelevant to everyday life	- Relevant to everyday life	3.57	0.11	3.58	3.62	0.14	0.21
Unenjoyable	- Enjoyable	4.19	0.11	4.19	3.70	0.12	0.21
Straight forward	- Complicated	2.66	0.10	2.73	2.39	0.10	0.17
Non-mathematical	- Mathematical	2.24	0.07	2.29	2.09	0.08	0.14
Few Calculations	- Many Calculations	2.20	0.08	2.16	1.90	0.08	0.14
Technological	- Theoretical	2.85	0.09	2.85	2.64	0.09	0.16
Clear Explanations	- Vague Explanations	3.46	0.13	4.44	4.98	0.13	0.23

S.E. Standard error of the mean

APPENDIX D: FIRST YEAR UNIVERSITY PHYSICS SURVEY AND RESULTS

(Print size reduced to 86%)

FIRST YEAR PHYSICS SURVEY

1) Please state the courses you are studying at University this year.

____

____

____

____

____

____

2) The following is a list of possible reasons for studying physics this year. Tick the boxes which best apply to you.

I am interested in physics	( )
I found physics interesting last year	( )
I enjoy doing practical laboratory work	( )
I need physics for everyday life	( )
I need physics for my career	( )
I am likely to score high marks in physics	( )
My friends are taking physics	( )
I was advised by my teachers to take physics	( )
I had to take physics because of the timetable	( )
I needed another course	( )
It was recommended to me by a student who had previously taken the course	( )
I enjoyed the physics I did last year	( )
I did well in the physics I did last year	( )

3) Now go back and put a second tick in the box (√√), beside the one reason you think is most important.

4) Have you chosen a career? Yes ( ) Go to 5
No ( ) Go to 6

- -

5) What career have you chosen? ______________________

Go to Question 7

6) Name the career area in which you are most interested.

____

7) Is a pass in first year physics required for your career? Yes ( )

No ( )

8) How important do you consider a knowledge of physics to be for that career? Please indicate with a tick how important or unimportant physics is for your chosen career.

unimportant						important

9) Why is physics important or unimportant for your chosen career?

____

____

____

____

10) How relevant is physics to your chosen career

irrelevant						relevant

11) Will you be continuing with the study of physics to second year level.

(i) Yes ( )

(ii) No ( )

(iii) Not sure ( )

Table 43. First year university physics students' possible reasons for studying physics N=95

	%
I am interested in physics	66
I found physics interesting last year	57
I enjoy doing practical laboratory work	34
I need physics for everyday life	13
I need physics for my career	68
I am likely to score high marks	14
My friends are taking physics	4
I was advised by my teachers to take physics	13
I had to take physics because of the timetable	5
I needed another course	21
It was recommended to me by a student who had previously taken the course	4
I enjoyed the physics I did last year	53
I did well in the physics I did last year	42

Table 44. First year university physics students' most important reasons for studying physics

	%
I am interested in physics	30
I found physics interesting last year	4
I enjoy doing practical laboratory work	2
I need physics for everyday life	1
I need physics for my career	44
I am likely to score high marks	1
My friends are taking physics	0
I was advised by my teachers to take physics	0
I had to take physics because of the timetable	1
I needed another course	8
It was recommended to me by a student who had previously taken the course	1
I enjoyed the physics I did last year	4
I did well in the physics I did last year	3

Table 45. First year university physics students' possible reasons for studying physics for those who chose career as the most important reason. (N=42)

	%
I am interested in physics	63
I found physics interesting last year	32
I enjoy doing practical laboratory work	37
I need physics for everyday life	12
I need physics for my career (only)	15
I am likely to score high marks	7
My friends are taking physics	7
I was advised by my teachers to take physics	12
I had to take physics because of the timetable	5
I needed another course	17
It was recommended to me by a student who had previously taken the course	0
I enjoyed the physics I did last year	29
I did well in the physics I did last year	29

Table 46. First year university physics students' possible reasons for studying physics for those who chose interest as the most important reason. (N=28)

	%
I am interested in physics (only)	0
I found physics interesting last year	75
I enjoy doing practical laboratory work	46
I need physics for everyday life	14
I need physics for my career	61
I am likely to score high marks	21
My friends are taking physics	7
I was advised by my teachers to take physics	4
I had to take physics because of the timetable	0
I needed another course	4
It was recommended to me by a student who had previously taken the course	7
I enjoyed the physics I did last year	82
I did well in the physics I did last year	68

Table 47. First year university students' career choice (N=96)

CAREER CHOICE	N
Architecture	3
Arts	2
Chemistry	6
Commerce	2
Computing	22
Electronics	7
Engineering	28
Flying	1
Geology/Earth science	5
Mathematics	2
Medicine	7
Physical science	9
Surveying	1
Uncertain	1

Table 48. Most important reason for studying physics by career choice.

	Architecture	Arts/Maths Commerce	Chemistry	Computing	Electronics	Engineering	Geology Earthscience	Flying	Medical	Physical Science	Surveying
I am interested in Physics		1	3	7	3	6		1	1	5	
I found Physics interesting last year		2		1			1				
I enjoy doing practical laboratory work				1			1				
I need Physics for everyday life									1		
I need Physics for my career	3	1		5	4	20	2		4	3	1
I am likely to score high marks		1									
My friends are taking Physics				1							
I needed another subject		1	2	3			1		1		
It was recommended to me by a student who had previously taken the course				1							
I enjoyed the Physics I did last year			1	1						1	
I did well in the Physics I did last year				2		2					

Table 49. Importance of physics for a career.

	%					
Unimportant	6	8	24	18	44	Important

	%					
Irrelevant	6	9	27	19	39	Relevant

Table 50. The number continuing with physics and whether a pass is required in first year physics.

CONTINUING WITH THE STUDY OF PHYSICS TO 2ND YEAR

	N	%
YES	29	31
NO	43	45
NOT SURE	23	24

IS A PASS IN FIRST YEAR PHYSICS REQUIRED FOR YOUR CAREER?

	N	%
YES	64	67
NO	27	29

APPENDIX E: INITIAL CAREER DESTINATION OF NEW PHYSICS GRADUATES

Table 51: The initial career destination of physics bachelor graduates

BACHELORS NZ OCCUPATION	1975 1976	1977 1978	1978 1979	1979 1980	1980 1981	1981 1982	1982 1983	1983 1984	Total
Total Graduating (NZ)	58	82	58	51	65	68	72	85	539
Further Study	29	36	29	19	27	33	35	44	252
Teachers College	8	11	4	5	6	7	7	4	52
Overseas Study	1	4	1	0	0	2	0	4	12
Overseas Other Reasons	3	2	6	3	2	2	2	3	23
Study Technical Institutes	0	0	0	1	1	0	2	0	4
Looking for Employment	1	7	6	1	5	2	11	7	40
Armed Services Personnel	1	1	0	1	1	0	1	0	5
Laboratory Technician - Physical Sciences	1	1	1		2	1	0	2	8
Laboratory Technician - Life Sciences	0	1		1		1			3
Civil Engineer	1								1
Electronics Engineer	1				1	1			3
Hospital Technologist	1				1			1	3
Computer Programmer	1	1		3	1	4			10
Secondary Teacher	3	2	3	1	4	3	1	1	18
Factory Manager	1								1
Radio and Television Repairman	1								1
Overseas Employment		1	2	5	2	1	0	2	13
Research Scientist - Physical Scientist		1	1	1	1	1			5
Statistical Research Officer		2						1	3
Lecturer/Tutor Tertiary Inst.		1							1
Management Trainee/Marketing Ass. Consultant		1				1	1	1	4
Production Liaison Officer		1							1
Staff Clerk/Bank Officer		1			1	1		1	4
Statistical Clerk		2							2
Buyer-Wholesale & Retail Trade		1							1
Construction/Labourer (temp.)		2				1	2	1	6
Technical Officer			1						1
Science Technician				1					1
Electronics Technician/Draughtsman				2	1		1	2	6
Actuary				1					1
Systems Engineer				1		1	1		3
Work Study Officer				1					1
Interim Barman etc.				3	2		2	1	8
Pilot					1				1
Computer Operator					2				2
Technical Service Agent					1			1	2
Meteorologist						1			1
Industrial Tools Engineer						1			1

Table 52: The initial career destination of physics honours and diploma graduates

B.SC. HONOURS & DIPLOMA N.Z. GRADUATES OCCUPATION	1975 1976	1977 1978	1978 1979	1979 1980	1980 1981	1981 1982	1982 1983	1983 1984	Total
Total Graduating	30	20	19	17	15	21	30	26	178
Teachers College	1	0	2	1	1	0	1	0	6
Further Study	17	14	11	6	7	9	18	13	95
Overseas Study	4	1	1	5	2	0	2	6	21
Overseas Other Reasons	1	0	1	0	2	1	4	0	9
Overseas Employment	1	0	0	0	0	0	0	0	1
Looking for Employment	1	2	2	1	1	0	0	0	7
Meteorologist	1			1	1	1			4
Research Scientist - Physical Science	1		2			2		1	6
Mechanical Engineering Technician	1								1
Traffic Engineer	1								1
Geophysicist		1							1
Interim Labourer		1					2		3
Metal Smelting (Temp.)				1					1
Physicist					1				1
Laboratory Technician Physical Sciences						1	1		2
Electronics Technicians						1		1	2
Computer Research						1			1
Computer Programmer						1		1	2
Electronics Engineer							1		1
Actuary							1		1
Patent Examiner								1	1
Public Secondary Teacher								1	1
Demonstrator Teaching Asst.								1	1

Table 53: The initial career destination of physics master's graduates

MASTERS OF SCIENCE N.Z. OCCUPATION	1975 1976	1977 1977	1978 1979	1979 1980	1980 1981	1981 1982	1982 1983	1983 1984	TOTAL
Total Graduating (NZ)	12	22	18	24	14	18	30	16	154
Teachers College	0	1	0	1	1	1	3	0	7
Further Study	2	3	5	4	3	2	8	0	27
Overseas Study	3	3	2	9	3	3	4	5	32
Overseas Other Reasons	0	4	2	0	1	1	2	0	10
Overseas Employment	1	0	0	0	1	0	0	0	2
Looking for Employment	1	4	2	3	0	3	0	5	18
Physicist		1			1			1	3
Geologist/Geophysicist		3					1	1	5
Research Scientist - Physical Science	2	1	3	1	2		3	2	14
Electronics Technician				1					1
Hospital Technologist									
System Engineer								1	1
Agronomist	1							1	
Public Secondary Teaching	1			1		1			3
Computer Programmer		1	1						2
University Lecturer		1					1		2
Meteorologist				2					2
Systems Analyst				1					1
Research and Development Manager							1		1
Interim Not Physics				1		1			2
Technical Rep.							1		1
Study at Tertiary Institute			1						1
Demonstrator Teaching Asst.			1						1
Armed Services Personnel									
Seismologist									
Laboratory Technician									
Electronics Engineer					1	1			2
University Technician									
Lecturer Tertiary					1				1
Research Scientist Life Science						1			1
Laboratory Technician Life Science						1		1	2
Actuary						1			1
Market Research Analyst						1			1
Insurance Clerk						1			1

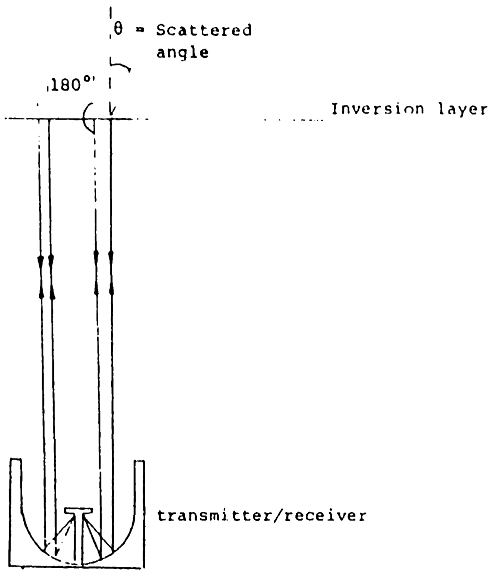
Table 54: The initial career destination of physics doctoral graduates

PH.D. DOCTORAL OCCUPATION	1975 1976	1977 1978	1978 1979	1979 1980	1980 1981	1981 1982	1982 1983	1983 1984	TOTAL
Total Graduating	11	4	10	3	9	11	12	4	64
Study Overseas	2	1	4	1	1	3	2	1	15
Employment Overseas	2	1	1		3	2	6	2	17
Looking for Employment	1	1			1				3
Study Further									0
Going Overseas Other Reasons			3		3	3			9
Meteorologist	1								1
Research Scientist - Physical Science	4		1	2		2	2		11
Educational Research Officer or Fellow	1								1
Lecturer		1	1				1	1	4
Seismologist					1				1
Technical Systems Analyst						1			1
Not available for Employment (Retired)							1		1

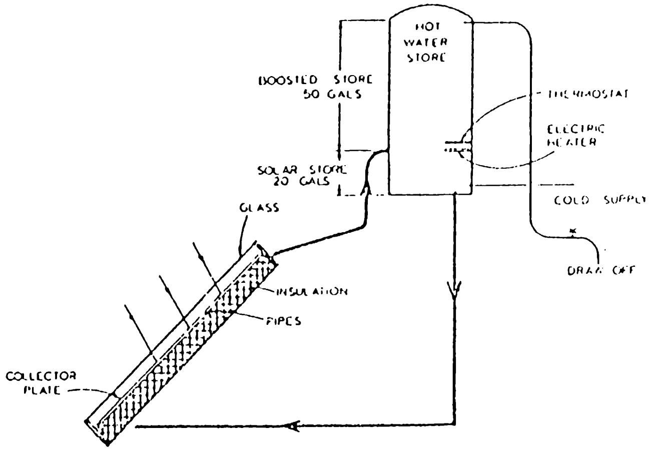
APPENDIX F: CARDS USED IN STUDENT INTEREST INTERVIEWS

(Diagrams reduced to 75-86% of original)

How the different temperature levels in the air can be detected.



How a solar water water heater works.

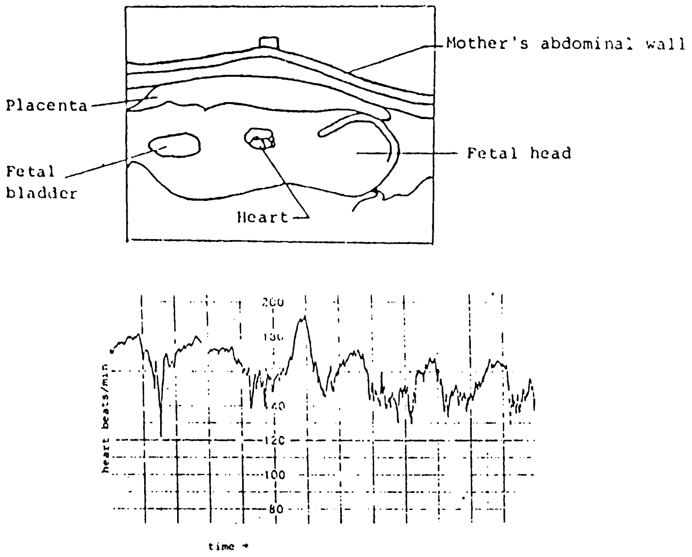


Finding out about the kinetic energy of a moving trolley.

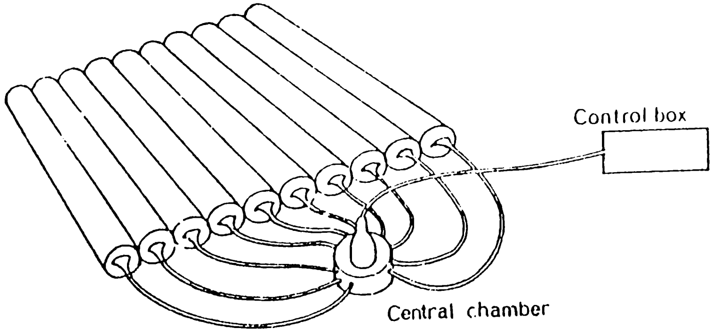
How a refrigerator works.

How a vacuum cleaner works.

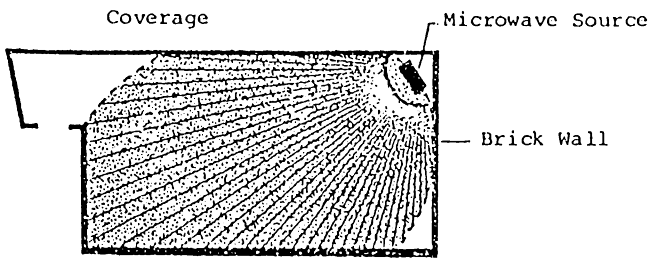
How doctors can measure foetal heart beat.



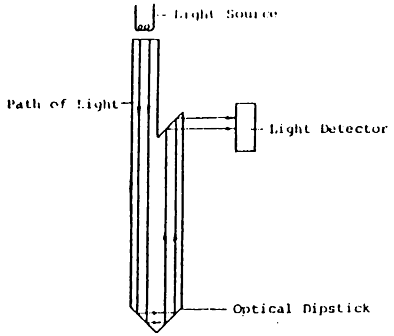
How a special mattress tells the nurses when a new born baby stops breathing.



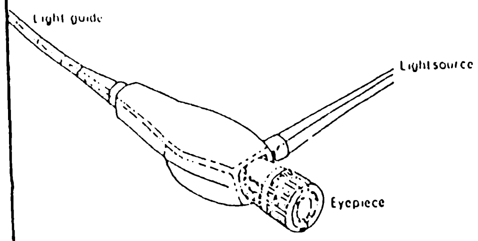
How a household burglar alarm works.

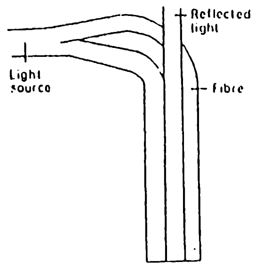


How light rays can be used to detect the level of petrol in large holding tanks.

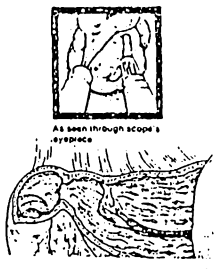


How doctors can see into a patient's stomach using light pipes (fibre optics).

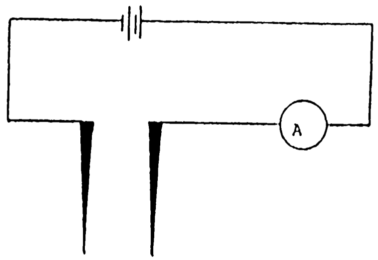




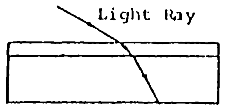
Stomach Surgery



How the purity of water is measured.



How by measuring the kiwifruit sugar content the orchardist can tell exactly when the kiwifruit is ready to be picked.



% sugar	n liquid (approx)
0	1.33
10	1.35
20	1.36
30	1.38
40	1.4
50	1.42
60	1.44
70	1.46
80	1.49
85	1.5

APPENDIX G: SURVEY AND RESULTS OF STUDENT INTEREST IN TECHNOLOGICAL APPLICATIONS

(Print size reduced to 86%)

INTEREST SURVEY

This is a survey to find out what you might be interested in finding out more about. There are no right or wrong answers, it is your own personal choice. There are five different categories you can choose:

(i) *Uninterested*

(ii) *Not Sure*

(iii) *Slightly Interested*

(iv) *Interested*

(v) *Very Interested*

Put a tick in the square which you think best describes how interested you would be to find out more about a particular topic.

For example

How interested would you be in finding out more about: -

	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
1. How an automatic toaster works:			✓		

This person was slightly interested in how an automatic toaster worked.

	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
2. How light bulbs work:	✓				

This person was uninterested in finding out how a light bulb worked.

