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USING TECHNOLOGICAL CONTEXTS FOR TEACHING SCHOOL PHYSICS

A Study Based In Two Cultures

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submitted in fulfilment of the requirements
for
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ABSTRACT

The study reported in this thesis explored the process and outcomes of using technological contexts that are relevant to students for the teaching of senior secondary school physics in the Maldives and in New Zealand.

Recent research findings indicate that the use of contexts that are relevant to the learner in the teaching of science enhances the affective and cognitive outcomes (e.g. Rodrigues 1993, Yager and Tamir 1993, The Cognition and Technology Group at Vanderbilt 1990, Cosgrove 1989, Jones 1988). These research studies were conducted in western countries, using a strategy referred to in this thesis as *contextual teaching*. Although these studies indicated that teachers and students may face difficulties in using the contextual approach, very little information about the nature of these difficulties was provided.

This study explored the possibility of using the contextual teaching strategy in a non-western country, the Maldives, and further clarified the process by using the same strategy in a western country, New Zealand. Particular attention was given to the difficulties teachers faced in using the strategy for the first time.

The research was conducted in four iterative phases. The first phase explored technological contexts students in the targeted populations considered relevant. Students in a sample of boys and girls from Grade 10 and Grade 11 physics classes in the Maldives (n=32) and the corresponding Form 5 science and Form 6 physics classes in New Zealand (n=32) were individually interviewed to clarify their interest and ideas about applications used in an area of technology common to the two countries—telecommunications.

The reasons for student interest in the applications were very similar in the two samples. The similarity in student interest in the two samples indicated that similar contextual teaching strategies may be successfully used in physics classrooms in the two countries.

During the second, third, and fourth phases of the study classroom interventions, based on the ideas of social constructivism, were conducted in physics classrooms in New Zealand and the Maldives. The interventions were designed to teach secondary school electromagnetism in the two countries. While the second and

third phases of the study clarified the process and outcomes of contextual teaching, the last phase of the research concentrated on the difficulties faced by teachers in using the strategy for the first time.

The contextual teaching strategies used in this study had similar success with students from the two cultures. The cognitive and affective outcomes for the majority of the students, particularly the weaker students, were enhanced. In spite of the socio-political and economic differences between the Maldives and New Zealand, students responded in a similar manner in the two countries.

Teachers, particularly those who were used to organising their lessons along conceptual hierarchies, faced difficulties in using the approach. These difficulties were mainly related to structuring and managing classroom activities during contextual teaching. The difficulties were partially addressed during the study.

The outcomes of the study has implications for learning, teaching, teacher development, and curriculum development.

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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Dedicated to my father
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CHAPTER ONE

INTRODUCTION

This chapter outlines the background leading to the research problem, introduces the contextual approach to learning and teaching of physics that is advocated in this thesis, and provides a rationale for using the contextual approach to teaching in normal classroom practice. The chapter then introduces the research study, specifies the research questions, and provides an outline of the thesis.

1.1. BACKGROUND TO THE RESEARCH STUDY

My interest in an in-depth study of teaching and learning physics in meaningful and relevant contexts stems partially from being involved with a group of physics teachers who met frequently to discuss problems in our teaching.

As secondary school physics teachers in the Maldives, we have to prepare our students for the General Certificate of Education (GCE) examinations, prepared and marked in London. Most of the secondary school curriculum in the Maldives is derived directly from the preparatory requirements for the GCE Ordinary Level and Advanced Level examinations. Every effort is made by schools to increase their pass rates and their results at these examinations; student pass rates and their examination results are the main indicators of the school's standard.

Discussions during our group meetings spanned a wide range of issues that may influence the student performance: text books, practicals, teaching strategies, remedial teaching, etc. Some of us felt the need for changing the examination prescription; a task that was beyond our control. Although we were in general agreement with the need for making the teaching of physics more meaningful and relevant to the students, we had different conceptions of how this may be achieved

within the constraints of the classroom and the examination prescription. Some of us suggested the use of strategies for making the teaching of physics more meaningful and relevant to the students.

In 1990 our voluntary work received financial and administrative support from the Ministry of Education, and I was able to take time off my teaching schedule and observe some of my colleagues in their classrooms. I realised that a strategy used by some teachers to make their teaching relevant and meaningful to the students was to use examples of applications of physics from the everyday lives of students. Although I used applications of physics in my teaching, they were not necessarily from the everyday lives of the students. When I made a conscious effort to relate my physics teaching to the everyday life of the students, the classroom atmosphere changed significantly and I felt that the students were learning more.