Please fill in the following information: (Please tick the appropriate square)

FORM 4th ☐ 5th ☐ 6th ☐

FEMALE ☐ MALE ☐

CAREER CHOICE ____________________

How interested would you be in finding out more about:

1. How solar water heaters work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

2. How refrigerators work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

3. How a special mattress tells if a baby stops breathing (cot death):

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

4. How a vacuum cleaner works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

5. Finding out about the kinetic energy of a trolley in a lab.:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

6. How the purity of water is measured:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

7. How the sugar content of kiwifruit is measured using light rays:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

8. How a household burglar alarm works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

9. How a microwave oven works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

10. What makes a rainbow appear:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

11. How a bicycle pump works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

12. How a transistor radio works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

13. How doctors use light pipes to see into a patient's stomach:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

14. How motor cars work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

How interested would you be in finding out more about:

15. How nuclear powered ships work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

16. What gravity is:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

17. How light bends:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

18. How doctors monitor a fetal heart beat (helps to save a life):

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

19. How speed detectors work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

20. How doctors measure blood flow:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

21. Communication Satellites in space:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

22. Measure the temperature inside the kiln at N.Z. Steel:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

23. How a microphone works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

24. Finding out how the Huntly power station works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

25. How a radiographer uses an X-ray machine:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

26. Measuring the forces on a moving object:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

27. Finding out about different types of energy:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

28. How lasers work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

29. How muscles in the human body work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

30. How doctors can tell if there is bleeding in the brain:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested

STUDENTS' RESPONSES
How interested would you be in finding out more about:

%

	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
1. How solar water heaters work:	27	15	35	22	1
2. How refrigerators work:	30	18	39	12	1
3. How a special mattress tells if a baby stops breathing (cot death):	8	5	21	40	27
4. How a vacuum cleaner works:	43	18	31	7	1
5. Finding out about the kinetic energy of a trolley in a lab.:	55	17	21	6	1
6. How the purity of water is measured:	20	13	39	24	5
7. How the sugar content of kiwifruit is measured using light rays:	16	12	25	35	11
8. How a household burglar alarm works:	10	9	34	35	12
9. How a microwave oven works:	10	7	30	37	16
10. What makes a rainbow appear:	21	8	33	27	10
11. How a bicycle pump works:	60	14	20	6	0
12. How a transistor radio works:	14	9	33	30	14
13. How doctors use light pipes to see into a patient's stomach:	10	7	22	40	2[illegible]
14. How motor cars work:	11	9	22	29	28

How interested would you be in finding out more about:

15. How nuclear powered ships work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
21	9	18	28	24

16. What gravity is:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
28	15	36	19	3

17. How light bends:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
23	16	36	19	7

18. How doctors monitor a fetal heart beat (helps to save a life):

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
8	11	24	33	23

19. How speed detectors work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
15	12	33	27	12

20. How doctors measure blood flow:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
18	14	32	27	9

21. Communication Satellites in space:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
18	9	27	28	18

22. Measure the temperature inside the kiln at N.Z. Steel:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
54	16	21	7	2

23. How a microphone works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
23	17	36	19	5

24. Finding out how the Huntly power station works:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
37	13	29	16	4

25. How a radiographer uses an X-ray machine:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
15	12	31	28	14

26. Measuring the forces on a moving object:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
47	16	27	8	3

27. Finding out about different types of energy:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
34	19	31	13	3

28. How lasers work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
9	7	25	32	26

29. How muscles in the human body work:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
9	7	30	32	21

30. How doctors can tell if there is bleeding in the brain:

Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
12	7	25	29	27

GIRLS' RESPONSES

How interested would you be in finding out more about:

%

	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
1. How solar water heaters work:	33	20	37	12	0
2. How refrigerators work:	32	19	42	8	0
3. How a special mattress tells if a baby stops breathing (cot death):	1	1	12	43	41
4. How a vacuum cleaner works:	44	16	30	6	1
5. Finding out about the kinetic energy of a trolley in a lab.:	60	16	19	4	1
6. How the purity of water is measured:	18	14	42	22	3
7. How the sugar content of kiwifruit is measured using light rays:	13	11	31	36	8
8. How a household burglar alarm works:	10	13	37	34	5
9. How a microwave oven works:	11	6	32	37	14
10. What makes a rainbow appear:	7	7	34	36	14
11. How a bicycle pump works:	56	15	24	4	0
12. How a transistor radio works:	14	12	35	28	10
13. How doctors use light pipes to see into a patient's stomach:	7	6	21	37	27
14. How motor cars work:	18	15	30	20	16

How interested would you be in finding out more about:

%

	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
15. How nuclear powered ships work:	27	15	30	20	16
16. What gravity is:	23	19	36	19	2
17. How light bends:	19	16	38	21	6
18. How doctors monitor a fetal heart beat (helps to save a life):	1	6	17	39	35
19. How speed detectors work:	20	17	38	22	3
20. How doctors measure blood flow:	9	9	30	37	14
21. Communication Satellites in space:	24	14	28	21	14
22. Measure the temperature inside the kiln at N.Z. Steel:	63	17	15	3	1
23. How a microphone works:	27	19	39	14	1
24. Finding out how the Huntly power station works:	43	14	29	11	2
25. How a radiographer uses an X-ray machine:	9	12	31	30	17
26. Measuring the forces on a moving object:	51	16	25	7	1
27. Finding out about different types of energy:	38	22	28	12	1
28. How lasers work:	14	11	29	28	17
29. How muscles in the human body work:	4	4	28	33	29
30. How doctors can tell if there is bleeding in the brain:	4	3	18	34	39

BOYS' RESPONSES

How interested would you be in finding out more about:

%

Item	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
1. How solar water heaters work:	20	12	34	32	3
2. How refrigerators work:	29	16	38	15	3
3. How a special mattress tells if a baby stops breathing (cot death):	14	9	29	38	11
4. How a vacuum cleaner works:	44	20	26	9	1
5. Finding out about the kinetic energy of a trolley in a lab.:	49	16	23	9	3
6. How the purity of water is measured:	21	13	35	23	7
7. How the sugar content of kiwifruit is measured using light rays:	19	12	20	35	14
8. How a household burglar alarm works:	10	6	30	35	18
9. How a microwave oven works:	9	9	29	35	18
10. What makes a rainbow appear:	35	10	33	16	6
11. How a bicycle pump works:	63	13	16	7	0
12. How a transistor radio works:	13	5	33	32	17
13. How doctors use light pipes to see into a patient's stomach:	13	8	23	32	23
14. How motor cars work:	5	3	14	38	40

How interested would you be in finding out more about:

%

Item	Not Interested	Not Sure	Slightly Interested	Interested	Very Interested
15. How nuclear powered ships work:	15	6	16	33	30
16. What gravity is:	31	11	34	19	5
17. How light bends:	25	15	34	17	8
18. How doctors monitor a fetal heart beat (helps to save a life):	15	17	32	28	9
19. How speed detectors work:	11	8	28	33	20
20. How doctors measure blood flow:	27	18	35	16	4
21. Communication Satellites in space:	13	5	27	33	22
22. Measure the temperature inside the kiln at N.Z. Steel:	43	15	28	11	3
23. How a microphone works:	18	15	33	22	10
24. Finding out how the Huntly power station works:	30	13	28	22	7
25. How a radiographer uses an X-ray machine:	22	12	30	26	10
26. Measuring the forces on a moving object:	42	15	30	9	5
27. Finding out about different types of energy:	29	15	35	15	5
28. How lasers work:	4	5	19	36	36
29. How muscles in the human body work:	14	10	32	31	13
30. How doctors can tell if there is bleeding in the brain:	20	11	31	25	13

Statistical analysis of interest data

Rank sum test applied to grouped data.

This test is used when the data is not normal.

T is the sum of the ranks of the experimental group.

$$Z = \frac{T - \frac{n(n+m+1)}{2}}{\sqrt{\frac{nm \times (n+m+1)}{12}}}$$

n = total number in group one.

m = total number in group two.

APPENDIX H: SURVEY SENT TO PHYSICS TEACHERS

(Print size reduced to 80-90% of original)

SCIENCE CENTRE

A RESOURCES AND EQUIPMENT CENTRE DEVELOPED IN THE INTERESTS OF BETTER SCIENCE TEACHING
BY THE DEPARTMENT OF EDUCATION, AUCKLAND SCIENCE TEACHERS AND THE SECONDARY TEACHERS COLLEGE

- November 1985

Senior Physics Teacher(s),
New Zealand Secondary Schools.

Dear Colleague,

We write to ask your help in an effort to assist physics teaching and learning in New Zealand.

Some years ago the Science Centre published a resource book "Physics at Work in New Zealand" by Alister Jones, University of Waikato. This work described modern technological applications of physics principles in areas of industry, medicine, agriculture and scientific research in New Zealand. Alister is presently engaged in further research in this area and we are considering a revision of this book and investigating the provision of additional resources.

This survey seeks to explore the place of technological examples in our present-day physics teaching and the desirability of providing further materials for students and teachers. We hesitate to impose on your time at this busy period of the year but hope that you will want to guide the direction of this project. We thank you for assistance and would welcome any further comment you may wish to make.

Could you return the enclosed questionnaire in the stamped, addressed envelope provided by 30 November 1985.

With kind regards.

Yours sincerely,

Colin Percy
Science Centre Director
Secondary Teachers College

Alister Jones
B.P. Fellow 1985/86
University of Waikato

Enclosure:

ADDRESS: SECONDARY TEACHERS COLLEGE, 60 EPSOM AVENUE, EPSOM, AUCKLAND
CORRESPONDENCE: DIRECTOR, SCIENCE CENTRE, SECONDARY TEACHERS COLLEGE,
PRIVATE BAG, SYMONDS STREET, AUCKLAND 1. TELEPHONE: (09) 686 179

A. QUESTIONNAIRE ON MODERN TECHNOLOGICAL APPLICATIONS IN PHYSICS TEACHING

SECTION ONE: INFORMATION ON PARTICIPANTS

Please complete the following information.

Please Tick

1. To what level of physics class do you teach?

Form 6	Form 7

2. As of December 1985 how many years of full-time physics teaching will you have completed?

3. Is physics your major teaching subject?

Yes	No

If not, what is your major teaching subject?

....

4. Was physics your major subject of study at the tertiary level?

Yes	No

If not, what was your major subject?

....

5. To what tertiary level did you study physics?

None	Stage 1	Stage 2	Stage 3	ABOVE M.Sc/B.Sc(Hons

6. Do you have work/research experience outside University/Teaching?

Yes	No

If yes - in what area was this?

.... [ ] years.

OPTIONAL:

This is an anonymous questionnaire but if you would like to identify yourself and/or your school please do so in the space below.

NAME:..

SCHOOL:..

SECTION TWO: TECHNOLOGICAL APPLICATIONS IN FORM 6-7 PHYSICS TEACHING

Some teachers we have talked to have made the following statements about using or showing modern technological applications of physics principles in their 6th or 7th Form physics teaching.

Please indicate with a tick how you feel about each of the statements. If you wish to comment please do so in the space provided at the end of this section.

		Strongly Disagree				Strongly Agree
2.1	"Students need to know about technological applications to understand physics".	1	2	3	4	5
2.2	"Technological applications are difficult to introduce because of the topics in the present syllabus".	1	2	3	4	5
2.3	"There is not enough time to introduce technological applications".	1	2	3	4	5
2.4	"There is no point in introducing technological applications because they are not in the exam".	1	2	3	4	5
2.5	"There is too much extra work required to include technological applications in my teaching".	1	2	3	4	5
2.6	"Technological applications help the students to be more interested in physics".	1	2	3	4	5
2.7	"There is a shortage of good examples of technological applications available to teachers.	1	2	3	4	5
2.8	"Technological applications of physics are really covered in experimental work".	1	2	3	4	5

<u>Comment on Section Two</u>: Introducing Technological Applications in physics teaching.

....

....

....

....

....

....

....

....

....

....

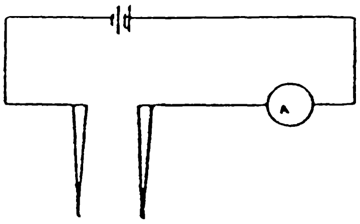
EXAMPLES OF MODERN TECHNOLOGICAL APPLICATIONS

Example 1

MEASUREMENT OF WATER PURITY

Whether a substance will conduct an electric current depends on the number of free electrons and ions present. This principle is used to measure the purity of water.

Pure water does not conduct electricity but water for everyday use contains contaminates which will allow for flow of electrons.



The device used to measure the purity of water consists of two metal probes about 5-7 cm apart connected in a circuit with a power supply and an ammeter.

When impure water comes in contact with the probes the current is measured by the ammeter. The greater the measured current the less pure is the water.

This method can also be used to measure the height of conducting liquids when they are contained in large sealed tanks.

Example 2

MEASUREMENT OF BLOOD FLOW

The principle of the Doppler effect can be used to measure blood flow in arteries and veins. A small hand held Doppler probe containing an ultra-sonic transmitter is used by a G.P. or a cardiovascular surgeon to detect vascular disease, constriction within the circulatory system and the position of veins and arteries.

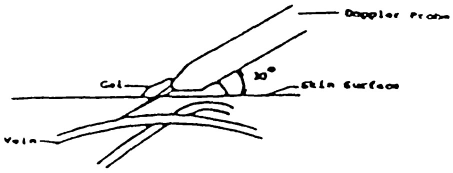
The transmitted signal, usually in the range of 10 MHz, is reflected back from the red blood cells flowing in the blood. The velocity of the red blood cell modifies the frequency of the reflected wave. The average velocity of red blood cells flowing in a large artery is typically 0.3 ms^{-1}. The velocity of the ultrasonic transmission is usually in the region 1500 ms^{-1}.

The angle the transmitter receiver is placed relative to the artery affects the quality of the signal. The smaller the angle the better the signal

$$\Delta f = \frac{2fv\cos\theta}{c}$$

$$= \frac{2 \times 1 \times 10^7 \times 3 \times 10^{-1}}{1500} \cos\theta \text{Hz}$$

$$= 4 \times 10^3 \cos\theta \text{Hz}.$$



The frequency change is much smaller for smaller arteries and veins where the blood flow is slower. The signal is usually detected audibly.

Example 3

TILTING BINS

At the Tiwai Aluminium Smelter faulty aluminium moulds are placed in large bins. When the bins are full they are of course very heavy and difficult to tip. A simple method is therefore required to empty these heavy bins.

On these bins the centre of mass changes as the bins are filled. When the bin is empty the centre of mass is at A, when it is full the centre of mass is at B and the bin tips easily. This is designed so that when the bin is full, by releasing the holding pin, the bin will rock forward displacing the metal. When the bin is empty the centre of mass is at A and the bin tilts back into its original position, and the holding pin secures it.

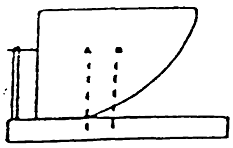


Fig. 1a

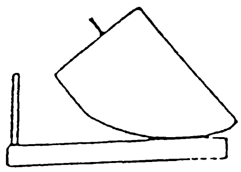


Fig. 1b

SECTION THREE: USING TECHNOLOGICAL APPLICATIONS

The previous page shows three examples of modern technological applications.

3.1 How often would you use examples of this kind in your teaching?

	Not at all	Once a week	Once a fortnight	Once a month	Once a term	Once a year	Uncertain
F6							
F7							

Comment: ____

____

____

____

3.2 Which texts or resource books do you use?

Form 6 ____

____

____

____

Form 7 ____

____

____

____

3.3 Would you like to introduce more technological examples into your physics teaching?

Yes	No

3.4 Please tick (more than one if you wish) which change(s) you think would be most effective in encouraging teachers to use more modern technological examples in their teaching?

Clear indication from physicists that such an approach is desirable. ☐

Change in syllabus emphasising this approach. ☐

Provision of resources based on such examples. ☐

e.g. O.H.P. Transparencies ☐
Student readers ☐
Videos ☐
Student workbook ☐
Teacher guide material ☐
Assessment items ☐

Greater emphasis on applications in examination questions. ☐

In-service courses ☐

Visits by science advisers. ☐

Comment on 3.4: ____

____

____

____

____

____

____

SECTION FOUR: EVALUATION OF 'PHYSICS AT WORK IN NEW ZEALAND'

4.1 Are you aware of this book?

Yes	No

If NO - we have no further questions. Thank you for your time and interest in completing this questionnaire.

If YES - please continue:

4.2 Do you have copies:

- In the school library ☐
- As a class set ☐
- As a class textbook ☐ (Please tick)
- For teacher reference ☐
- As a personal copy ☐

'Physics at Work in New Zealand' was intended primarily as a teacher resource. Could you comment on these points?

4.3 How useful do you consider it in your teaching?

Not useful	1	2	3	4	5	Useful
	☐	☐	☐	☐	☐	

Why? ____

____

4.4 How would you rank the difficulty level of the examples in the book?

(a) For teacher understanding

Difficult	1	2	3	4	5	Straightforward
	☐	☐	☐	☐	☐	

(b) For pupil understanding

Difficult						Straightforward
	1	2	3	4	5	

Why? ____

____

4.5 How well do the examples in the book relate to each topic in the syllabus?

Don't relate						Relate well
	1	2	3	4	5	

4.6 How easily do the examples in the book fit into your lessons?

Not easy						Easy
	1	2	3	4	5	

Why? ____

____

4.7 How much does the material in this book need to be modified by you before you can use it in class?

Considerably						Not at all
	1	2	3	4	5	

In what ways is modification necessary?

____

____

____

4.8 Would you be interested in using support material based on the examples described in 'Physics at Work in New Zealand'?

	YES	NO
Student readers		
Student workbook		
Videotapes		
O.H.P. Transparencies		

Could you underline the one resource you would find most useful?

4.9 Any other comments concerning physics teaching resources?

____

____

____

____

____

____

____

____

Thank you for the time you have taken and the interest you have shown in completing this questionnaire. We hope that the results will assist in providing more and better resources for physics teaching and learning in New Zealand.

* * * *

APPENDIX I: THE TEACHING PACKAGES

SCIENCE AND TECHNOLOGY APPROACH TO TEACHING ELECTRICAL CAPACITANCE (7th form)

Teachers notes and student work sheets.

Equipment supplied:

1) Camera flash gun
2) Cut away Xenon flash tube circuit
3) Variable Capacitive Bridge
4) Circuit boards and components (4).
5) Signal generator and model of controller for Apnoea mattress
6) Slides

MAKING A BIG FLASH

TEACHER NOTES[1]

Introduction

Start the lesson with a camera flash. Encourage the students to ask questions about what is happening when the flashgun is being used.

What do we know about camera flash guns? (Typical student questions)

Why is it a flash and not a constant light?
How is the light able to be so bright?
[Examine the type of lamp used.]
Why does it require a break between flashes?
[Try holding your finger down on the switch.]
What is involved in the circuit?
Can batteries just drive the flash?
[Show lamp in the circuit.]
What size batteries does it use?
What is inside the flash unit?
What is the range of the flash?

Try a few demonstrations. How do the switches work? Try putting batteries across the lamp,etc.

Examination of a Xenon Flash Tube - carry out a few demonstrations of the unit.

The circuit is basically a series of resistors, a flash tube which requires a high voltage to fire, and a transformer to increase the voltage. However the circuit does not work just by holding the switch down i.e. when the switch is closed there so current flowing around the circuit. There is something else in the circuit - a capacitor.

What do the students already know about capacitors? [Student question]
What questions do they have about capacitors?

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1. These are guide notes only. The actual lesson structure is left to the teacher.

TEACHER DEMONSTRATION

Examine the capacitor in the flashing circuit. How can we find out more about the capacitor. Try out some of the students ideas in the investigation. Allow the students to control the investigation as much as possible.

Show the capacitor in circuit with markings i.e. 350V 20μF etc. What do these mean? Show several similar capacitors. Explain the unit of Farads i.e. pF nF μF mF F.

An example of the sequence of further investigations.

- Connect a DC voltmeter across the marked terminals. Open and close the switch.
- Connect oscilloscope across the terminals and notice the shape of the graph when the switch is opened and closed.
- Turn the main switch off and show that there is still energy and charge within the circuit by pushing the trigger switch down.
- Turn the power supply on again then switch off. Make sure DC voltmeter is across the capacitor. Then discharge the capacitor and hold the switch down. Show the decay of the capacitor.
- (This can also be shown on the oscilloscope by slowing the trace right down). A graph of this can be drawn by the students.
- Put the leads across the xenon tube to examine firing voltage.
- Show the photograph and the chart recording of the charging and discharging of the capacitor.

STUDENT INVOLVEMENT (Class Discussion)

- Get the students to discuss or write down what they know already about capacitors from examining the circuit.

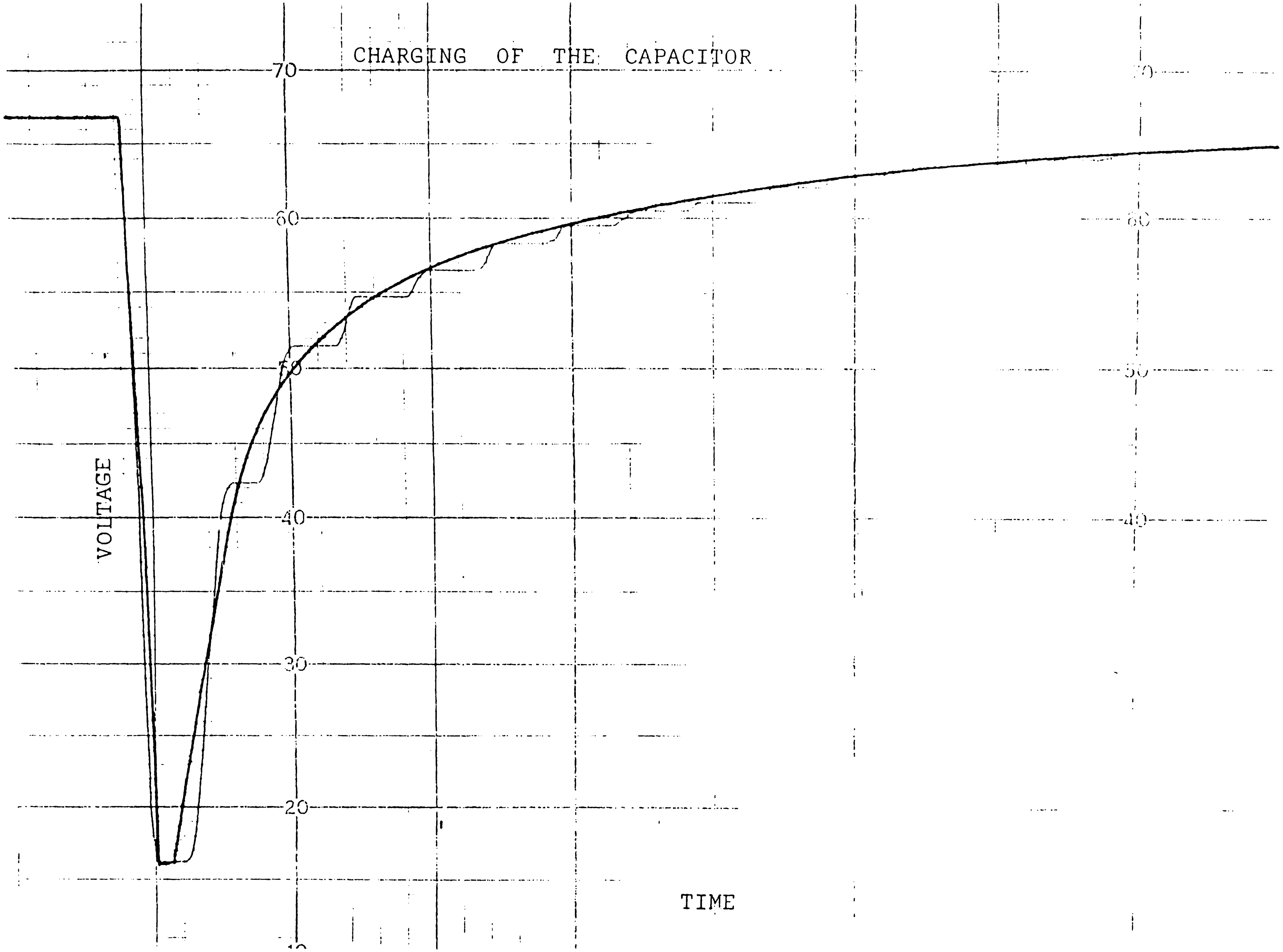
An example of what they might know.

- Able to store charge i.e. charge and energy.
- Takes a while to accumulate this charge.
- Able to draw the graphs charging and discharging of a capacitor through a resistor (Voltage versus time).

TEACHER DEMONSTRATION

Demonstration of charge-discharge of 2200μF capacitor from DC supply.

- Sparking against metal objects
- Lighting a bulb directly from a capacitor.
- Then further class discussion of capacitors.



CHARGING OF THE CAPACITOR
70
60
50
40
30
20
VOLTAGE
TIME

Student Activity - Camera Flash Gun Experiment

Class summaries about what they know already about capacitors. List some of the things that you (students) would like to find out about the camera flash gun and capacitors. Then use separate student experiment sheets and the circuit board guides.

Findings (objectives)

Capacitance measured in farads.

Capacitor holds charge

Takes time to charge and discharge a capacitor through a resistor.

Drawing of charging and discharging curves (voltage versus time).

Accumulation of charges on plate. (see energy explanation.)

Relationship between Q, C, V $C = Q/V$

Energy of capacitor. $\frac{1}{2}$ QV (see separate sheet for development)

How circuit works. Discharge of capacitor.

Passes AC

Parallel plate capacitor - separation of charge.

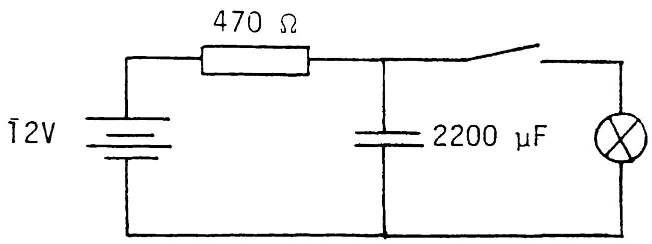
Drawing of current time graphs of charging capacitor.

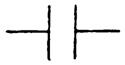
EXPERIMENT

Making a model of a camera flash gun

This experiment sheet is a guide only. You may carry out other investigations that will help you answer any questions you have about camera flash guns and capacitors.

Let's find out how much difference a capacitor makes in a circuit. Consider this circuit of a resistor, a switch, capacitor and lamp.



The symbol  represents a capacitor. Does this symbol give you any idea what a capacitor might look like?

Construct this circuit on the circuit board. Open the switch in your circuit for approximately 20s then close it. Record what happens.

Place a voltmeter across the capacitor in each case to find out what is happening to the capacitor. Record your findings - be descriptive.

Does it matter if you open and close the switch very quickly or if you leave switch open for a 30s or so? Does it make any difference if the switch is left open for longer?

Repeat with two other different capacitors in the circuit and record what happens. Use a 100μF and a 470μF. Complete Table 1. Try any others you wish.

Table 1

V(Same)	Capacitor	Charge (Brightness of light)
"	100μF	
"	470μF	
"	1000μF	

If we reduce the voltage across the capacitor what happens to brightness of the lamp. Try three different voltages using the 1000μF capacitor. Record your results: in table form Voltage, Capacitance, Brightness.

What can you conclude from these results?

Teacher Direction

$C \alpha Q$ when V same

$Q \alpha V$ The larger the capacitor the more charge it holds for the same potential.

Conclude that $Q = CV$

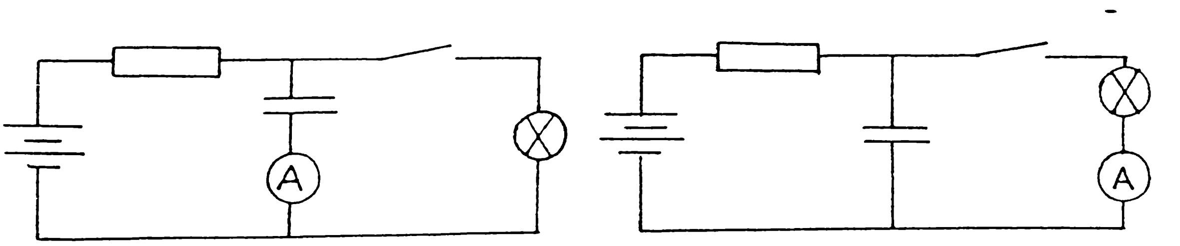
For a given capacitor, the amount of charge Q acquired by each plate is found to be proportional to the potential difference.

If the lamp lights with greater capacitance then more energy must be stored.

$E_p \alpha Q$ greater charged stored

$E_p \alpha V$ energy of charge.

How can we find out about the current in the circuit? Place an ammeter after the capacitor. Try three or four different capacitors. Open and close the switch as before.



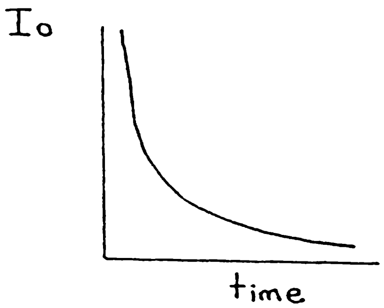
Draw a graph of what you think is happening.

Then place it after the lamp. Record your findings and observations.

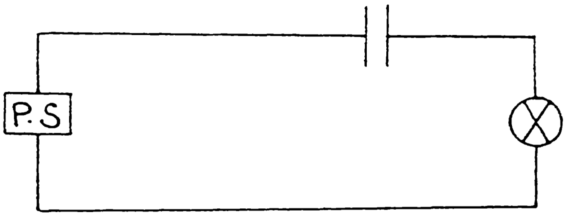
Use several different capacitors.

Teacher Direction

Notice the current is large as soon as the switch is closed then decreases.



We have used a DC power supply. The flashing unit had a rectifier to change AC to DC. What happens if we use AC. Try the following circuits.



With AC and DC supplies

Record your observations and results.

Teacher direction

Designed to show the positive on one side of capacitor and negative other and that capacitors don't pass DC but pass AC. With AC the charge on each plate alternates between positive and negative.

Lead pupils to get ideas for accumulation of charge then discharged.

Using all the information you have gained about capacitors and your knowledge of electrical currents. Try to explain how this circuit works.

Teacher direction

A capacitor stores charge when the switch is open. There is no detectable current. Voltage across the capacitor increases as the charge is stored. Fast then slow as more work is required. The capacitor reaches a certain voltage which is able to light the bulb.

Problems

1. Problem of electric fence capacitor.

Many electric fences used on farms have a capacitor in the power supply that is charged up and then discharged. This provides the pulse in the electric fence. If the voltage was continuous, i.e. not pulsed then it would become dangerous.

The electric fence is run directly from the mains 240V. It is passed through a voltage doubler. The capacitor is a 20μF. Calculate the charge on each plate.[2]

$Q = VC$
$= 480 \times 20 \times 10^{-6}$ Answer
$= 9.6 \times 10^{-3}$ C.

2. The resting potential of nerve and muscle cells is about 85mV relative to the interior potential. The charge on each side is found to be 1.1×10^{-13}C. Calculate the capacitance of an animal cell.

$C = \frac{Q}{V}$
$= \frac{1.1\times10^{-13}}{8.5\times10^{-2}}$ Answer
$= 1.3\times10^{-12}$F
i.e. 1.3 pF

3. Calculate the energy stored in the above capacitors.

4. In designing an electrical system you are required to include a capacitor that is capable of storing 0.25J of energy. The supply voltage to the system is 300V. Calculate the size of the capacitor required.

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2. The information in the boxes is for the teacher. For student copies these boxes can be removed.

5. Calculate the amount of charge stored by the capacitor in the xenon flash circuit and in the circuits you made.

6. Calculate the energy stored in each case.

TEACHER NOTES

ENERGY IN A CAPACITOR

Energy stored in a capacitor

Seen that $E_p \propto Q$

$E_p \propto V$

$Q = VC$

$C = \frac{Q}{V}$ $V = \frac{Q}{C}$ $V \propto Q$

$C \propto Q$ then assume the size of the capacitance relates to amount of charge.

The energy stored in a capacitor will be equal to the work done to charge it up.

When there is similar charge on one plate it requires work to add more charge of the same sign. Because like charges repel the more charge on the plate the greater the amount of work required to add more.

Illustrate this idea from the students' voltage time graphs.

The amount of work required to add more charge Δq when the p.d. across the plates, is $\Delta w = \Delta qV$.

As we have seen the capacitor charges up quickly when there is not much charge on the plates but charges up slowly when there is more charge on the plates.

The work will be much greater to add charge Δq when the p.d. across plates increases. $(V = Q/C)$

Voltage increase will be from 0 to the final value. The work done will be the same as moving all the charge Q at once across the plates equal to the average potential difference for the whole process i.e. $V_{final/2}$

$$W = \tfrac{1}{2}VQ = \text{Energy stored.}$$

Class Summary

Get the students to report back what they have learnt about the camera flash gun and capacitors. Class discussion of results. Start developing the relationships between C, Q, V, Ep, from the students ideas.

Derive the formulae and do the problems provided plus extra.

PART B LESSONS

Summary of what we know already about capacitors.

Teacher demonstration of tuning capacitor.

Show the tuning capacitor from a radio (Capacitive bridge connected to signal generator at 1KHz). Area increasing, increasing capacitance. What other factors do you think are involved in determining the size of a capacitor?

Encourage class questions and discussions of what is happening.

Probably the main idea that has been examined so far is that a capacitor consists of parallel plates which accumulate positive charge on one plate and negative charge on the other. It would seem therefore that the greater the area of the plates the greater the amount charge that can be accumulated. Since C α A then the greater the area of the plates, the greater the capacitance.

What other factors do you think are involved in determining the size of a capacitor? Develop the lessons from the student replies.

Examine a cut-away capacitor, then the 5kV 10kpF capacitor and then examine the unrolled one. The cut-away and the unrolled are of similar size.

Typical of the student observations might be:

1. Capacitor as symbol i.e. parallel plates with a certain distance between them.
2. Show how rolled up sheets give a large area.
3. Made of aluminium on one side.
4. Plastic or some other material.
5. Tightly wrapped together.

Pupil summary of observations and notes on area, etc.

What other factors affect capacitance?

THEME - DETECTING CHANGES WITHIN OUR ENVIRONMENTS

1. How does a condensor microphone work?

2a. How do aircraft pilots tell what altitude they are flying at?
b. How do the meteorological service tell what the pressure is in the clouds?

3. How a baby's breathing can be monitored.

4. How can we get early information on volcanic eruptions?

Choose one of these questions. Answer the questions and write a summary on how these devices work. Reporting back to the class as a whole class seminar.

Device warns of quakes

The recent seismic activity has created new interest in a device which can give a brief warning of an impending quake.

The electronic trigger device, developed several years ago by Lower Hutt electronics firm Solid State Equipment Ltd, can also be used to shut down flame sources.

In recent years the electricity division of the Ministry of Energy has bought the devices for use in power generation plants.

The detector can activate emergency power sources in an earthquake to provide, for example, lighting to evacuate a building.

So far, sales have largely been confined to this country, with the Ministry of Works and Development buying it for key buildings. One has been installed in the Michael Fowler Centre and contractors have installed them in buildings where natural gas boilers are used.

There is also one used on the new cable car as an emergency stopping device.

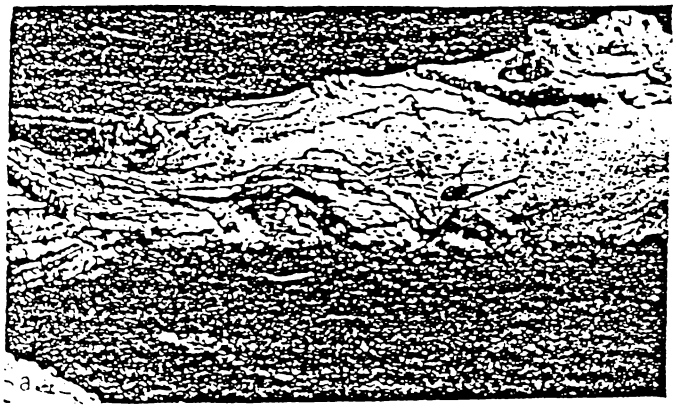
Solid State Equipment's general manager, Mr George Jones, says the device still has a large number of earthquake-related functions, which have been largely untapped by potential users.

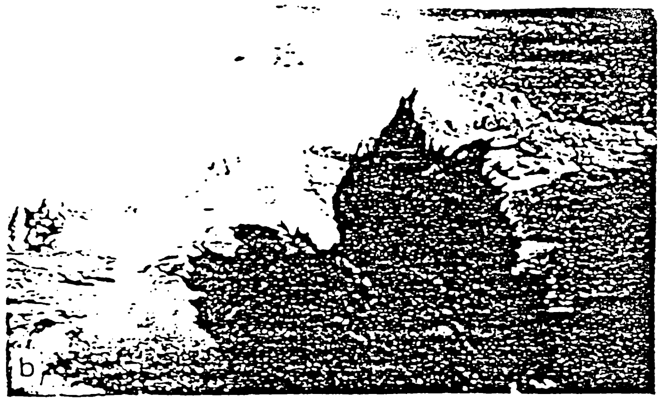
It can be used to shut down gas and fuel lines, turn off the power to electric lines, switch on emergency power supplies in places like hospitals, stop electric trains, as a safety device in nuclear plants, or to stop a lift in an emergency at the nearest floor.

The device has a vibration detector inside it and can be wired up for different functions.

The $825 detector picks up the first vertical shake that precedes the dangerous horizontal shake. It can provide a few seconds warning of a major shake, which can be vital.

So far only one of the devices has been exported, to an Australian nuclear research plant. Mr Jones says the only places overseas that manufacture a similar device are Japan and America.





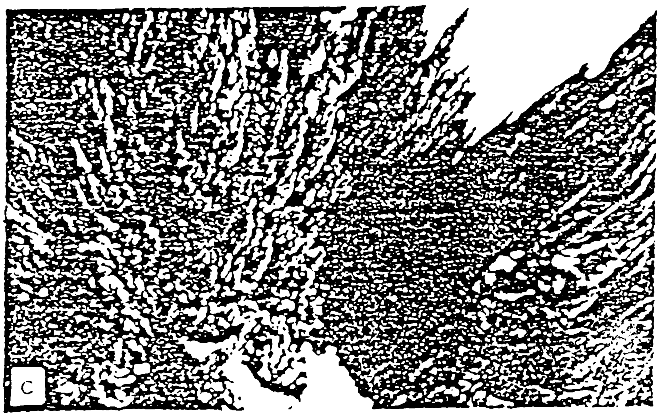


Figure 1. Ruapehu Crater Lake, taken from the same spot, on 8 May 1971. (a) shows the lake steaming strongly. (b) shows the start of an explosive eruption; mud, water, and hot rocks are ejected to a height of about 300 m above the lake. (c) was taken 14 sec. after (b) and is shown at the same scale. An awesome explosion, originating about 1 km below the surface, has ripped through the lake, ejecting water, mud, hot ash, and partially molten rocks to a height of about 8000 m. The rocks are travelling at between 100 and 150/m sec. This is an example of a phreatomagmatic eruption. This sequence of photographs underlines the interest, excitement, and sometimes sheer terror, associated with the science of volcanology!

Dominion 14 August 1984

EARLY INFORMATION ON VOLCANIC ERUPTIONS

Details of the Device

A device used to measure the earth deformation just before a volcanic eruption is a capacitive tiltmeter. Its name gives some idea of what the device consists of. It is a capacitor arranged such that it measures the movement of the earth. It is difficult to get large tiltmeters near active volcanoes. Capacitive tiltmeters only need 50mm diameter holes drilled in the rock to contain them.

The capacitive tiltmeter is shown below.

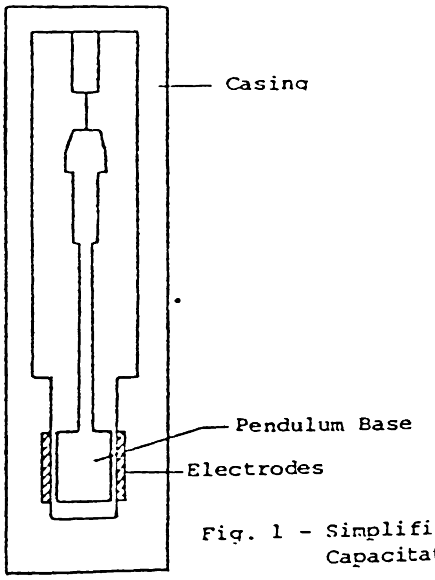


Fig. 1 - Simplified Diagram of the Capacitative Tiltmeter

The tiltmeter has a pendulum suspended between 4 electrodes each at 90^0 to each other and separated. The pendulum bob itself is one electrode so it forms a capacitor with each of the electrodes. The typical distance between the pendulum base and each of the electrodes is 0.82mm. The tiltmeter is fitted with silicone oil which damps the pendulum motion. There does not have to be much change in capacitance as any slight change will be detected.

If the pendulum moves there is a change in distance between the electrodes which will result in a change in capacitance.

If there is any earth deformation i.e. movements then the casing of the tiltmeter will move with the earth but the pendulum will tend to remain in the rest position (inertia) and the distance between the pendulum and other electrodes will change.

In the table below is shown how the distance between the electrodes affects the capacitance.

Capacitance (pF)	distance (mm)
4.3	0.82
5.9	0.6
11.8	0.3
35.4	0.1
39.3	0.09

Questions:

(1) What do you notice about the relationship between capacitance and distance between the plates?

(2) Draw a graph to find the relationship between capacitance and distance.

(3) The capacitance is measured at approximately 36pF; what is the distance between the plates?

(4) If the distance between the plates was 0.2mm what would be the capacitance?

(5) If the distance between the charged plates is reduced by 1/4 of the original distance by what factor will the capacitance change?

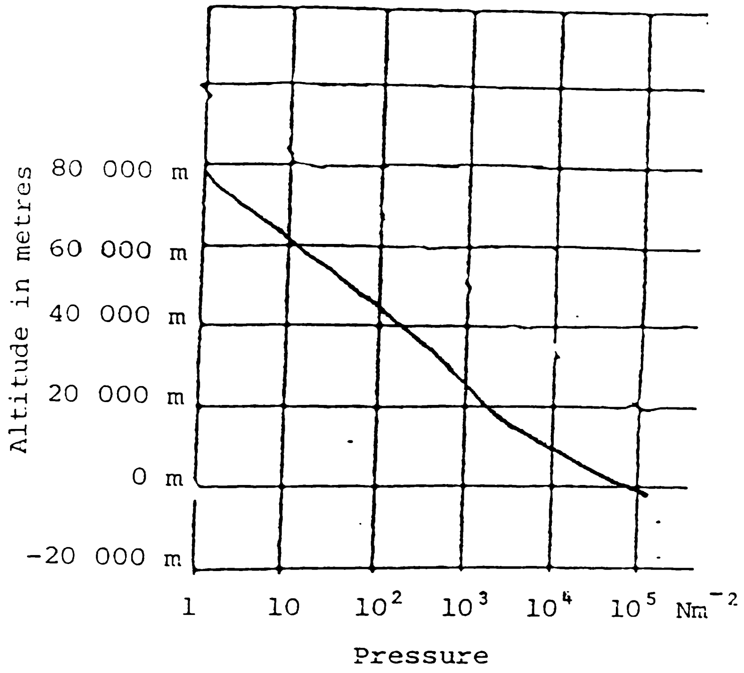
(6) It is found that the distance between the charged plates is doubled. By what factor will the capacitance change?

ALTITUDE MEASUREMENT

Background

The atmospheric pressure (air pressure) decreases as the height above the earth increases. The pressure at the surface of the earth i.e. at sea level is approximately 10^5 Nm^{-2}, whereas at a height of 10 000m it is approximately $3x10^4$ Nm^{-2}. At 80 000m the pressure is 1 Nm^{-2}.

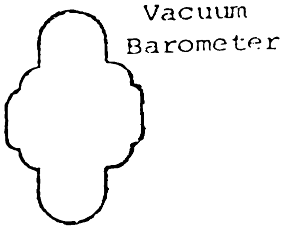
The graph of altitude verses pressure is shown below.