The biggest change was made by some girls who had been grouped together in a class classified as under-achievers. In attempting to teach the class concepts of household electricity, I conducted an 'electrical junk workshop' where the students brought in certain household electrical equipment for use in teaching the topic. The topic turned out to be the best physics topic these girls had ever studied and they surprised themselves by answering typical physics problems and exercises that they would not normally even attempt. In the next unit test some of the girls performed better than certain high-achievers in parallel classes.

On sharing these experiences with my colleagues, some were very comfortable with the idea of using everyday applications and students' ideas about them in the physics classroom. Others found such a process to go against the accepted norms of physics teaching. The variety of responses made me inquisitive about existing research that may inform the use of everyday examples and applications in teaching physics.

Some research into the use of everyday examples and applications in teaching physics and science are reported in literature. Some of these studies used a strategy referred in this thesis as *the contextual approach* to teaching and learning. This study was designed to explore this approach, and to study possible difficulties teachers may face in starting to use it. The contextual approach is clarified next.

1.2. THE CONTEXTUAL APPROACH TO TEACHING

Physics teachers have always used everyday examples and applications in their teaching. However, there are marked differences between the use of everyday examples and applications in normal classroom practice, and in the contextual approach used by the studies mentioned in the last section.

Science lessons are usually structured along a predetermined sequence of concepts. The sequence is often hierarchical with prerequisite concepts introduced before more complex concepts. The logical position of examples and applications is thus at the end of the sequence, after teaching all the prerequisite ideas needed to understand the examples and applications. The physics concepts are normally taught in the abstract and these concepts are applied to related examples in the end.

The examples and applications used in normal classroom practice are not necessarily from the everyday life of the students, but generally from the science laboratory and the world of science. Even when the occasional example or an application from the everyday life of the students is used, it is often modified and simplified to the extent that it is no longer familiar to the students. The everyday aspects are normally avoided because they introduce other and confusing variables that impede classroom progress.

The contextual approach uses everyday examples and applications that are relevant to the learners to introduce and to teach the concepts. In this approach the contexts are introduced at the beginning of the teaching process to engage the learners with the everyday aspects of the applications as well as with the scientific knowledge. The everyday aspects of the examples and applications are considered essential for making the scientific knowledge relevant to the learner.

For example, in using the contextual approach, a teacher may use a guitar as an example of how the concept of sound generated from vibrating strings is made use of in everyday life. The everyday aspects of the example include music, different types of guitars, the use of a guitar, and other features that may be associated with the guitar. These aspects give the guitar its real-life nature; they make the guitar relevant to the learner. Without these aspects, the guitar is simply a sonometer that produces various frequency sounds using strings of different lengths, thicknesses,

and tensions; it becomes just another piece of equipment in the laboratory. The contextual approach to teaching is further clarified in Chapter Two.

The contextual approach to teaching appears to be a major shift from normal classroom teaching. The case for adding the new style of teaching to the existing selection of strategies is explored in the next section.

1.3. RATIONALE FOR USING THE CONTEXTUAL APPROACH

The case for using the contextual approach to teaching as advocated in the last section is based on the assertion that learning physics in contexts that are meaningful and relevant to the learners produces better learning outcomes. This claim is explored below within the framework of the following educational concerns:

- enhancing the learning outcomes for all learners;
- enhancing the quality of learning for those proceeding for higher education.

1.3.1. Enhances the learning outcomes for all learners

Secondary school science has to cater to a variety of learners. Some may proceed to further studies in science-related areas, many may not. Whatever the future aspirations of the students may be, the science curriculum is required to equip all learners with the scientific literacy that is required for their future lives in societies that are becoming increasingly dependent on science and technology (Fensham 1988a).

In spite of this requirement to provide science for all, common practice suggests that science education caters only to the elite who intend to proceed to science-related further studies (Fensham 1988a, Claxton 1991). Science education is thus accused of excluding the majority.

A strategy that is used by some education systems to provide science for all is to design different science curricula for different learners (Fensham 1988a). Often based on attainment scores, students are grouped into science and non-science

streams (Hodson and Reid 1988). The science stream caters for those proceeding for higher studies in science-related areas. The non-science stream provides the science required for the every-day life of the learner; it provides the scientific literacy.