This means that a reasonably accurate measure of the altitude can be obtained by measuring the air pressure. This principle is used in aircraft altimeters and by the meteorological service to measure the height of their weather balloons and the air pressure inside clouds. A device that measures atmospheric pressure is called a barometer.

Details of the Device

One method of measuring the barometric pressure (air pressure) is to use a capacitive pressure sensing capsule. The sensing capsule is a sealed metal container with a springy diaphragm (See diagram below).



The diaphragm and metal plates are charged thus forming a capacitor. When the capsule is at ground level the pressure acting on it will be 10^5 Nm^{-2}. As the capsule reaches higher altitudes the diaphragm moves out because the pressure on the outside has been reduced.

As the altitude increases the capsule expands and the plates are further apart. This results in a change in the capacitance. It is found that as the pressure decreases and the altitude increases that the capacitance decreases. This means that the further the plates are apart the lower the capacitance. The table below shows how the capacitance varies with altitude.

Altitude (m)	Distance between plates (mm)	Capacitance (pF)
0	1	49.6
5 000	2	24.8
10 000	3	16.5
15 000	4	12.4
20 000	5	9.9

Questions

(1) What do you notice about the relationship between capacitance and distance?

(2) Draw a graph of capacitance versus distance between the plates? Comment on the relationship between capacitance and distance.

(3) If the plates were 6mm apart what would the capacitance be?

(4) It is possible to use this device (pressure measurer) below sea level where the pressure is increased. The distance between the plates is found to be $\frac{1}{2}$mm or 0.5mm. Estimate what the capacitance will be.

(5) If the distance between the charged plates is reduced by $\frac{1}{4}$ of the original distance how much larger will the new capacitance be?

(6) It is found that the distance between the charged plates is doubled. By what factor will the capacitance change.

MICROPHONE

Background

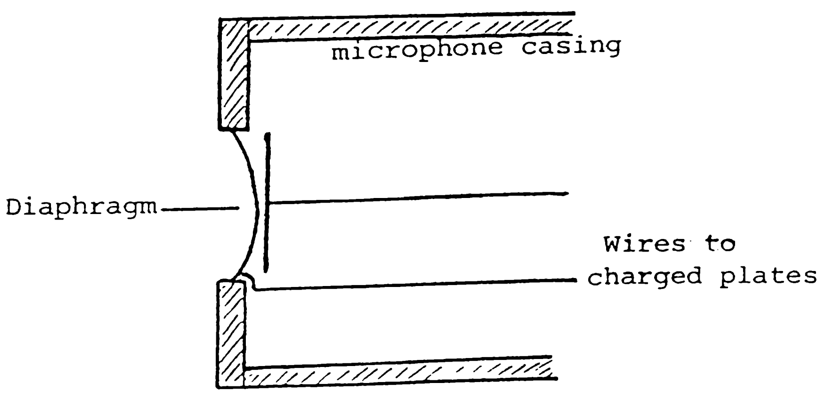
When a person speaks the vibration of the vocal cords causes the air to compress and expand in the form of a sound wave. These sound waves are detected by the ear. The ear has three main divisions, outer, middle and inner. The sound waves cause vibrations on the outer ear (ear drum). Where there is an expansion of air the ear drum is bent very slightly outwards and when the air is compressed the ear drum moves slightly inwards. These vibrations are conducted through the middle ear where they are amplified. In the inner ear these vibrations are converted from sound waves to electrical signals and sent to the brain.

A microphone works in a similar manner. In place of the ear drum there is a diaphragm which moves in and out due to the compression and expansion of the sound waves. The movement of this diaphragm converts sound waves into electrical signals which can be modified, amplified and transmitted.

One particular device that does this is a condenser or capacitive microphone.

Details of the Device

The variable capacitive microphone consists of two charged plates one of which is stationary or fixed and the other acts as the diaphragm. See the diagram below.



It is found that when the diaphragm is compressed toward the stationary plate the capacitance is higher than when it moves away.

This means that the closer the plates are together the higher the capacitance. The greater the pressure of the sound wave, the smaller the distance between the plates, the greater the capacitance. The change in capacitance directly affects the output signal.

The following results were found:

Capacitance (pF)	Distance between the plates
9	0.1 mm
11	0.08 mm
14	0.06 mm
22	0.04 mm
44	0.02 mm
88	0.01 mm

Questions

(1) What do you notice about the relationship between capacitance and distance between the plates?

(2) Draw a graph of capacitance versus distance between the plates. Comment on the relationship between capacitance and distance.

(3) A capacitive microphone contains a capacitor in the 88pF range. What is the distance between the plates?

(4) If you wanted to increase the capacitance to 176pF what distance would you need between the plates?

(5) If the distance between the charged plates is reduced to 1/4 of the original distance how much larger will the new capacitance be?

(6) It is found that the distance between the charged plates is doubled. By what factor will the capacitance change?

SIMPLE BREATHING DETECTOR

. With the rise in cot deaths (Sudden Infant Death Syndrome) a device was needed not just to detect apnoea (ap-nee-a) (non-breathing) but breathing patterns in very young children. In infant children the breathing patterns may not be regular, particularly under conditions where the incidence of cot deaths maybe higher. The areas where cot deaths maybe higher are with babies whose mothers may not have had adequate antenatal care, are smokers or are teenagers. There maybe other factors such as tiredness, cold weather etc. Babies that have had surgery within a day or two of birth appear to be slightly more susceptible. However there does not appear to be a clear cut answer.

A simple device has been developed to monitor the respiratory patterns to see if there are different patterns in different babies. With babies the measuring device must cause the least disturbance and any technique applied must have the highest standards of safety.

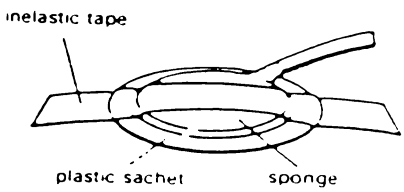
These devices are used to monitor breathing patterns rather than just detect non-breathing as do the cot death alarm mattresses. These devices have disadvantages for full-time monitoring as they can restrict the babies movement, the sensor can become detached from the body of the baby, and the sensor needs to be placed in the correct way.

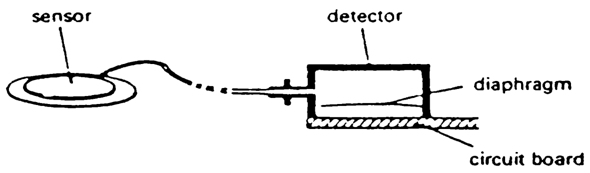
Details of the Device

The device consists of two distinct parts, the sensor which is attached to the baby and the detector.

The sensor which is attached to the baby is a plastic sachet filled with a sponge so as to maintain a fixed volume of air. The sachet is attached to the babies abdomen by inelastic tape. When the baby breathes the plastic sachet is compressed due to the movement of the babies abdomen.

Attached to the sensor is an airtight tube leading to the detector. The detector consists of a sealed chamber with a flexible diaphragm acting as one end. (See diagram). This means that any pressure changes in the sensor will result in pressure changes in the sealed chamber, which means the flexible diaphragm will move. For example if the air pressure is increased, i.e. the baby breaths out compressing the sachet then the diaphragm will move outwards. (See diagram over page).





The diaphragm acts as one plate of a capacitor with the other plate being at the base of the chamber. Changes in pressure cause changes in the distance between the plates of the capacitor.

It is found that if there is increased pressure the plates will be closer together and capacitance will be greater. When the pressure is reduced then the plates are further apart and the capacitance is reduced. So the change in pressure will give you a corresponding change in capacitance.

Note how capacitance varies with the distance between the plates.

Capacitance (pF)	Distance (mm)
62	0.1
21	0.3
10	0.6
6.8	0.9
6.2	1.0

<u>Questions</u>

(1) What do you notice about the relationship between capacitance and distance between the plates?

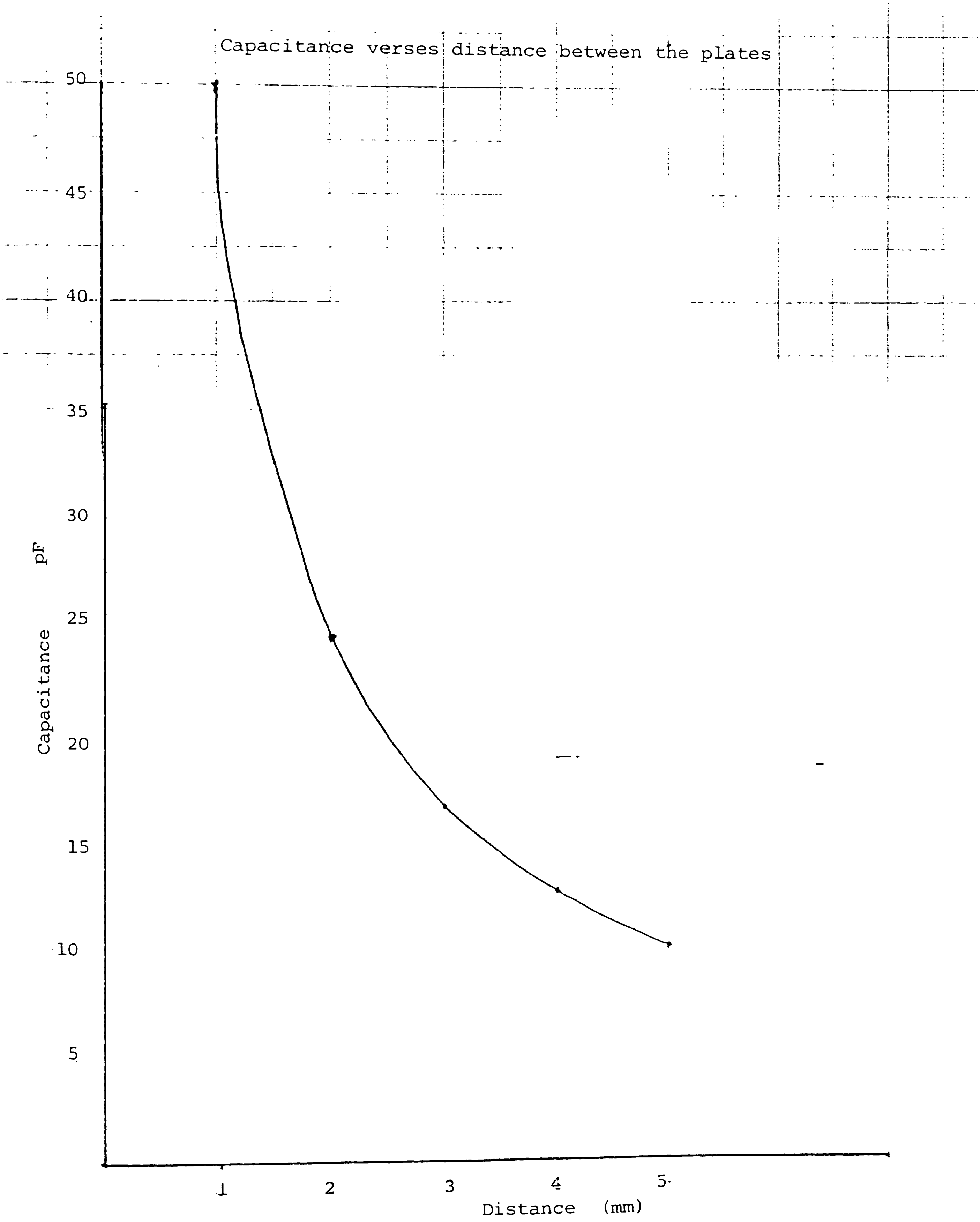
(2) Draw a graph of capacitance versus distance between the plates. Comment on the relationship between capacitance and distance.

(3) The diaphragm is found to be 0.2mm from the other plate; using the graph calculate the capacitance.

(4) What would be the capacitance if the distance between the plates was 0.05mm.

(5) If the distance between the charged plates is reduced to 1/4 of the original distance by what factor will the capacitance change?

(6) It is found that the distance between the charged plates is doubled; by what factor will the capacitance change?


Capacitance verses distance between the plates
Capacitance pF
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
Distance (mm)

Teacher Notes

Students report to the class about what they have learnt and further questions they may have.
They also ask each other questions.
Teacher direction to achieve

$$c = \frac{\epsilon_0 A}{d}$$

by using ϵ_0 as a constant $c \propto A$

$$c \propto \frac{1}{d}.$$

Relate back to the manufactured capacitor with a large area because it is rolled up and a very very small distance between the plates.

Talk about the construction of large capacitors when a lot of charge is needed to be stored.
Using the information gained so far, get the students to design a capacitor.

Relate this back to the 2200μF capacitors that they used, compared with the 100pF capacitors used in monitoring equipment. μF capacitors without huge areas would be impossible.

A capacitance of 1μF or more would require huge plates if something else is not used. Carry out a calculation (students).

The capacitor we took apart did not appear to have an air gap. What covered the plates? - thinking about some material between the plates.

Look at some examples.

Teacher direction for dielectric is probably needed but start with the Humidity Sensor as an example. See separate sheets. These can be set up as technological problems for the class to discuss and explore. For example , once the humidity sensor has been discussed by the teacher and the class the capacitive level measurer could be set up as a technological problem (How can we measure the level of dried food in a large container?). The thickness measurer can be given as a student worksheet.

CAPACITIVE LEVEL MEASURER

U.B/S Teachers Guide, p. 35

PRINCIPLE:

The capacitance value of a plate conductor depends upon the distance d between the two plates, the area A of the plates and the dielectric between the plates.

$$\varepsilon = \varepsilon_o \varepsilon r \qquad \varepsilon r \text{ is the dielectric constant.}$$

$$C = \frac{\varepsilon A}{d}$$

APPLICATION:

This principle is used in capacitive level indicators to measure the height of material in containers. An electrical probe is placed inside the tank which forms a capacitor between the wall of the tank and the probe, see Fig. 1. The level of the material between the probe and wall affects the capacitance. This type of level indicator is used by the food industry to measure the height of dried food.

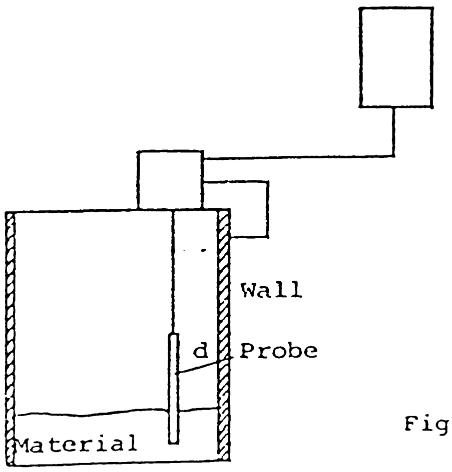


Fig. 1.

DETAILS OF THE DEVICE:

Since the surface A and the distance d are kept constant, the only variable in this system is formed by the dielectric of the filling material. The capacitance of the capacitor is therefore proportional to the amount of material between the probe and the wall. The change in capacitance is measured by connecting the probe and the container wall to an AC voltage with a constant high frequency. As the level rises on the probe the capacitance will increase owing to the increase in the dielectric between the plates.

HUMIDITY SENSOR

UB/S Teachers Guide p. 35

PRINCIPLE:

The capacitance of a capacitor can be varied by changing the dielectric between the plates.

APPLICATION:

This principle is incorporated in a humidity sensor used by the Forest Research Institute (F.R.I.) to measure the humidity in the controlled environment rooms.

DETAILS OF THE DEVICE:

The sensor makes use of capacitance changes caused by water entering a microscopically thin dielectric layer 10^{-5}m thick. A porous gold film forms the two conductors of the capacitor. The gold film which is permeable to water will exclude dust. Also molecules larger than water cannot enter the layer making the sensor highly resistant to impurities.

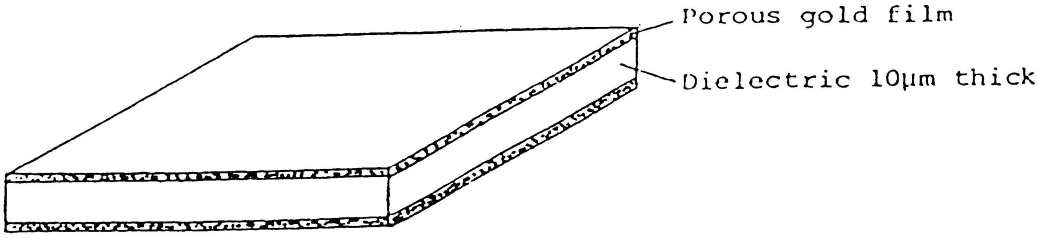
The average capacitance is usually about 5×10^{-8} F. The area of the capacitor is arranged so that it measures 1×10^{-2} m^2. The dielectric constant of the thin layer is approximately 5.6 when dry.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$ where ε_r = dielectric constant, A = area, d = distance between plates

$$C = \frac{8.85 \times 10^{-12} \times 5.6 \times 10^{-2}}{10^{-5}}$$

$$\simeq 5 \times 10^{-8} \text{F.}$$

Water at room temperature has a dielectric constant of 80. So even when a smaller amount of water is added the change in the capacitance will be detected.



DIELECTRIC OF BITUMEN PAPER

UB/S Teacher's Guide page 36.

PRINCIPLE:

The capacitance depends on the dielectric constant.

APPLICATION

In the manufacturing of bitumen (building) paper it is important to know how much bitumen is within the paper. As the dielectric constant of the paper depends on the amount of bitumen, the dielectric constant is measured by placing the finished paper between two charged plates. The relationship

$$\varepsilon r = \frac{Cd}{\varepsilon_0 A}$$

is therefore used to indirectly determine the amount of bitumen in the paper.

where ε_r = dielectric constant

c = capacitance

d = distance between the charged plates

A = area of plates

ε_0 = permittivity of vacuum

THICKNESS MEASURER

Background

Industries that paint filing cabinets or such household appliances as refrigerators and freezers often use electrostatic painting techniques. The appliances are painted automatically. A method was required to determine the thickness and consistency of the painting process.

A device that measures the thickness of paint is called a capacitive thickness measurer.

Principle of Operation

This device relies on the principle that the distance between two charged plates is inversely proportional to the capacitance, that the area of the plates is directly proportional to the capacitance, as is the dielectric constant.

Details of the Device

A small section of one corner of the coated material is removed so that the metal is laid bare. An electrode is placed onto the bare metal and another is placed on the coating. The electrode placed on the coating is circular with a radius of 7mm. (Hence an area $A = \pi r^2 = 1.5\times10^{-4} m^2$).

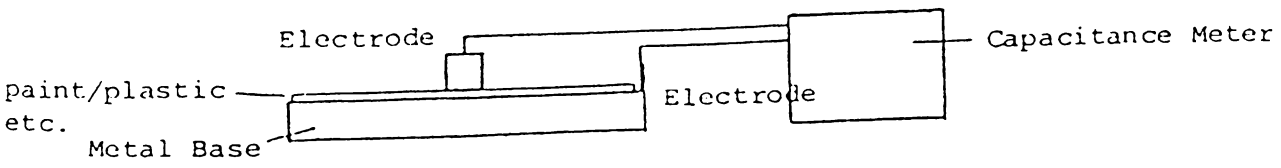
The dielectric constant (ϵ_r) of paint or plastic ranges from 1.5 - 8 at room temperature. By knowing the dielectric permitivity then ϵ can be calculated. $\epsilon = \epsilon_0 \epsilon_r$

The capacitance is measured by a capacitive meter then the thickness

can be calculated using $c = \frac{\epsilon A}{d}$ $\epsilon_0 = 8.85 \times 10^{-12}\ N^{-1}\ m^{-2} C^2$

$$\text{i.e. } d = \frac{\epsilon A}{c}$$

c is usually in the range of 120-131pF so d can be calculated i.e. approximately ~ 10^{-4}m thick.



Problems

(1) If a new electrode is designed with a circular radius of 12mm calculate the capacitance if dielectric constant of the paint is 5 and the paint is $3x10^{-4}$m thick.

(2) If the paint thickness is found to get thinner across a sample piece of metal what will happen to the measured capacitance.

(3) Using the information on the capacitive thickness measurer calculate the thickness of paint if the dielectric constant is 6 and the capacitance is found to be 120pF.

(4) If the distance is known to be $1x10^{-4}$m calculate the capacitance if the dielectric constant is 8 (use information sheet).

(5) Calculate the charge on each electrode if the capacitance is 100pF and the supply is 16V.

(6) Calculate the energy stored in the above system.

(7) How could the Capacitive Thickness Measurer be used to measure the amount of a certain substance in paint. [Hint: dielectric]

(8) Complete the table

Capacitance	Area (m)	Distance (m)	Dielectric
	1	$1x10^{-5}$	2
188pF		$3x10^{-4}$	4
14.5pF	$4.1x10^{-3}$	$5x10^{-2}$	
	$4x10^{-2}$	$2.8x10^{-3}$	6
10nF	$2x10^{-4}$		100

COT DEATHS (SUDDEN INFANT DEATH SYNDROME)

Introduction

Start the lesson with a brief discussion of cot deaths.

What do the students already know? (The students will probably bring their own ideas. (Emphasise that no-one has the answers as to why these occur).

Use the newspaper articles to trigger interest and questions about the monitor. Lead the discussion or questions to emphasise the use of a monitor.

Apnoea means non-breathing. Apnoea mattress and alarm means a non-breathing detector.

Use Background information - the apnoea mattress is used in the hospital when

- babies are premature
- after operations

- In the hospital and the home
  - premature
  - smoking mothers
  - drinking mothers
  - poor antenatal care
  - mother under stress
  - other cot deaths in the family.

Show the Slides

Discussion of how the monitor works. (See separate sheets).

- Show the demonstration of the model of the control box.
- Connect the model control to the signal generator (1 kHz).
- Use control knob to vary to voltage.
- Show the changing-discharging - voltage time. The time it takes to charge. (Connected to an oscilloscope).
- Explain the x-axis.
- The changing resistance i.e. heating and cooling does not allow the voltage across the capacitor to increase so much. However, if the resistance from the thermometer decreases, i.e. heats up the voltage across the capacitor increases. When the output voltage

reaches a certain value, i.e. 1 volt the alarm begins to sound. If, however, the baby does not move then the resistance will continue to decrease and the alarm gets louder. If there is no movement the capacitor becomes fully charged.

Take the back off of the model alarm unit and see the capacitor being charged up through a resistor.

Questions and exercises

1. Copy down the waveform shown on the oscilloscope. From what you already know about capacitors explain what is happening.
2. The article mentions that the doctor can adjust the time the capacitor takes to charge by adjusting a resistor. How do you think this works? Write down your ideas.
   What affect do you think a resistor will have on the charging of a capacitor.
3. Other questions.

Cot Deaths Still Mystery

Herald Corres
Dunedin

Some babies might simply "give up the ghost," according to a British cot death expert, Professor John Emery.

There was some evidence to suggest babies could lose their drive to live just as old people might decide life was no longer worth living, he said.

Dr Emery, emeritus professor of paediatrics and pathology at Sheffield University, England, and a world authority on cot deaths, is on a four-week tour of New Zealand hosted by the Plunket Society.

But he is offering no simple remedies for the bereaved parents and puzzled health workers gathering to hear him talk and maybe supply the answers.

Combination

If a baby did give up the ghost, it would not be the cause of death in isolation – it may have been the last straw.

"The message I want to give you is that cot death is not a disease: it is a combination of a whole lot of conditions," he told a Dunedin audience.

"Some of these we certainly have no clues about and no means of preventing."

Dr Emery, a father of six (and grandfather of 11) lost one of his children to cot death before the condition was recognised and labelled as such.

The United States took the initiative on the syndrome, after concern that parents were being blamed for the death of their child when most of the deaths were from natural causes.

"Suddenly there appeared in the statistics of the world a new disease." It is also known as sudden infant death syndrome.

Dr Emery led a famous Sheffield study which saw cot death rates fall from among the highest in Britain to well below the national average.

He believes that although the exact causes of cot death remains a mystery, the condition can be prevented in many cases.

By gathering all the information relating to births in a Sheffield maternity unit, measuring the babies who survived against those who died, he found significant differences in cot death causes.

Factors

Social class featured and so did age. It appeared that the younger the mother and the lower the social class, the higher the risk of cot death.

But when one factor was related to the other the position changed.

"We found that when we related the age of the mother and the social-class factor together, the social class disappeared. It was no longer significant."

According to statistics, an 18-year-old mother from a so-called advantaged background faced the same risk of losing her child as did a woman of the same age from an underprivileged home.

Dr Emery gave a warning against misinterpretation. Factors which had a high profile statistically have not necessarily caused the problem.

The study scored the mothers on factors such as age and whether or not the baby had been bottle or breast-fed.

The younger the woman the higher the risk and, therefore, the larger the score.

Feeding

In feeding methods, bottles gained the most points for the same reason. It revealed that a 20-year-old mother who was breast feeding faced the same risk of cot death as a woman aged 26 who bottle-fed her baby.

However, a woman in the Dunedin audience told Dr Emery that her first child was born when she was aged 19 and unmarried. The child, who was bottle-fed, was now 6 years old but two subsequent children, born after marriage and breast fed, had died in their cots.

There were no slick answers, said Dr Emery.

The complexity of cot death is also illustrated in the range of theories on causes. Colder temperatures are thought to have an effect, an idea which is supported by the experience in places like New Zealand and England.

But some of Europe's coldest spots have a low incidence.

Some had suggested the condition was related to long bouts of travelling. Increasing numbers of deaths had been occurring in cars, but if babies spent more time asleep in vehicles because their mothers used them more, the chances were higher anyway, Dr Emery said.

Gimmicks

Apnoea (cessation of breathing) monitors are widely used but Dr Emery is completely against them unless there is evidence that the baby has something wrong with its breathing mechanism.

He said he was worried about the spread of "these sorts of gimmicks."

Meanwhile, the New Zealand Plunket Society, is canvassing the Government for more Plunket nurses to help to prevent cot deaths.

But Dr Emery said there was no evidence that an increase would help to reduce the rate.

However, he is wary of postnatal depression in women, a third of whom are affected at an age when cot death occurs.

Warning Signs

For this reason, he discouraged the idea of teaching mothers the warning signs which might avert cot death. They were already under pressure, he said.

"This is where the unitary concept of looking after children is a bad one."

Baby care should be a group activity involving not just the Plunket nurse but the mother, father and grandparents.

In Hong Kong the incidence of cot death was remarkably low, but there were three or four people around every baby.

The Swedish environment was also much more supportive and the cot death rate reflected this. Every baby was weighed once a week and people more often used the health services, which were designed for the whole community.

It was important for people like the Plunket nurse to be clued in with the individual family situations — to know whether the mother was gaining enough sleep, for instance.

Women were "stressing themselves," Dr Emery said. "This is a major problem, this business of women trying to do too much.

"They are trying to look after the babies themselves without support. They can do it perfectly well for short periods but when they get unwell the baby is at a disadvantage."

N.Z. Herald 9/5/86

Living proof that radio can help save lives.

Auckland Star 15/4/86

New Zealand has one of the highest rates of cot death in the world. Worse still, nobody knows exactly why. But one thing we can do is provide better care for babies diagnosed at high risk from cot death.

In September 1985, Radio Pacific and the Zonta Club of Auckland launched an appeal to buy some desperately-needed infant breathing monitors. These devices cost $1000 each and provide an immediate alert should a sleeping baby stop breathing. The station lifted community awareness of the problem with a sensitive publicity campaign, culminating in a one day Radiothon on Sunday, September 22. As a result, $107,000 was donated by listeners to buy the vital monitoring equipment.

Mobil salutes this achievement by presenting Radio Pacific with the Mobil Radio Award for the outstanding community project of 1985.

It's an award that recognises the contribution made by community radio on what is, literally, an issue of life and death.

Thanks to the efforts of Radio Pacific and their associates, the baby pictured above – and his parents – can sleep much easier.

Mobil Radio Awards

Radio Pacific (Auckland) – Metropolitan Station of the Year | Radio BOP (Tauranga) – Provincial Station of the Year

Cot deaths – a new shock

N.Z. Truth 29/4/86

Deaths from the dreaded, mystery baby-killer cot death are soaring in New Zealand.

Shock figures just released show Sudden Infant Death Syndrome (cot death) has rocketed since the last figures were compiled.

They show that our cot death rate is now running at around 250 babies a year.

When the last figures were taken New Zealand was the 17th worst country in the world for the mystery baby killer.

Reversed

Now the Royal New Zealand Plunket Society says "we must expect our placing to be even less favourable."

A trend for babies to survive the early weeks of birth – which began to emerge in 1975 – has now reversed, says the society.

And more babies are now dying at two and three months.

So serious is the problem in New Zealand now that about five babies in every thousand can be expected to die from cot death.

In Japan, Singapore and Sweden the figure is only one per 1000.

In the USA, Australia and Great Britain it is three per 1000.

Medical experts are baffled as to the cause of our frighteningly high rate.

By John Wilson

Babies are at the greatest risk when they are between two and three months of age in New Zealand, according to a leading article on cot death in the latest NZ Medical Journal.

The writer of the article L. B. Hassall, Plunket's Director of Medical Services, says that as well as finding out what causes our alarmingly high rate "effective help must be available for the bereaved."

Prevention

"The main aim however must be prevention," he adds.

And greater attention should be paid to "at-risk" babies, says the writer.

These include ones with teenage parents, smoking mothers and mothers who have a history of poor ante-natal care.

Babies who had low birth rate, "near misses" and breathing trouble should also be carefully checked.

"In such cases continuous electronic home monitoring may be the best management that is available," says I. B. Hassall, but adds: "But even given these conditions babies have died while on monitors."

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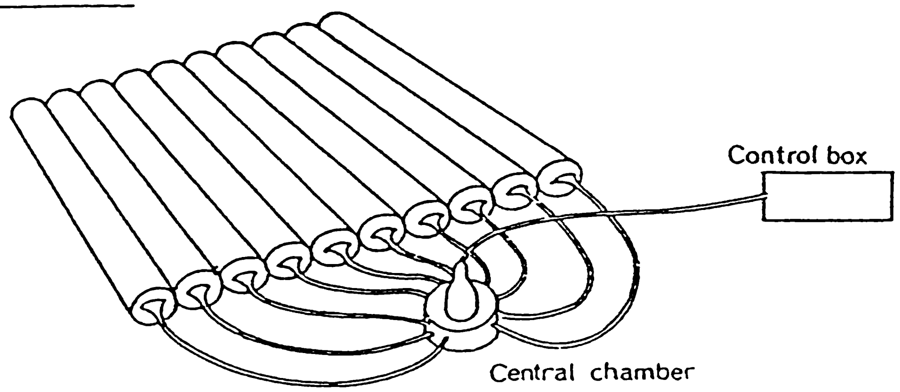
APNOEA MATTRESS

Premature babies have difficulty in breathing and at times may even stop altogether because their respiratory control centres are not fully developed. A device was needed to monitor the breathing of a baby without the placement of electrodes and wires.

The baby is placed on an air filled mattress (Apnoea Mattress) which is divided into 10 segments. Each section of the mattress has a tube leading from it to a central chamber and from there into the other segments. As the baby moves air flows from one segment to another. If it stops breathing the air ceases to flow.

DETAILS OF THE DEVICE:



In the central chamber there is a device (see further details) which changes resistance depending on the temperature. This device is heated from the central control box. As long as the baby is moving, air flows from one segment to the next passing over this device which cools it. If no air flows, then the device continues to heat up. If after heating up constantly, for a time determined by the doctor, and there is no cooling, an alarm is set off.

FURTHER DETAILS

This device is called a thermistor. A thermistor is a solid state device whose electrical resistance changes rapidly with temperature. For example,

Temperature	Resistance
0°C	10KΩ
25°C	3KΩ
100°C	0.2KΩ

SLIDE SEQUENCE ON APNOEA MATTRESSES

1. Babies in the newborn unit i.e. an intensive care for newly born babies are usually placed in incubators with monitoring equipment, so the babies vital signs can be monitored.
   - Point out the air filled mattress the baby is lying on.
   - Control box.
   - Drips in baby.
   - General setting of scene.

2. Closer view.
   - Note the air filled mattress.
   - See page 52 *Physics at Work in New Zealand*
   - Point out the junction and discuss how this works

3. Just showing mattress another view

4. A clearer view of the mattress and the alarm. The different chambers joining at the thermistor.
   - Point out the wire going from the central chamber (thermistor) to the control box.
   - Mention here that we will be primarily concerned with the control box.
   - Note the delay times as these will be the basis behind τ = RC.
   - Brief description of how the control box works (reference see Control box of apnoea mattress PAWNZ attached sheet).

5. Show next slide to gain clearer view.

6. Notice the different delays - 10s if not being closely watched, i.e. the nurse or mother is out of the room.
   - 20s if mother or nurse in room.
   - These are time between movement of the baby i.e. breathing or muscle movement.

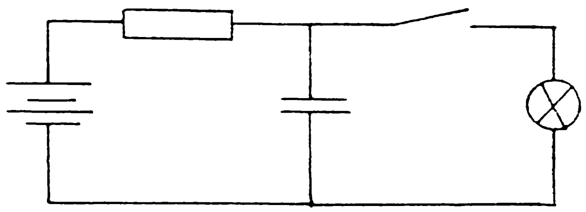
7. Different type of mattress. Used with larger babies.

8. Same slide.

EXPERIMENT

This experiment is designed to test out your ideas about the affect a resistor has on the charging of a capacitor.

Set up the same circuit you had for the camera flash gun model.



Use three different resistors 470 Ω
1 kΩ
10 kΩ
and the 2200μF capacitor.

Record the time for the voltmeter across the capacitor to reach approximately 50% of the input voltage. Try the 3 different resistors and record the time required. Try a 2 kΩ resistor in the circuit. Record your results in a table form with Resistance Capacitance Time.

Repeat the same experiment using a 1000μF capacitor.

Write down the areas where your values will be inaccurate.
What happens to the relationship between the various values?

Teacher Notes

Summary

The larger the resistance the longer the capacitor takes to charge.

[Teacher Information on τ = RC if they wish]

Problems

1. The alarm on one of the apnoea mattresses had a 10s and 20s delay. These are delays set by the doctor. For example when the nurse is out of the room the delay will be set at 10s. When the nurse is in the room the delay will be set at 20s.

   a) Why are these different time delays?

   b) The capacitor involved in the circuit is 15μF. Calculate the resistor required for the 10s and 20s delay.

2. The other type of apnoea mattress alarm had a 10s, 15s and 20s delay. A 330μF capacitor was used in this circuit. Calculate the resistor required for these delays.

3. Design a circuit that illustrates how these delays could be set out.

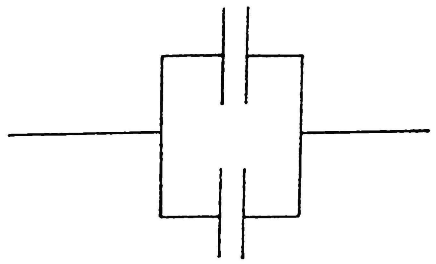
When we are designing the timing circuit for the apnoea mattress control bar we may want to change the size of the capacitor. We may want to be able to store a large amount of charge and energy, or we may even want to reduce the amount of stored charge.

How could we increase the size of a capacitor.

Let's go back to the original equation we talked about

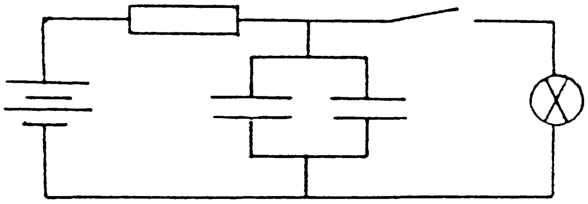
$$c = \frac{\epsilon_0 A}{d}$$

If we increase the area then we can increase the capacitance. By putting two capacitors in this formation we can increase the area.



EXPERIMENT

Test this theory out by putting the capacitors in the camera flash gun circuit.



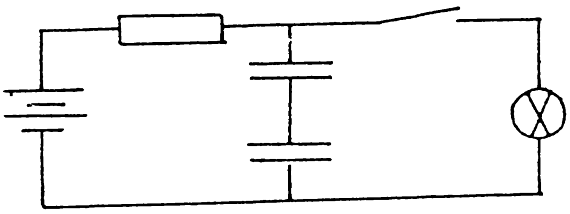
Measure the voltage across each capacitor and across both of them. Then discharge them through the lamp. Note the brightness of the lamp with different combinations. Compare this with your results from earlier experiments.

Has the capacitance increased or decreased? Record your results.

What conclusions can you reach?

> Teacher direction
>
> $Q_1 = C_1V$ $\qquad$ $Q_2 = C_2V$
>
> $Q = Q_1 + Q_2$
>
> $\quad = C_1V + C_2V$
>
> $CV = C_1V + C_2V$
>
> $C = C_1 + C_2$

What happens when the capacitors are put in series in the circuit?



Measure the voltage across the capacitors in the series or circuit and across both the capacitors.

What do you notice about the brightness of the lamp. Use capacitors you used in the first experiment then try any others. Record your result.

What conclusion can you draw? [$V = V_1 + V_2$]

> Teacher direction
>
> The charge will be divided amongst all the plates.
>
> $V = V_1 + V_2$ $\qquad$ $V = Q/C$
>
> $$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2}$$
>
> $$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$ for series capacitors

Problems

1. Calculate the total capacitance of the 2200μF and 1000μF when they are placed first in series then in parallel.
2. From the capacitors that you have available how would you make a 5000μF capacitor?.
3. From the capacitors that you have available how would you make a 5μF capacitor?

MASTITIS DETECTOR

PRINCIPLE:

(a) Capacitor and variable resistor in series.

(b) $V = Qc \qquad Q = It$

$V = It/c \qquad \Rightarrow t = RC$

APPLICATION:

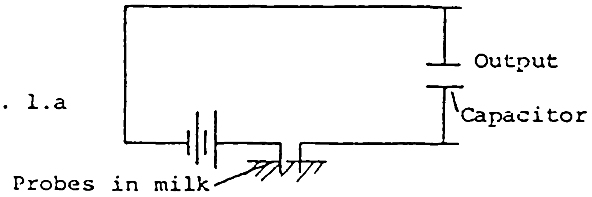
When cows contract mastitis (an infection of the teat) the milk that is subsequently produced is contaminated. A routine method for checking for mastitis is needed so that the affected cow can be isolated and not infect the rest of the herd.

The milk of a cow that is infected is more conductive, i.e. the resistance of the milk is lowered. A device has been designed using this principle, to provide early detection of the disease.

DETAILS OF THE DEVICE:

Two electrical probes are placed in each cup of the milking machine. These form a circuit with the battery and the capacitor.

Fig. 1.a



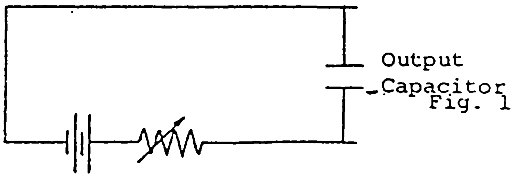
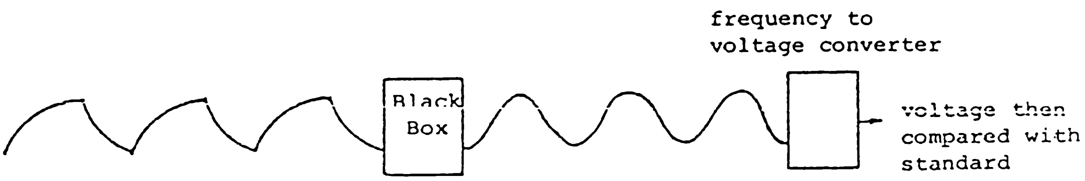


Fig. 1.b.

The two probes in contact with the milk form a variable resistor. The equivalent circuit is shown in Fig. 1b. This produces a wave form as shown below and the capacitor is discharged by a switch.

Waveform

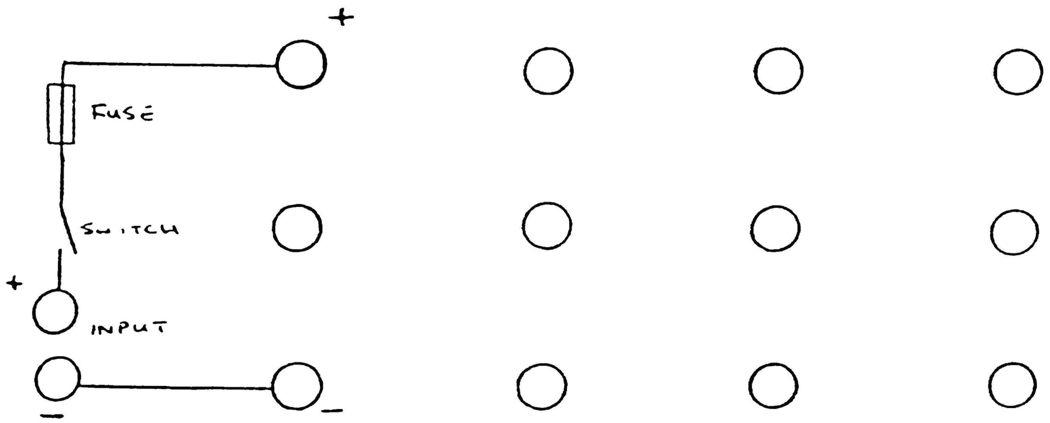
The shape of the waveform depends on the value of the resistance. If the cow has mastitis then the shape will be altered as R will be decreased. The wave form that is produced passes through a "black box" where it is converted into a sine wave where the period of the wave still depends on RC. The frequency of the sine wave is then converted to a voltage which is compared with the standard voltage for unaffected milk. If the voltage is less than the standard, a light is activated indicating possible infection of mastitis.



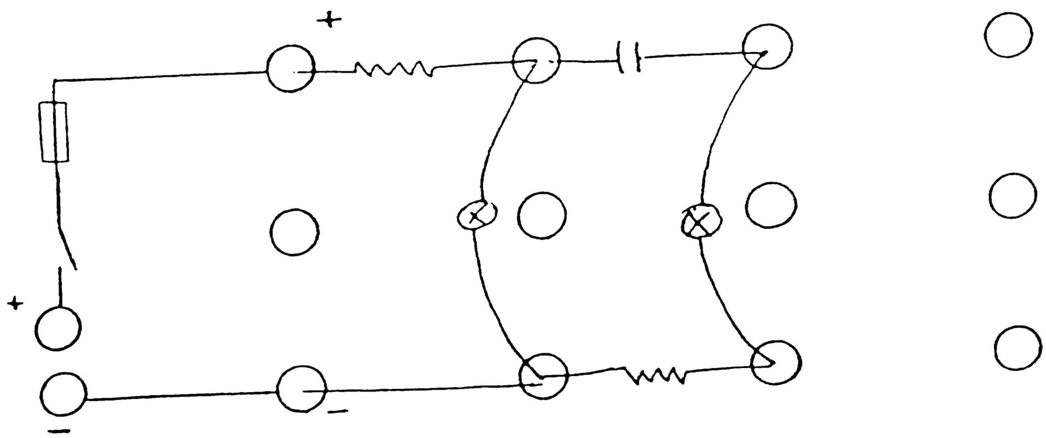
Instructions for Circuit Boards

The circuit board is a board where you can plug in electrical components rather than connecting them up. The board consists of 2 input plugs that can be used for A.C. and D.C. inputs. A switch so that the board is isolated while you make changes to your circuit. A fuse to protect the components if the board is wired up incorrectly. There are 12 connecting plugs.