The strategy of providing different science curricula for different learners has been questioned on several grounds. Proponents of educational equality claim that it is too early to divide students into science and non-science students at secondary school levels; the opportunities for the non-science students are severely limited by denying them access to certain sorts of knowledge too early in their schooling (Hodson and Reid 1988). Furthermore, learners in the science streams are also claimed to be disadvantaged because they are often deprived of the opportunities to link their learning to their everyday life (Osborne and Freyberg 1985), and this is seen to limit the learning of many students (see next section).

Choosing universal scientific literacy as an objective of a common curriculum, according to some, is likely to burden the school science "with responsibilities it can not hope to meet" (Jenkins 1990, p 43). A major deterrent against a common science curriculum is a belief that if it is designed to provide widespread scientific literacy then it can not provide an adequate base from which to draw those going on to be scientific professionals (see Fensham 1988a). This implies that, in order to cater for the weaker students, the curriculum will have to be watered-down and its science content reduced to the extent that it is no longer useful to the brighter students. However, the outcomes of some recent research studies contradict this view.

Recent studies have used the contextual strategy that is advocated in this study to enhance the learning outcomes for the majority of the students in secondary school science and physics classes (Jones 1988, Cosgrove 1989, Yager and Tamir 1993, Rodrigues 1993). In these studies contexts from the everyday life of the students were used to teach the prescribed science curricula without 'watering it down', and without using any more than the classroom time specified by the curriculum. The learning outcomes of low ability students were enhanced and the high ability students continued to perform well. These studies are explored further in the next chapter.

1.3.2. Enhances quality of learning for those proceeding for higher education

School science has also been accused of failing to properly equip many of those who proceed for higher education in science-related areas (Claxton 1991, Fensham 1988a). The inert knowledge problem, and misconceptions held by students have been major concerns.

The inert knowledge problem

The inert knowledge problem is the inability of many students to spontaneously use their knowledge and skills in solving relevant problems even when they are able to recall the scientific knowledge and skills when explicitly asked to do so.

Although the inert knowledge problem has been brought to the attention of educators as early as 1929 by writers like Whitehead (1929), the fact-oriented approaches that dominate normal classroom practice have not been very effective in overcoming this problem. Fact-oriented approaches to teaching are based on transferring facts. Many students come to view science as bits of information that need to be memorised. They often memorise these facts for the purpose of passing tests and examinations, and once the tests are over they see no apparent use for the science they have studied at school. They fail to see science as a part of "their life experiences and concerns; they do not realise its potential as an aid to dealing with the problems that they meet in their daily out-of-school lives; and they do not see it as internally coherent" (Claxton 1991, p 15).

Fact-oriented instruction may be effective for experts who are familiar with an area of expertise. However, for novices a different approach needs to be used. According to the Cognition and Technology Group at Vanderbilt (1990):

> When introduced to new theories, concepts and principles that are relevant to their area of interest, the experts can experience the changes in their own thinking that these ideas afford. For novices, however, the introduction of concepts and theories often seem like the mere introduction of new facts or mechanical procedures to be memorised. Because the novices have not been immersed in the phenomenon being investigated, they are unable to experience the effects of the new information on their own noticing and understanding. (p 3)

Several studies indicate that meaningful problem-oriented approaches to learning, organised along everyday contexts, work better than fact-oriented approaches in overcoming the inert knowledge problem (Adams *et al* 1988, Lockhart *et al* 1988, The Cognition and Technology Group at Vanderbilt 1990). When learning is set in everyday problem-solving contexts, it is easier for students to perceive science as a tool for solving everyday problems, which provides meaningful and relevant purposes for learning science other than passing examinations.

The proposition that learning in problem-oriented everyday contexts works better than fact-oriented approaches in overcoming the inert knowledge problem is also explained in terms of epistemology. According to Bereiter (1992), "most of the concepts and principles schools try to teach only make sense when they are viewed as problem-centred rather than referent-centred knowledge" (p 340). Bereiter's argument may be summarised as follows. Knowledge organised around topics are referent-centred and recollected only when the topic becomes relevant. Problem-centred knowledge is organised around problems and is recollected when learners encounter situations where the knowledge will be helpful in understanding a phenomenon or in solving a problem. Although very few types of knowledge may be classified as either problem-centred or referent-centred, according to Bereiter most high-level conceptual knowledge is more problem-centred than referent-centred. Learning set in everyday problem-solving contexts enables learners to organise these concepts around problems rather than around referents. The organisation of knowledge around problems helps overcome the inert knowledge problem and facilitates the recollection of appropriate concepts when learners encounter situations where the knowledge will be helpful.