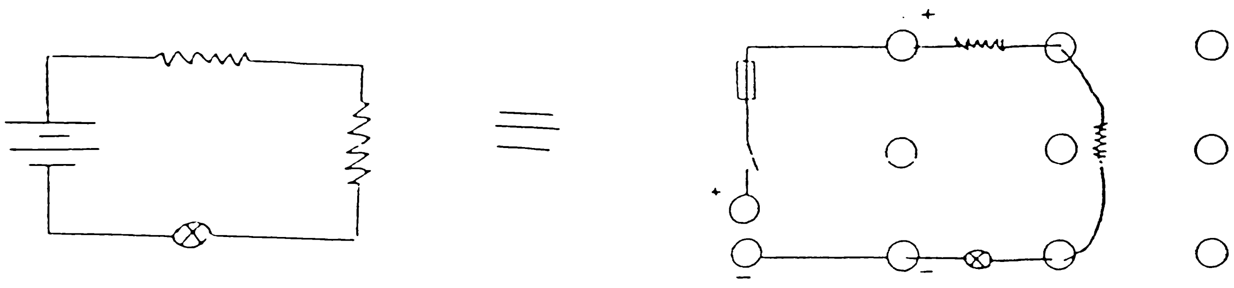
A diagram of the circuit board is shown below.



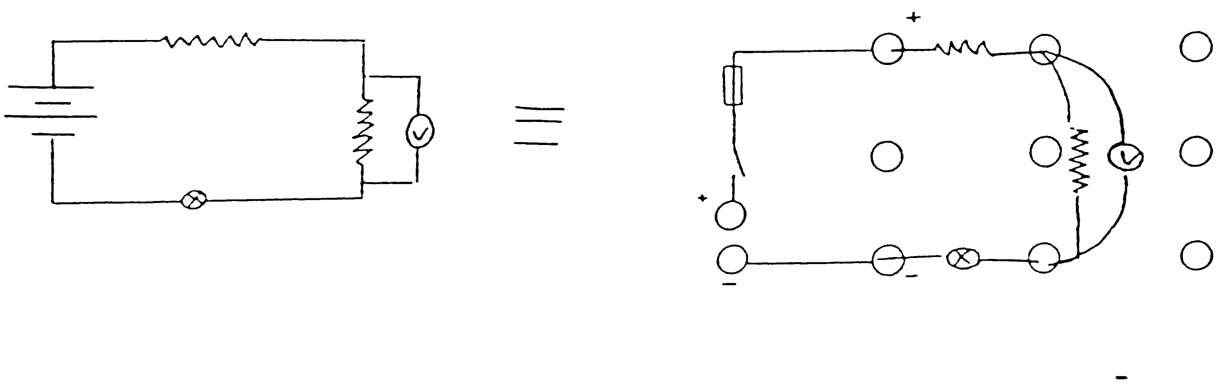
The components in the circuit are connected to the remaining plugs. Wire leads maybe needed to complete the circuit.



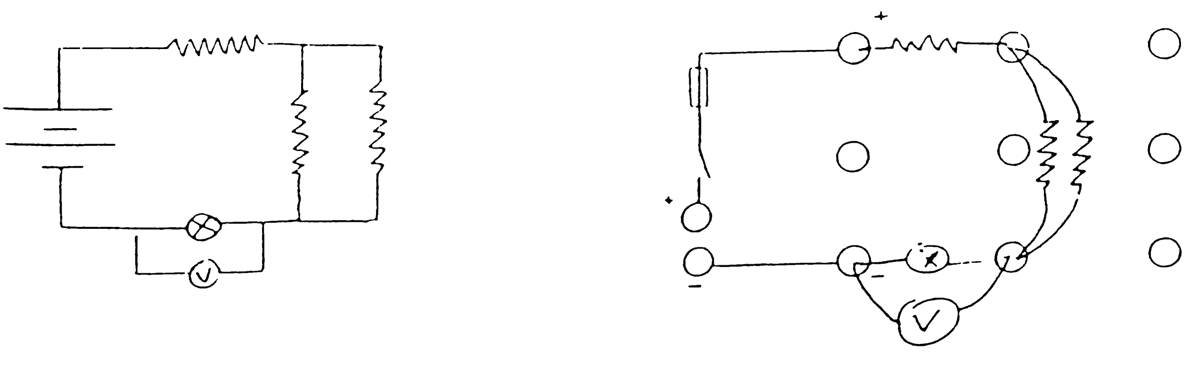
This circuit should be wired up on the board like this:



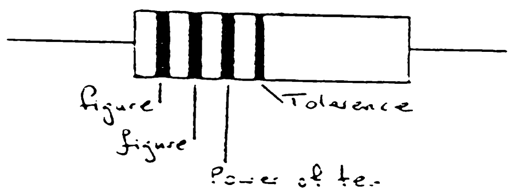
Putting a voltmeter across one of the components is easy.



If components need to be put in parallel then the plugs can be stacked one on top of the other.



Resistor Codes



Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Purple	7
Silver	8
White	9

A brown Black Red Resistor will be $10 \times 10^2\Omega$.

A Yellow Blue Brown Resistor will be $46 \times 10^1\Omega$ i.e. 460Ω.

A red red Brown Resistor will be $22 \times 10^1\Omega$ i.e. 220Ω.

SCIENCE AND TECHNOLOGY APPROACH TO TEACHING DOPPLER EFFECT (7th form)

Teachers notes and student work sheets.

Equipment supplied:

1) Video of technological applications and demonstrations.

2) Overhead projector transparencies of wavefronts.

THEME

DETECTING MOVING OBJECTS

VIDEO

There are times when we want to measure the movement of objects remotely. How can we do this?

Start the video

For example speeding. How do traffic officers detect the speed of moving vehicles using microwaves. What are these sound type (microwaves) waves and how do they detect moving cars?

The flow of blood in arteries and veins can be detected using a device called an ultrasonic doppler probe. An audible sound can be detected. This device sends out ultrasonic type waves. How do they detect blood flow?

Another device used in hospitals detects the movement of a foetal heart wall. When a baby is about to be born a foetal heart beat monitor is used to monitor the heart beat for any signs of foetal distress.

Maybe we don't have much use for devices that have been shown but maybe we could use a similar device to protect our possessions.

- Point out the transmitter and receiver.

All these devices operate using sound and electromagnetic waves. The waves go out and somehow detect the moving object.

TEACHER DIRECTION

How can we detect moving objects by using waves?

How do you think these devices might work?

Maybe a starting point is to look at which we already know about.

Let's make a list of what we already know?

What are microwaves?

What are ultrasound waves?

Typical list might be - List the ideas in their notes.

Reflection
Compression type waves
Have different frequencies
Speed of sound waves is approximately $330ms^{-1}$
Speed of electromagnetic radiation is $3 \times 10^8 ms^{-1}$

These devices use waves and were detecting moving objects.

What do we know about the sound from moving objects?

What happens to the sound of a motor bike or motor car that passes you? What sort of noise does it make?

If they come up with the idea:

The change in pitch as something passes you is known as the Doppler effect.

Show the video [Car (with horn sounding) driving down the road].

Talk about what the students notice. Write down their ideas of what is happening.

Stimulate the discussion as to why this should be.
The reasons for the change in frequency.

2 situations a horn or fixed frequency device coming towards us then moving away from us.
Then moving towards a stationary source of sound.

Explore in detail the pupils ideas of what they think is happening.
Use the pupils' ideas to develop the theory.

Then show the ripple tank to try and explain what is happening.

Get the pupils to develop a descriptive account of what is happening rather than a mathematical approach.

Get them to identify the change in frequency and the change in wavelength and transfer this to what has happened with the car. i.e. emphasis the transfer of a model to the real situation.

Describe the source moving towards the observer in terms of shorter wavelength therefore higher frequency.

As the car moves towards the stationary source the car will come across a lot more wavefronts.

Moving Source

Moving towards Observer

$$\lambda' = \frac{340-20}{800}$$

$$= 0.4 \text{ m}$$

$$f' = \frac{v}{\lambda'}$$

$$= \frac{340}{0.4}$$

$$= 850 \text{ Hz.}$$

$$f' = \frac{v}{v-v_s/f}$$

$$= f' = f\left(\frac{v}{v-v_s}\right)$$

Moving away from Observer

$$\lambda^1 = \frac{340+20}{800}$$

$$= \frac{360}{800}$$

$$= 0.45 \text{ m}$$

$$f^1 = \frac{v}{\lambda^1}$$

$$= \frac{340}{0.45}$$

$$= 756 \text{ Hz.}$$

$$f^1 = \frac{v}{\frac{v+v_s}{f}}$$

$$f^1 = f\left(\frac{v}{v+v_s}\right)$$

Which is what our ears tell us. Our ears are actually a lot more sensitive than most measuring instruments we have at school.

Try f_0 = 800Hz $v = 30ms^{-1}$ and $v = 10ms^{-1}$

These equations tell us the faster the object is moving the greater the frequency change.

Moving Observer. Stationary Source

f_0 = 800 Hz $v = 20ms^{-1}$

As the car approaches the stationary source it will come across more waves than when it is moving away.
Example of boat in the sea. Going towards the source of the waves meets many more than when going away.
Maybe this could be explored with the ripple tank. Get pupils to try out different ideas. Use the O.H.P. transparencies etc.

Towards the source

$$f^1 = f_0 + \frac{v_s}{\lambda} \qquad \lambda = \frac{v_0}{f_0}$$ Explain in terms of ripples.

$$f^1 = f_0 + \frac{v_s}{v_0/f_0}$$

$$= f_0 + \frac{v_s f_0}{v_0} \qquad f_0\left(\frac{v_0+v_s}{v_0}\right)$$

$$= f_0\left(1 + \frac{v_s}{v_0}\right)$$

$$= 800 \left(\frac{340+20}{340}\right)$$

$$= 847 \text{ Hz.}$$

When its moving away it will come across fewer wavefronts in the same time.

$$f^1 = f_0 - \frac{v_s}{\lambda}$$

$$= f_0 - \frac{v_s}{v_0/f_0}$$

$$= f_0 - f_0\frac{v_s}{v_0} \qquad f_0\left(\frac{v_0-v_s}{v_0}\right)$$

$$= f_0\left(1 - \frac{v_s}{v_0}\right) \Rightarrow 800 \times \left(\frac{v_0-v_s}{v_0}\right)$$

$$= 753 \text{ Hz.}$$

Try different velocities and frequencies.

STUDENT PROBLEM

Super Snooper Problem

You have been employed by a company who want you to develop a device which will detect just the microwaves used by the traffic department. The device they have in mind will only detect a small range of frequencies.

The frequency used by the traffic department is found to be 10^{10} Hz. The speed of these waves is $3 \times 10^8 ms^{-1}$ because they are electromagnetic rather than acoustic.

Calculate for a range of speeds what the frequency will be hitting the car.

(These values will be approximate because of rounding by the calculator which has only 6 or 8 significant figures).

It has been found that traffic department can now detect the speed of cars moving away from microwave source. Calculate for various speeds the frequencies hitting the car.

STUDENT PROBLEM

Medical Diagnostics

As a medical doctor you are using an ultrasound device to examine various organs in the human body. (This device is used in obstetrics, surgery including plastic surgery and most aspects of medicine). These devices rely on reflection not frequency change yet for some reason there appears to be a change in frequency when the device is put near the heart or main arteries.

Why do you think this would be?

These ultrasound devices use a frequency of 7 MHz. The speed of sound waves in a liquid is $1500ms^{-1}$.

Find the frequency that will be interacting with the heart wall if it moves with a velocity of $0.075ms^{-1}$

a) away from

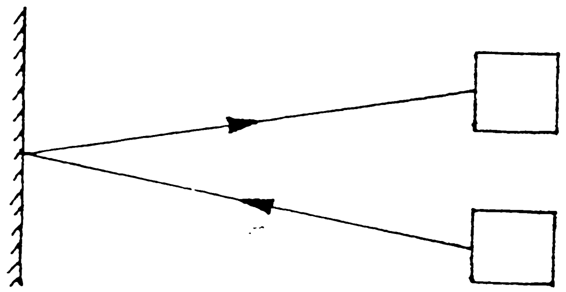
and b) towards the source

The frequency impinging on a red blood cell is found to be 1.0002×10^6Hz when it is moving towards the source. Calculate the speed of a red blood cell in the aorta. Velocity of waves is again $1500ms^{-1}$.

Teacher Summary

Show Moving Plates on Video

Explanation There are actually two doppler shifts.



The reflector acts as a receiver and a transmitter. When the sound wave is sent out the frequency if the reflector is moving away will decrease so use $f\left(\frac{v}{v+v_s}\right)$. As the waves are reflected the reflector acts as a moving source moving towards a stationary observer $f\left(\frac{v-v_s}{v}\right)$ combining the two for when the reflector is moving away results in $f' = f\left(\frac{v-v_s}{v+v_s}\right)$ i.e. a reduction in frequency.

When the reflector moves towards the source the reflector acts as an object moving toward the source $f\left(\frac{v_0+v_s}{v_0}\right)$ this wave is then reflected as if it were a moving source towards a stationary observer. $f\left(\frac{v_0}{v_0-v_s}\right)$ Giving $f^1 = f\left(\frac{v_0+v_s}{v_0-v_s}\right)$ which is an increase in frequency.

Does this agree with what you saw?
Show the video again.

Check the information provided about the reflector and frequency change by doing some examples and comparing figures.

Does this information provide us with some idea how the devices mentioned earlier may work?

Moving Away.

$$f' = f\left(\frac{c-v_c}{c+v_s}\right)$$

$$f' = 40035\left(\frac{u-v_s}{u+v_0}\right)$$

$$= 40035\left(\frac{340-0.05}{340+0.05}\right)$$

$$= 40023$$

If moving at $0.05ms^{-1}$

Estimate the speed and do some calculations.

Moving towards

$$f' = f\left(\frac{v+v_0}{v-v_0}\right)$$

$$= 40035 \left(\frac{340.05}{339.95}\right)$$

$$= 40047 \qquad \Delta f = 12 \text{ Hz.}$$

If moving at 7.5cms^{-1} what is the frequency?

Moving away the frequency goes down - Moving towards the transmitter receiver the frequency increases.

Show video experiment results.

Work out the above results using the beat frequency.
Give the students the choice of what they would like to learn more about

a) Microwaves, speed detection and burglar alarms

b) Ultrasonics, foetal heartbeat monitors and blood flowmeters.

Microwaves, Speed Detection and Burglar Alarms

Microwaves are electromagnetic waves as are radiowaves. Microwaves have a frequency in the region of 10^8 - 10^{12} Hertz. These waves are produced by electronic equipment. Electromagnetic waves have a velocity of approximately $3 \times 10^8 ms^{-1}$. Microwaves are used in radar, communication links for the post office, cooking etc.. They are also used by the Traffic department for speed detection and are used in burglar alarms.

The principle behind these detection devices is the Doppler Effect and the reflection of waves.

Let's examine what we already know about the Doppler effect with regard to moving objects and apply this information to a microwave detector and a burglar alarm.

Microwave Detector

The microwave speed detector used by the traffic department contains both a transmitter and a receiver. The microwaves are sent out from the detection unit (transmitter), reflected off the moving car back to the receiver.

The microwaves hitting the car will be changed in frequency since the car acts as an observer approaching a stationary source. The frequency of the microwaves incident on the moving car will be changed to $f' = f\left(\frac{u + v_0}{u}\right)$.

i) The frequency used by the traffic department is 10^{10} Hz and the car is moving toward the detector at 140 kmh^{-1} (40ms^{-1}) calculate the frequency incident on the car. For electromagnetic waves $U = 3 \times 10^8 ms^{-1}$.

[Hint - Calculator may not be able to complete all the calculations
$\left(\frac{u+v_0}{u}\right) \Rightarrow \frac{3\times10^8+40}{3\times10^8} = 1.0000001$]

The incident frequency on the car is then reflected back. The car then acts as a moving source with a frequency of f′ where $f' = f\left(\frac{u+v_0}{u}\right)$.

Therefore the frequency at the stationary receiver will be $f'' = f'\left(\frac{u}{u-v_s}\right)$

ii) Calculate the frequency detected by the receiver

Combining the two equations

$$f'' = f\left(\frac{u+v_0}{u}\right)\left(\frac{u}{u-v_s}\right)$$

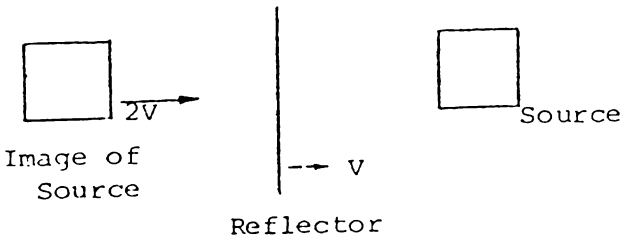
$$= f\left(\frac{u+v_0}{u-v_s}\right)$$

Ans = 10000002000Hz

iii) Use the following equation to check your answer.

There is a change in frequency of 2000 Hz. (This is approximate because of rounding). The microwave detector compares the frequency of the transmitted wave with that of the reflected wave. The difference between the transmitted frequency and the received frequency is called the beat frequency.

Another way to think of this phenomena is to imagine the object that microwaves are reflecting off - in this case a car, will act something like a mirror. The reflector is moving toward the source at a velocity v, therefore the image of the source will move with a velocity of 2v.



Therefore acts an an observer moving towards a stationary source at 2v.

$$f' = f\left(\frac{u+2v_s}{u}\right)$$

$$= f\left(\frac{u_0}{u} + \frac{2v_s}{v_0}\right)$$

$$= f\left(1 + \frac{2v_s}{u}\right)$$

$$\Delta f = f' - f = \frac{2fv_s}{u}$$

This is the beat frequency the difference between the transmitted and received frequency. This is the actual frequency recorded by the device and then converted to a speed.

This can be written as $f_B = \frac{2f_0v}{u}$.

Find the beat frequency using the equation for the car moving at 140 kmh^{-1}.

$$f_B = \frac{2x1x10^{10}x40}{3x10^8}$$

$$= 2666 \text{ Hz}$$

If this microwave device was used to measure cars moving away from the detector discuss how you would find the frequency change? Would you expect the frequency change to be higher or lower than the transmitted signal?

> Hint Car moving away acts as an observer moving away from source and then as a source of waves moving away from a stationary observer.

(vi) Find a formula for the frequency change involved. Use both methods. Discuss your reasoning in full.

Using the beat frequency formula (remember beat frequency is $f_B = f_r - f_s$ where f_r = received frequency f_s = source frequency. When the object is moving away from the source is $f_B = -\frac{2f_0v_0}{u}$

If the object is moving toward the source the frequency is increased. If the object is moving away from the source the frequency is decreased. ∴ beat frequency i.e. difference between transmitted and reflected frequency will be positive when the car is moving towards the detector and negative when the car is moving away from the detector.

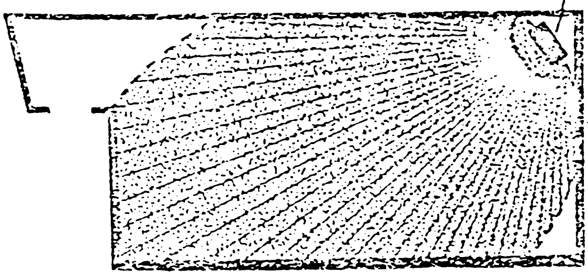
Convert the following speeds into a beat frequency for a microwave detector.

Speed	Direction	Beat frequency
50 kmh-1	towards	
70 kmh-1	towards	
100 kmh-1	towards	
140 kmh-1	towards	
20 kmh-1	away	
60 kmh-1	away	

Microwave Burglar Alarm

These devices are used in warehouses and factories where large open areas need to be under surveillance. The long range version can detect movement up to 36 metres.

The microwave burglar alarms consist of a transmitter which fills the room with waves at a frequency of approximately 1×10^{10}Hz and a receiver which picks up the sound waves reflected from objects in the room. The stationary objects reflect the sound waves back at the same frequency as was transmitted. If there is an intruder in the room the waves that are reflected from the intruder undergo a frequency change because of the intruder's movement. The receiver analyses all the incoming frequencies and if there is a reflected wave at a different frequency from the original an alarm will sound. The figure below shows the amount of area covered by this device.



The device is very sensitive and can pick up very small frequency changes. The sensitivity of the device can be varied depending on the situation. In some cases the device may be set so it will detect a frequency difference of 20Hz. Using the beat frequency formula

$f_B = \frac{2fv_0}{u}$ calculate the velocity of the moving object.

If an intruder is detected moving $\sim 1\text{ms}^{-1}$ the frequency detected will change by 67Hz which will trigger the alarm.

$$\Delta f_B = \frac{2vf}{c}$$

$$= \frac{2 \times 1 \times 10^{10}}{8 \times 10^{8}}$$

$$= 67 \text{ Hz.}$$

1. Explain in terms of waves and the Doppler effect how this device works i.e. explain how the change in frequency comes about.

2. Some of these devices trigger even when there is no burglar in the room. What else could trigger the alarm?

3. If heaters are left on the alarm sometimes sounds. Think of a reason why this would be so.

Ultrasonics, Foetal Heart Beat Monitors and Blood Flow meters

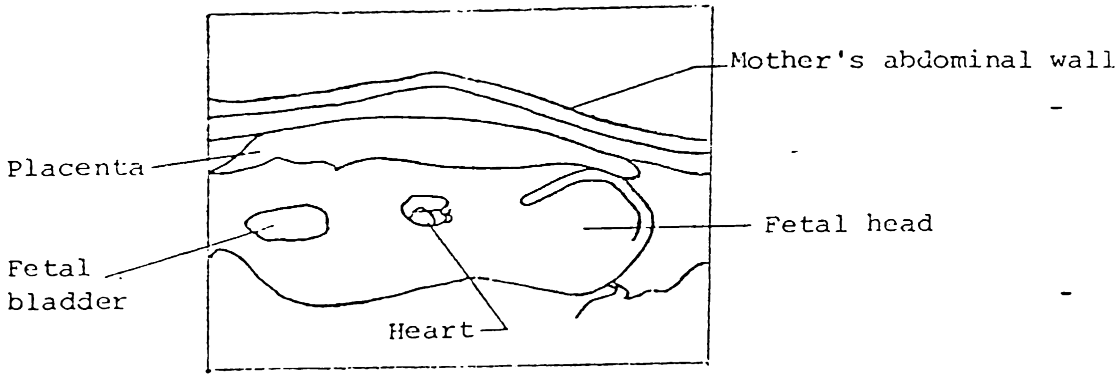
Ultrasound are high frequency sound waves with frequencies above 20 000Hz. Ultrasound can presently be produced at frequencies up to 10^9Hz. It is widely used as a diagnostic, therapeutic and surgical tool in medicine. The velocity of sound waves in a liquid is approximately $1500 ms^{-1}$. In examining Foetal heart beat monitors and blood flow meters we will examine ultrasound waves as a diagnostic tool.

The principle behind these diagnostic devices is the Doppler Effect and the reflection of waves.

Let's examine what we already know about the Doppler Effect with regard to moving objects and apply this information to a Foetal Heart Beat Monitor and a Blood Flow detector.

Foetal Heart Beat Monitor

Prior to the commencement of labour the Doppler shift probe is used to check the baby's heart beat and to monitor it for foetal distress during labour, i.e. rapid fluctuations in heart beat. The baby's heart beat rate usually indicates if there is something wrong prior to birth. If the baby becomes too distressed appropriate action can be taken by the doctors, for example, a caesarean.



The foetal heart beat monitor consists of a Doppler Shift Probe which contains a transmitter and a receiver. The Doppler Shift Probe is placed on the mothers abdomen, over the babies heart which has been found by more traditional methods.

The ultrasonic waves at a frequency of 5 MHz are sent out from the transmitter and are reflected off the moving heart wall back to the receiver. The ultrasonic waves hitting the heart wall as it moves toward the transmitter will be changed in frequency since the heart wall will act as an observer approaching a stationary source. The frequency of the ultrasound waves incident on the heart will be changed to $f' = f\left(\frac{u+v_0}{u}\right)$.

Since the frequency used is 5MHz and if the heart wall is moving toward the transmitter at $0.075 ms^{-1}$ (which is the average velocity of a foetal heart). Calculate the frequency incident on the heart wall. Speed of sound in a liquid is $1500 ms^{-1}$.

The incident frequency on the heart wall is then reflected back. The heart wall then acts as a moving source with a frequency of f′ where $f' = f\left(\frac{u+v_0}{u}\right)$. Therefore the frequency at the stationary receiver will be $f'' = f'\left(\frac{u}{u-v_s}\right)$

ii) Calculate the frequency detected by the receiver.

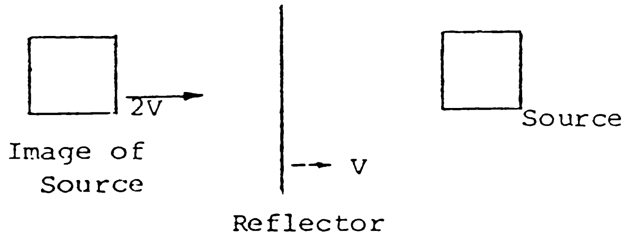
Combining the two equations $f'' = f\left(\frac{u+v_0}{u}\right)\left(\frac{u}{u-v_s}\right)$

$$= f\left(\frac{u+v_0}{u-v_s}\right)$$

iii) Use this equation to check your answer. Show working.

There is a frequency change of 500Hz.

Another way to think of this phenomena is to imagine the object that the ultrasonic waves are reflecting off, in this case an expanding heart wall, will act something like a mirror. The reflector is moving toward the source at a velocity v, therefore the image of the source will move with a velocity of 2v.



Therefore it acts as an observer moving towards a stationary source at 2v

$$f' = f\left(\frac{u+2v_s}{u}\right)$$

$$= f\left(\frac{u}{u} + \frac{2v_s}{u}\right)$$

$$= f\left(1 + \frac{2v_s}{u}\right)$$

$$f'-f = \frac{2fv_s}{u}$$

This is the beat frequency, the difference between the transmitted and received frequency. This is what the foetal heart beat monitor records and converts to a heart rate.

This can be written as $f_B = \frac{2f_0 v}{u}$

(iv) Calculate the beat frequency when the heart is expanding at a rate of $0.075 ms^{-1}$.

(v) The Doppler Shift probe also measures the frequency change as the heart wall contracts, i.e. moves away from the probe. Discuss how you would find the frequency change? Would you expect the frequency change to be higher or lower than the transmitted signal?

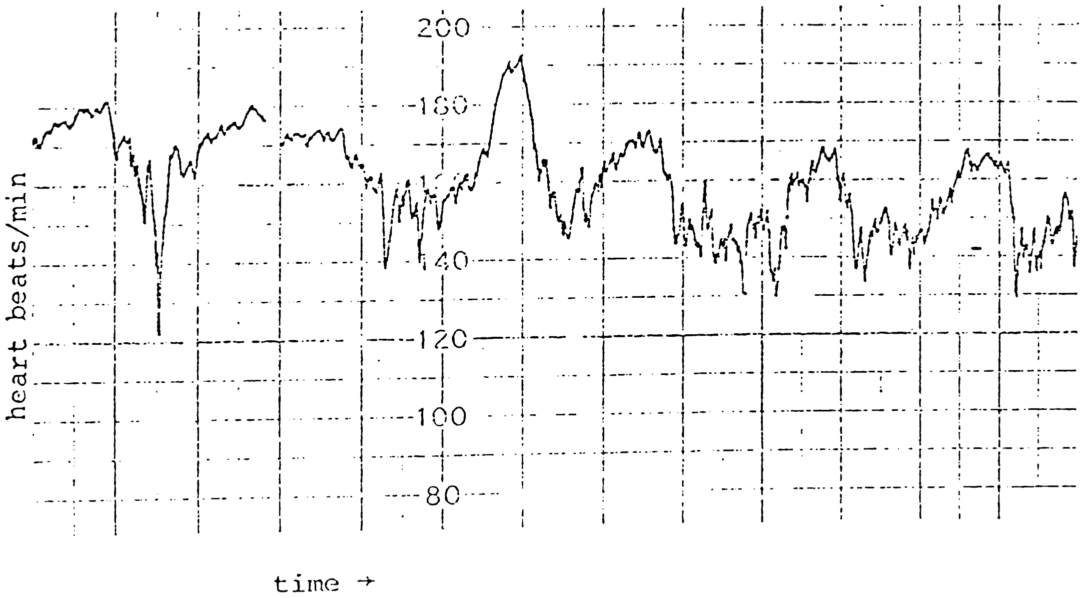
<u>Hint</u> As the heart wall moves away from the probe it acts as an observer moving away from the source and then when it reflects the waves it acts as a source of waves moving away from a stationary observer.

(vi) Find a formula for the frequency change involved. Use both methods.

The beat frequency formula (remember beat frequency is $f_B = fr - f_s$ where f_r = received frequency, f_s = source frequency) when the object is moving away from the source is $f_B = -\dfrac{2f_0v_0}{u}$.

If the heart wall moves toward the source the frequency is increased. If the object is moving away from the source the frequency is decreased. The beat frequency will be positive when the heart is expanding and negative when it's contracting.

The changes in beat frequency are graphed in terms of changes in heart beat per minute so that the doctor has a continuous record of foetal activity.



(vii) Convert the velocity of the heart wall to a beat frequency. Use 5MHz

ms^{-1}	frequency
0.07 0.06 0.02 0.08	

(viii) Convert the above velocities to the actual frequency. Use 5MHz.

cms^{-1}	Movement	frequency
0.07 0.075 0.061 0.065	contracting expanding contracting expanding	

Measurement of Blood Flow

A combination of the Doppler effect and ultrasonic technique can be used to measure blood flow. This technique is useful for detecting whether or not blood is flowing correctly in arteries and veins. It can be used to detect vascular disease, constrictions within the circulatory system and the position of the veins and arteries.

The device is connected to an amplifier to provide an audio signal. In the video a cuff was put on so that the surging of the blood through the artery would be heard.

The acoustic head of the device is covered with a gel to improve the transmission of the sound waves. The transmitted signal is reflected back from the red blood cells flowing in the blood. The velocity of the red blood cells modifies the frequency of the reflected wave. The frequency of the ultrasound waves used for this measurement is 10MHz.

Red blood cells flow at $0.3ms^{-1}$ in a large artery and $1x10^{-3}ms^{-1}$ in a capillary. In this device the frequency shift is converted to an audible signal and amplified. The higher the pitch of the sound the greater the blood flow velocity.

1. Explain in terms of the Doppler effect and reflection of waves how this device works.

2. Calculate the beat frequency when ultrasound waves are reflected off a red blood cell in an artery and a capillary. Use the above information.

3. What will be the frequency incident on a red blood cell moving in an artery at $0.2ms^{-1}$. If it is moving away from the Doppler Shift Probe.

4. Calculate the frequency incident on a red blood cell moving at $1.5ms^{-1}$ towards the Doppler Shift Probe.

APPENDIX J: THE SEMANTIC DIFFERENTIAL SCALE USED IN THE EVALUATION OF THE TEACHING PACKAGES

How do you feel about the physics course this year.
Please indicate along the scale.

Boring	:___:___:___:___:___:___:___:	Interesting
Difficult	:___:___:___:___:___:___:___:	Easy
Irrelevant to career	:___:___:___:___:___:___:___:	Relevant to career
Irrelevant to everyday life	:___:___:___:___:___:___:___:	Relevant to everyday life
Unenjoyable	:___:___:___:___:___:___:___:	Enjoyable
Straightforward	:___:___:___:___:___:___:___:	Complicated
Non-mathematical	:___:___:___:___:___:___:___:	Mathematical
Few Calculations	:___:___:___:___:___:___:___:	Many Calculations
Technological	:___:___:___:___:___:___:___:	Theoretical
Clear explanations	:___:___:___:___:___:___:___:	Vague explanations
Unsatisfying	:___:___:___:___:___:___:___:	Satisfying
Worthless	:___:___:___:___:___:___:___:	Valuable
Unfamiliar	:___:___:___:___:___:___:___:	Familiar
Inadequate Theory	:___:___:___:___:___:___:___:	Adequate Theory
Dull	:___:___:___:___:___:___:___:	Exciting
Uninformative	:___:___:___:___:___:___:___:	Informative

APPENDIX K: STATISTICAL DATA FROM THE EVALUATION OF THE TEACHING PACKAGES

APPENDIX K.

The statistical analysis of the evaluation data

The semantic differential scale was used initially as a probe for interviewing the students on how they felt about the trial units. Two tests were used to identify along with the interviews student responses to the trialled units.

The two tailed t-test was used to calculate the change in mean response to each item. The change in mean did not provide a complete picture as students who scored lowly may have been the only ones to move, the number of questions compared to the number of respondents was large, and many questions were related.

The sign test provided data on the number of students who had changed either positively or negatively. The following test was used.

$$Z = \frac{|D|-1}{\sqrt{N}}$$

where D is the difference between the number of + and - signs. N is the number who changed. The test assumed that the responses were reasonably stable.

Table 55: Comparison of traditional physics with the new capacitance unit

	Traditional physics Mean	Capacitance Unit Mean	S.E.D	t	
Boring-Interesting	4.47	5.83	0.31	4.33	**
Difficult-Easy	3.17	5.21	0.20	10.15	**
Irrelevant to-Relevant to career career	4.73	3.45	0.41	3.14	**
Irrelevant to- Relevant to everyday life everyday life	4.03	5.00	0.35	2.76	**
Unenjoyable-Enjoyable	4.43	5.48	0.36	2.92	*
Complicated-Straightforward	3.20	4.86	0.32	5.19	**
Mathematical-Nonmathematical	2.27	3.66	0.26	8.36	**
Many -Few calculations-calculations	1.93	3.69	0.28	6.28	**
Theoretical-Technological	3.53	4.79	0.34	3.71	**
Vague -Clear Explanations Explanations	5.10	5.62	0.32	1.63	
Unsatisfying-Satisfying	4.60	5.07	0.34	1.38	
Worthless-Valuable	5.13	5.03	0.33	0.30	
Unfamiliar-Familiar	4.23	3.97	0.34	0.79	
Inadequate theory-Adequate theory	5.40	5.66	0.31	0.82	
Dull-Exciting	4.37	4.76	0.32	1.23	
Uninformative-Informative	5.40	5.86	0.24	1.93	

** significant at least at 1% level using a two tailed T-test
* significant at at at 5% level
S.E.D Standard error of the difference between the means.

Table 56: Comparison of traditional physics with the new Doppler effect unit

	Traditional physics Mean	Doppler unit Mean	S.E.D.	t	
Boring-Interesting	4.47	5.54	0.29	3.67	**
Difficult-Easy	3.17	4.50	0.33	4.05	**
Irrelevant to career-Relevant to career	4.73	3.93	0.43	1.87	
Irrelevant to everyday life- Relevant to everyday life	4.03	5.57	0.31	4.89	**
Unenjoyable-Enjoyable	4.43	5.32	0.31	2.82	*
Complicated-Straightforward	3.20	4.11	0.38	2.41	*
Mathematical-Nonmathematical	2.27	3.46	0.29	4.13	**
Many calculations -Few calculations	1.93	3.61	0.24	7.00	**
Theoretical-Technological	3.53	4.54	0.33	3.01	**
Vague Explanations -Clear Explanations	5.10	5.11	0.34	0.02	
Unsatisfying-Satisfying	4.60	4.82	0.30	0.72	
Worthless-Valuable	5.13	4.75	0.31	1.24	
Unfamiliar-Familiar	4.23	3.61	0.37	1.67	
Inadequate theory-Adequate theory	5.40	5.18	0.34	0.65	
Dull-Exciting	4.37	4.43	0.27	0.23	
Uninformative-Informative	5.40	5.57	0.26	0.65	

** significant at least at 1% level using two tailed T-test
* significant at at least at 5% level
S.E.D Standard error of the difference between the means.

Table 57: Comparison of trial school with traditional school

	Trial school Mean	Traditional school Mean	S.E.D	t	
Boring-Interesting	4.47	3.91	0.43	1.29	
Difficult-Easy	3.17	2.82	0.31	1.13	
Irrelevant to career-Relevant to career	4.73	4.55	0.47	0.40	
Irrelevant to everyday life- Relevant to everyday life	4.03	3.27	0.39	1.97	
Unenjoyable-Enjoyable	4.43	3.64	0.42	1.92	
Complicated-Straightforward	3.20	2.95	0.39	0.63	
Mathematical-Nonmathematical	2.27	2.91	0.38	1.69	
Many calculations -Few calculations	1.93	2.41	0.35	1.34	
Theoretical-Technological	3.53	2.91	0.40	1.56	
Vague Explanations -Clear Explanations	5.10	3.00	0.30	6.90	**
Unsatisfying-Satisfying	4.60	3.82	0.40	1.77	
Worthless-Valuable	5.13	4.59	0.37	1.45	
Unfamiliar-Familiar	4.23	3.64	0.41	1.47	
Inadequate theory-Adequate theory	5.40	4.81	0.44	2.77	
Dull-Exciting	4.37	3.50	0.35	2.46	
Uninformative-Informative	5.40	5.00	0.29	1.36	

** significant at least at 1% level using two tailed T-test.

S.E.D. Standard error of the difference between the means.

Table 58: Comparison of traditional physics with traditional capacitance

	Traditional physics Mean	Traditional capacitance Mean	S.E.D.	t	
Boring-Interesting	3.91	3.50	0.51	0.81	
Difficult-Easy	2.82	3.55	0.38	1.93	
Irrelevant to career-Relevant to career	4.55	3.00	0.60	2.58	*
Irrelevant to everyday life- Relevant to everyday life	3.27	3.25	0.54	0.04	
Unenjoyable-Enjoyable	3.64	3.20	0.41	1.06	
Complicated-Straightforward	2.95	3.95	0.46	2.14	
Mathematical-Nonmathematical	2.91	3.15	0.45	0.54	
Many calculations -Few calculations	2.41	3.9	0.44	3.36	**
Theoretical-Technological	2.91	3.45	0.44	1.22	
Vague Explanations -Clear Explanations	3.00	3.60	0.38	1.59	
Unsatisfying-Satisfying	3.82	3.10	0.43	1.61	
Worthless-Valuable	4.59	3.90	0.47	1.59	
Unfamiliar-Familiar	3.64	3.65	0.53	0.03	
Inadequate theory-Adequate theory	4.18	4.55	0.48	0.76	
Dull-Exciting	3.50	3.20	0.39	0.76	
Uninformative-Informative	5.00	4.45	0.41	1.33	

** significant at 1% level using two tailed T-test.
* significant at 5% level

S.E.D Standard error of the difference between the means.

Table 59: Sign test for the new capacitance and Doppler effect units.

	Capacitance Z	Doppler Z
Boring-Interesting	4.08**	2.83**
Difficult-Easy	4.56**	3.2**
Irrelevant to-Relevant to career career	2.94**	0.95
Irrelevant to- Relevant to everyday life everyday life	2.51**	4.16**
Unenjoyable-Enjoyable	3.06**	2.6**
Complicated-Straightforward	3.34**	1.32
Mathematical-Nonmathematical	4.4**	1.89
Many calculations-Few calculations	4.51**	3.97**
Theoretical-Technological	3.49**	2.83**
Vague Explanations-Clear Explanations	1.8	0.19
Unsatisfying-Satisfying	0.98	0.57
Worthless-Valuable	0.20	0.19
Unfamiliar-Familiar	0.20	0
Inadequate theory-Adequate theory	0.20	0
Dull-Exciting	1.55	0.19
Uninformative-Informative	2.18*	1.5

** significant at 1% level
* significant at 5% level

REFERENCES

AHLGREN, A. and WALBERG, H.J. (1973). Changing attitudes towards science among adolescents. Nature, 245, 187-189.

AIKENHEAD, G.S. (1980). Science in Social Issues - Implications for Teaching. Ottawa: Science Council of Canada.

ALLPORT, G.W. (1961). Pattern and Growth in Personality. New York: Holt Rinehart and Winston.

ASHTON, P.M.E. and MEREDITH, C.M. (1969). Attitudes to science and scientists. School Science Review, 51 (174), 15-19.

ASSESSMENT PERFORMANCE UNIT. (1985). Science in Schools. Age 11. Report No 4. D.E.S. London.

AUSUBEL, D.P. (1968). Educational Psychology: A Cognitive View. New York: Rinehart and Winston, Inc.

BALDWIN, J.O. (1975). High-school students shun careers in physics. Physics Today, 28(3), 9.

BARCLAY, A.W. and GIBBON, J.A. (1980). Physics Principles at Work. B.P. Educational Service. London.

BARKER, M.A. (1986). The Description and Modification of Children's Views of Plant Nutrition. Unpublished D.Phil. Thesis, University of Waikato, Hamilton.

BELL, B.F. (1985). The Role of Existing Knowledge in Reading Comprehension and Conceptual Change in Science Education. Unpublished D.Phil. Thesis, University of Waikato, Hamilton.

BELL, B.F. and OSBORNE R.J. (1981). Interviewing children - A checklist for the I.A.I. interviewer. Working Paper of the Science Education Research Unit, University of Waikato, Hamilton.

BIDDULPH, F. and OSBORNE, R.J. (1984). Making Sense of Our World. An Interactive Teaching Approach. University of Waikato, Hamilton.

BLACK, P. and HARRISON, G. (1985). In place of Confusion. Technology and Science in the School Curriculum. London: Nuffield-Chelsea Curriculum Trust.

BOLSTAD, W.M. (1979). Statistical Inferences (I). Hamilton: University of Waikato.

BONDI, H. (1975). Physics Education and Society. Physics Education, 10(7), 469-474.

BRANSKY, J. and SUZKOVER, E. (1980). Teaching of modern technology to students with a modest scientific knowledge. In Ganiel U (Ed). Physics Teaching, GIREP, Balaban, Jerusalem, 269-273.

BRIDGMAN, R.G. and WELCH, W.W. (1969). Physics enrolments and grading practices. Journal of Research in Science Teaching, 6(9), 44-46.

BROWN, C.J. and ELLIOT, W.E. (1973). Perception of physics and physics teachers by college students. Journal Research in Science Teaching, 10(1), 51-54.

BRYHNI, E. and LIE, S. (1985). Girls and the image of physics - an evil circle. Contributions to the Third GASAT Conference. London: Chelsea College, University of London.

BURNS, J. (1982). An evaluation of 6th and 7th form Chemistry in terms of the Needs of the Students and the Community. Report to the Department of Education, Wellington, N.Z.

BUTCHER, H.J. (1969). The structure of abilities, interests and personality in 1,000 Scottish school children. British Journal of Educational Psychology, 38, 154-165.

CARR, M.D. (1985). A research method for science education based upon interviews-about-events. Working Paper No 210, Science Education Research Unit. Hamilton: University of Waikato.

CASIMIR, H.B.G. (1976). Education, Physics and Technology. Physics Education, 11(1), 11-15.

CLAXTON, G.L. (1984). Teaching and acquiring scientific knowledge. In Keen, T. and Pope, M. (Eds). Kelly in the Classroom. Educational Application of Personal Constraint Psychology. Montreal, Cybersystems.

CLAXTON, G.L. (1985). Mini theories: A user friendly view of domain-specific learning. Centre for Science and Mathematics Education, Chelsea College, University of London.

*
COSGROVE, M.M. and MUERGGENBURG, G. (1986). Refrigeration: A teaching unit for Form 6 Physics. Working Paper No 211, Science Education Research Unit. Hamilton: University of Waikato.

COSGROVE, M. and OSBORNE, R. (1985). Lesson frameworks for changing children's ideas. In Osborne, R. and Freyberg, P (Eds), Learning in Science: the implications of children's science. Auckland: Heinemann.

COSGROVE, M., OSBORNE, R. and CARR, M. (1984). Using practical and technological problems to promote conceptual change. Aspects of Understanding Electricity. Proceedings of an international workshop, 257-266.

* COHEN, L. and MANION, L. (1980). Research Methods in Education. London: Groom-Helm.

CROSS, R.J., CARTER, J., SLOCOMBE, M. and WERNER, T. (1985). Towards the teaching of the new technologies. Australian Science Teachers Journal, 31(1), 38-45.

DAINTON, F. (1971). Science: Salvation or Damnation. Southhampton: University of Southhampton.

DEPARTMENT OF EDUCATION (1972). Curriculum Development Unit Bulletin, No 58. Physics, University Entrance Teachers Guide. Wellington, N.Z.

DEPARTMENT OF EDUCATION (1973). Curriculum Development Unit Bulletin No 48. Bursaries/Scholarship Teachers Guide. Wellington, N.Z.

DIEDERICH, M.E. (1969). Physical science and processes of inquiry: A critique of CHEM, CBA, and PSSC. Journal of Research in Science Teaching, 6, 309-315.

DILAVORE, P. (1973). Physics of technology - a report of the Tech Physics Project. Physics Teacher, 11(8), 473-482.

DITCHFIELD, C. (1984). Technology education: What have science teachers to offer? Review, No 3, 5-6.

DODD, J.D. *et al*. (1985). A survey of science teaching in New Zealand High Schools. Dunedin: University of Otago.

DONALDSON, M. (1978). Children's Minds. London: Fontana.

DONOVAN, E.P., FRANK, R.H. and HORTON, P.B. (1985). A new science and engineering career interest survey for middle school students. Journal of Research in Science Teaching, 22(1), 19-30.

DOWDESWELL, W.H. (1979). Science and Technology in the Classroom. European Journal of Science Education, Vol 1(1), 51-55.

DRIVER, R. (1982). Children's learning in science. Educational Analysis, 4(2), 69-79.

DRIVER, R.H. (1984). A review of research into children's thinking and learning in science. In Bell, B., Watts, M., Ellington, K. (Eds). Learning Doing and Understanding Science. Proceedings of a conference. Secondary Science Curriculum Review. London.

DUCKWORTH, D. and ENTWISTLE, N.J. (1974). Attitudes to school subjects: a repertory grid technique. British Journal of Education Psychology, **44**, 76-83.

EASLEY, J.A., (1982). Naturalistic case studies exploring social cognitive mechanisms and some methodological issues in research on problems of teachers. Journal of Research in Science Teaching, 19(3), 191-203.

EBISON, M.G. (1972). The role of the history and philosophy of physics in the physics curriculum. (In) Implementation of Curriculum in Science Education. Kiel: UNESCO , 14-19.

EIJKELHOF, H. (1985). Ethics in the Classroom: Goals and Experiences. In Musschenga, A. and Gosling, D. (Eds). Science Education and Ethical Values. Geneva: World Council of Churches.

ELLEY, W.B. and LIVINGSTONE, I.D. (1972). External Examinations and Internal Assessment: Alternative Plans for Reform. Wellington: New Zealand Council for Educational Research.

ENTWISTLE, N.J., and DUCKWORTH, D. (1977). Choice of science courses in secondary schools: trends and explanations. Studies in Science Education, 4, 63-82.

ENTWISTLE, N., HANLEY, M. and HOUNSELL, D. (1979). Identifying distinctive approaches to study. Higher Education, 8, 365-380.

FARRER, K.T.H. and SEARBY, M.H. (1970). Science education - an industrial view point. Search, 1(2) 64-68.

FENSHAM, P.J. (1977). The nature and knowledge of the sciences. Search, 8(1-2), 26-32.

FENSHAM, P.J. (1985). Science for all. A reflective essay. Journal of Curriculum Studies, 17(4), 415-435.

FERGUSON, G.A. (1971). Statistical Analysis in Psychology and Education. New York: McGraw Hill.

FIBEL, L.R. (1973). Survey of technical physics. Physics Teacher, 11(8), 491-493.

FRENCH, H.W. (1981). The CEI view. Physics Education, 16, 206-208.

FREY, K., HAUSSLER, P., HOFFMAN,L., ROST, J., and SPADA, H. (1980). Physics Education for Everyone in an Industrialized Society. In McFadden, C.P. (Ed). World Trends in Science Education. Halifax: Atlantic Institute of Education, 116-122.

FREYBERG, P.J. and OSBORNE, R.J. (1982). Learning in Science Project (form one to four) final report. Science Education Research Unit. Hamilton: University of Waikato.

FOX, D. (1983). Personal theories of teaching. Studies in Higher Education, 8(2), 151-163.

GAGNE, R.M. (1970). The Conditions of Learning (2nd Ed). New York: Holt, Rinehart and Winstone, Inc.

GALLAGHER, J.J. (1971). A broader base for science teaching. Science Education, 55(3), 329-338.

GARDNER, P.L. (1974). Determination of high school students' attitudes to physics. Nature, 250, 456-466.

GARDNER, P.L. (1976). Attitudes towards physics: personal and environmental influences. Journal of Research in Science Teaching, 13(2), 111-125.

GEORGE, D.A. (1981). An engineer's view of science education. A discussion paper. Ottawa: Science Council of Canada.

GILBERT, J.K. and WATTS, D.M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. Studies in Science Education, 10, 61-98.

HAPPS, J.C. (1984). The utility of alternative knowledge frameworks in effecting conceptual change: some examples from the earth sciences. Unpublished D.Phil. Thesis, Hamilton: University of Waikato.

HARDING, J. (1983). Switch off: The science education of girls. Schools Council Programme. London: Longman for Schools Council.

HARDING, J. (1986). Personal communication.

HARVEY, T.J. and EDWARDS, E. (1980). Children's expectations and realisations of science. British Journal of Educational Psychology, 50, 74-76.

HASAN, O.E. (1975). An investigation into factors affecting science interest of secondary school students. Journal of Research in Science Teaching, 12(3), 255-261.

HEAD, J. (1985). The Personal Response to Science. Cambridge: Cambridge University Press.

HEAD, J. and SUTTON, C. (n.d.). Structures of understanding and the ontogenesis of commitment. Occasional Paper, Chelsea College, University of London and University of Leicester.

HOFFMAN, L. (1985). Differences in the subjective conditions of interest in physics and technology for boys and girls. Contributions to the Third GASAT Conference. London: Chelsea College, University of London.

HOPSTEIN, A. and KEMPA, R.F. (1985). Motivating strategies in science education: Attempt at an analysis. European Journal of Science Education, 7(3), 221-229.

HUDSON, H.T. (1986). A comparison of cognitive skills between completes and dropouts in a college physics course. Journal of Research in Science Teaching, 23(1), 41-50.

HUDSON, L. (1967). The Stereotypical Scientist. Nature, 213, 228-229.

JOHNSON, S. and MURPHY, P. (1986). Girls and Physics. APU Occasional Paper No 4. London: The University of Leeds and Kings College.

JONES, A.T. (1982a). Physics at Work in New Zealand. Auckland: Science Centre.

JONES, A.T. (1982b). School Physics and Physics in Society. Various aspects of their interrelationship. Unpublished M.Sc. Thesis. Hamilton: University of Waikato.

JONES, A.T. (1983). Investigation of Students Understanding of Speed, Velocity and Acceleration. Research in Science Education, 13, 95-104.

JONES, A.T. (1986). Technology, help or hindrance in the classroom. Paper presented at New Zealand Association for Research in Education. Hamilton.

JONES, A.T. and OSBORNE, R.J. (1985). Students' Perceptions of Physics in Society. Research and Development in Higher Education, 8, 348-354.

JONES, J. (1979). Physics Interface. Higher Education Research Office. Auckland: University of Auckland.

JONG, T. (1985). The impact of new physics curriculum on girls' appreciation of physics. Contributions to the Third GASAT Conference. London: Chelsea College, University of London.

KAHLE, J.B. (1985). An assessment of the impact of science experiences on career choices of male and female biology students. Contributions to the Third GASAT Conference, London: Chelsea College, University of London.

KELLY, A. (1976). Women in Physics and Physics Education. In Lewis, J.L. (Ed). New Trends in Physics Teaching, Vol 3, 241-266. Paris: UNESCO.

KELLY, A. (1978). The Missing Half: Girls and Science Education. Manchester: Manchester University Press.

KELLY, D.T. (1983). 'A level' engineering science: a progress report. Research in Science and Technological Education, 1(1), 89-99.

KELLY, G.A. (1955). The Psychology of Personal Constructs. New York: W.W. Norton and Company.

KOLESNIK, W.B. (1978). Motivation: understanding and influencing human behaviour. Boston: Allyn and Bacon.

KORTLAND, K. (1985). Curriculum Emphasis in the PLON physics curriculum. Paper presented to the Third International Symposium on World Trends in Science and Technology Education. Brisbane.

LAYTON, D. (1973a). Science for the People. London: George Allen.

LAYTON, D. (1973b). The Secondary School Curriculum and Science Education. Physics Education, 8(1), 19-23.

LAZAROWITZ, R. and HERTZ LAZAROWITZ, R. (1979). Choices and preferences of science subjects by junior high school students in Israel. Journal of Research in Science Teaching, 16(4), 317-323.

LEWIS, J.L. (1972) (Ed). Teaching School Physics. Paris: UNESCO.

LIND, G. (1982). The structure of interest in physics. European Journal of Science Education, 4(3), 275-283.

LIJNSE, P. (1986). 'Methods' of promoting student motivation in physics education. Paper presented to International Conference on Trends in Physics Education. Japan.

LOVELL, K. and WHITE, G.E. (1958). Some influences affecting choice of subjects in school and training college. British Journal of Educational Psychology, 27, 15-24.

MACKAY, L.D. (1971). Changes in physics students in three states over a two year period. Research, 109-118.

MCINTYRE, D. and BROWN, S. (1978). The conceptualisation of attainment. British Educational Research Journal, 4(2), 1-15.

MCKIM, F.R. (1983). The Physics Plus Project. Physics Education, 18, 221-228.

MURRAY J. *et al*. (1980). Advanced Physics Project for Independent Learning. Student's Guide. London: Inner London Education Authority.

NEWMAN, B. (1987). Evaluation of refrigeration: A teaching unit for Form 6 Physics. Learning Science from Technology. Working Paper 212. Science Education Research Unit. Hamilton: University of Waikato-Hamilton Teachers College.

NICHOLL, B. (1982). Physics or technology or both? Physics Education, 17, 67-69.

NORMAN, H. (1985). Girls and Science. N.Z. Science Teacher, 45, 6-13.

ORMEROD, M.B. with BOTTOMLEY, J.M., KEYS, W.P. and WOOD, C. (1979). Girls and physics education. Physics Education, 14, 271-277.

ORMEROD, M.B. with DUCKWORTH, D. (1975). Pupils' Attitudes to Science. Slough: NFER.

OSBORNE, R.J. (1973). The shortage of physics graduates in New Zealand secondary schools. New Zealand Journal of Education Studies, 8(1), 25-38.

OSBORNE, R.J. (1976). Using student attitudes to modify instruction in physics. Journal of Research in Science Teaching, 13(6), 525-531.

OSBORNE, R.J. (1980). Force. Working Paper No. 16, Learning in Science Project. Hamilton: University of Waikato.

OSBORNE, R.J. (1981a). The Framework: toward action research. Working Paper No 28, Learning in Science Project. Hamilton: University of Waikato.

OSBORNE, R.J. (1981b). Physics teachers in New Zealand Schools, 1971-1980. New Zealand Science Teacher, 30, 17-22.

OSBORNE, R.J. (1983). Are we heading for a crises in physics teaching? A paper prepared on the request of the chairman, Education Committee for the New Zealand Institute of Physics.

OSBORNE, R.J. (1984). Children's Dynamics. Physics Teacher, 22(8), 504-508.

OSBORNE, R.J. and FREYBERG, P.S. (1985). Learning in Science. The implications of children's science. Auckland: Heinemann.

OSBORNE, R.J. and GILBERT, J.K. (1979). Investigating student understanding of basic concepts. Using an Interview about Instances technique. *Research in Science Education*, 9, 85-93.

OSBORNE, R.J. and WITTROCK, M. (1983). Learning Science: A generative process. *Science Education*, 64, 489-508.

OSBORNE, R.J. and WITTROCK, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education*. 12, 59-87.

OSBORNE, R.J., TASKER, C.R. and STEAD, K. (1979). A visit to a classroom. Working paper No. 13, Learning in Science Project. Hamilton: University of Waikato.

PAGE, J.E. (1979). A Canadian context for science education. Ottawa: Science Council of Canada.

PAULSEN, A.C. (1980). The legitimacy of physics teaching. *In* Ganiel, U. (Ed). *Physics Teaching*. GIREP, 43-49. Balaban: Jerusalem.

PENICK, J.E. and YAGER, R.E. (1986). Trends in science education: some observations of exemplary programmes in the United States. *European Journal of Science Education*, 8(1), 1-8.

PETERS, M. and MILLER, A. (1976). Physics in the real world; a problem for schools. *Physics Education*, 11(7), 496-497.

PINDER, N. (1986). Personal communication.

POPE, M. and GILBERT, J. (1985). Theories of Learning: Kelly. *In* Osborne, R.J. and Gilbert, J. (Eds). *Some Issues of Theory in Science Education*, Hamilton: University of Waikato.

POSNER, G.J. and GERTZOG, W.A. (1982). The clinical interview and the measurement of conceptual change. *Science Education*, 66(20), 195-209.

REEDER, D. (1979). A Recurring Debate. Education and Industry. *In* Bernhaum, G. (Ed). *Schooling in Decline*, 115-145. London: MacMillan Press.

REID, M.I., BARNETT, B.R. and ROSENBERG, H.A. (1974). *A Matter of Choice*. Windsor: NFER.

RENNER, J.W. (1982). The power of purpose. *Science Education*, 66(5), 709-716.

RENNER, J.W., ABRAHAM, M.R. and BIRNIE, H. (1985). The importance of the FORM of student acquisition of data in physics learning cycles. *Journal of Research in Science Teaching*, 22(4), 303-325.

RENNER, J.W. and LAWSON, A.E. (1973). Piagetian theory and instruction in physics. *The Physics Teacher*, 11, 165-169.

REYES, L.H. (1984). Affective variables in mathematics education. The Elementary School Journal, 84(5), 558-581.

RONEN, M. and GANIEL, U. (1984). Physics in medical diagnosis - an optional unit for high schools. Physics Education, 19, 228-291.

ROTHMAN, A.I., WELCH, W.W., WALBERG, H.J. (1969). Physics teacher characteristics and student learning. Journal of Research in Science Teaching, 6, 59-63.

SCHIBECI, R. (1977). Attitudes to science: A semantic differential instrument. Research in Science Education, 7, 149-155.

SCHOLLUM, B. and OSBORNE, R.J. (1985). Relating the new to the familiar. In Osborne, R.J. and Freyberg, P.J. (Eds). Learning in Science. Auckland: Heinemann.

SELKIRK, J. (1973). Subject choice in the sixth form. Education Research, 16(1), 3-7.

SHAYER, M. (1972). Conceptual demands in the Nuffield 'O' level physics course. School Science Review, 54(186), 26-34.

SHAYER, M. and ADEY, P. (1981). Towards a Science of Science Teaching - Cognitive Development and Curriculum Demand. London: Heinemann.

SJÖBERG, L. (1983). Interest, achievement and vocational choice. European Journal of Science Education, 5(3), 299-307.

SMAIL, B. and KELLY, A. (1984). Sex Differences in Science among 11 year old school children: II - affective. Research in Science and Technological Education, 2(2), 87-106.

SMAIL, B., WHYTE, J. and KELLY, A. (1982). Girls into Science and Technology. School Science Review, 63, 620-630.

SNEED, G.C. (1975). Science Serves Society. Oxford: Pergamon Press.

SOLOMON, J. (1983). Learning about energy: How pupils think in two domains. European Journal of Science Education, 5(1), 49-59.

SULLIVAN, R.J. (1979). Students' interests in specific science topics. Science Education, 63(5), 591-598.

TALISAYON, V.M. (1986). Methods of promoting students motivation to study physics. Keynote Address. International Conference on Trends in Physics Education. Japan.

TAMIR, P., ARZI, A., ZLOTO, D. (1974). Attitudes of Israeli high school students towards physics. Science Education, 58(1), 75-86.

TAWNY, D.A. (1976). Evaluation and Science Curriculum Projects in the U.K. Studies in Science Education, 3, 31-54.

TASKER, C.R. and OSBORNE, R.J. (1983). Portraying pupils' classroom experiences. Research in Science and Technological Education, 1(2), 133-144.

TASKER, C.R., FREYBERG, P. and OSBORNE, R.J. (1979). Focus on the Learner. Working Paper 6. Learning in Science Project. Hamilton: University of Waikato.

THIER, H.D. (1983). Societal issues and concerns: a new emphasis for science education. Paper prepared for presentation at the United States/Italy Joint Seminar on Science Education (Frascali and Rome, Italy. October 24-29, 1983).

THOMAS, G.E. (1986). Cultivating the interest of woman and minorities in high school mathematics and science. Science Education, 70(1), 31-43.

THOMAS, I.D. (1985). Assessing student understanding of science-technology-social interaction. Australian Science Teacher Journal, 31(1), 33-37.

WALBERG, H.J. (1969). Predicting Class Learning: an approach to the class as a social system. American Educational Research Journal. 6(4) 529-542.

WALKER, H.M. and LEV, J. (1969). Elementary Statistical Methods. New York: Holt, Rinehart and Winstone, Inc.

WATTS, D.M. and BELL, B.F. (1984). A view of learning. In Bell, B.F., Watts, D.M. and Ellington, E.C. (Eds). Learning, Doing and Understanding. Proceedings of the Secondary Science Curriculum Review Conference, Wooley Hall, 11-13, July 1984.

WELCH, W.W. (1969). Correlates of course satisfaction in high school physics. Journal of Research in Science Teaching, 6, 54-58.

WELCH, W.W. and WALBERG, H.J. (1967). Are the attitudes of teachers related to declining percentage enrolments in physics? Science Education, 51(5), 436-441.

WELTNER, K., LIEBIG, H., HALBROW, D., MAICHLE, U., REITZ, H., SCHOFIELD, G. (1980). Interest of intermediate-level secondary students in physics and technology. European Journal of Science Education, 2(2), 183-189.

WESSEN, J.P. (1985). Science courses and social issues. Australian Science Teachers Journal, 31(1), 15-22.

WHITE, R.T. (1973). Research in learning hierarchies. Review of Educational Research, 43, 361-375.

WHITE, R.T. and MACKAY, L.D. (1973). A note on a possible alternative to likert scales. Science Education Research, 3, 75-76.

WHITE, R.T., and MAYER, R.E. (1980). Understanding intellectual skills. Instructional Science, 9, 101-127.

WIERSTRA, R. (1984). A study on a classroom environment and on cognitive and affective outcomes of the PLON-curriculum. Studies in Educational Evaluation, 10, 273-282.

WOLFGANG, R.L. (1971). Chemistry for Citizens. Journal of Chemical Education, 48(1), 22-33.

WOODALL, A.J. (1967). Science history. Physics Education, 2, 297.

WOOLNOUGH, B.E. (1975). The place of technology in schools. School Science Review, 56(196), 443-448.

YAGER, R.E. and YAGER, S.O. (1985). Changes in perceptions of science for third, seventh and eleventh grade students. Journal of Research in Science Teaching, 22(4), 347-358.

ZIMAN, J. (1980). Teaching and learning about science and society. Cambridge: University Press.

ZOLLER, U. and WATSON, F.G. (1974). Technology education for nonscience students in the secondary school. Science Education, 58(1), 105-116.

ZUCKERMAN, S. (1971). Public knowledge, hope and fears. Times Literary Supplement, 12th November 1971, 1422.