Alternate frameworks

Research shows children to have ideas about natural phenomena from a very young age (for example see Osborne and Freyberg 1985). Some of these ideas contradict scientific views and are often referred to as misconceptions (Novak 1985) or alternate frameworks (Hewson 1985).

Research shows that alternate frameworks are not normally addressed in the teaching of science at school, and even when they are addressed they are difficult to change through direct instruction (White 1992). Research also shows that teaching strategies that engage with the everyday experiences of students have

been effective in changing alternate frameworks of students (for example see Rowell *et al* 1990, Osborne *et al* 1983).

The inert knowledge problem and the alternate frameworks of students are not directly researched in this study. However the positive influence of context-based teaching strategies on these educational concerns contribute to the case for using the contextual strategy advocated by this thesis in the science and physics classrooms.

The research outcomes indicating the merits of relating learning and teaching of science to the everyday life of the learners have persuaded some educational systems to explicitly require the use of everyday contexts in the science classroom.

1.3.3. Contextual teaching and learning is required by some curricula

A recent example of a curriculum that has focused on the need for learning of science at school to be relevant to the everyday life experiences of the learner is the national science curriculum in New Zealand (Ministry of Education, NZ, 1993a).

The use of familiar contexts for teaching and learning science has been a major feature of curriculum debates in New Zealand since the mid 1980's (Bell 1992), and the importance of facilitating learning in relevant and meaningful contexts has been emphasised in the recently published document *Science in the New Zealand Curriculum* (Ministry of Education, NZ, 1993a). The following statement from the document clearly illustrates the view of the role and effect of relevant and meaningful contexts on students' learning in science.

> Students learn effectively, and see relevance in learning science, when they have opportunities to develop and use their science ideas and skills, first in a variety of familiar contexts and later in other challenging situations. (p 17)

According to the draft curriculum statement, *Physics in the New Zealand Curriculum,* (Ministry of Education, NZ, 1993b) learning in physics is enhanced when:

- students investigate real situations of interest to them ...

- learning contexts, learning experiences, and teaching approaches are accessible, interesting, and relevant to students of all ethnic backgrounds and of both genders ...
- students get the chance to investigate and apply ideas both in simplified contexts and in a variety of more realistic contexts ... (p 5)

Furthermore, the curriculum is designed "to give schools the flexibility to choose whether to teach physics contextually, by topic, or in some combination of the two" (p 7).

The requirement to use relevant and meaningful contexts in the learning science is not explicitly stated in many curricula. However, this is often implicit in their aims. For example, in the Maldives, where the secondary school physics curriculum is based on the General Certificate of Education (GCE) syllabuses designed by the University of London Examination and Assessment Council, one of the three national objectives for education is to make learning relevant to the local environment (Ministry of Education, Maldives, 1985). Furthermore, the GCE syllabuses for physics require the teaching to "arise out of or lead directly towards the applications of physics" wherever appropriate (ULEAC, 1993, p 563).

Although the statements of intent or the broad aims of science education require the use of relevant and meaningful contexts in the teaching and learning of science, what largely determines the classroom processes is the examined learning outcomes or the assessment objectives. The aim of teaching is ultimately reduced to "covering the syllabus requirements in such a way that nothing is left to chance on examination day" (Lee 1992, p.132); if the examinations do not directly test the ability of students to relate the classroom science to their everyday life, there is no apparent need for teachers and students to attempt to learn science in context.

The London GCE O'level and A'level examinations used in the Maldives as well as the various secondary school attainment examinations used in New Zealand, do test the students' ability to apply their knowledge. However, application questions in these examination papers are outnumbered by questions that may be answered by mere recall.

Within science education, physics is one of the curriculum areas most often accused of not catering for the majority of learners. In a study conducted by Jones

(1988) in New Zealand, it was found that students considered school physics to be difficult, unenjoyable, mathematical and of limited application. Studies in other western countries yielded similar results (Duckworth and Entwistle 1974, Tamir *et al.* 1974, Ormerod with Duckworth 1975, Weltner *et al.* 1980).

1.4. CLARIFYING THE RESEARCH PROBLEM

The principal argument for using the contextual approach to teaching and learning is that it enhances cognitive and affective outcomes. The research quoted above supports this contention. However, all of the above studies have been conducted in western societies by teachers who were considered to be experts in using the contextual approach to teaching (see the literature review in chapter 2). This raises two major questions: Can contextual teaching and learning be used in non-western cultures? What problems may be faced by some teachers who attempt to use contextual teaching?

It was thus decided to conduct a study in a western country and a non-western country—New Zealand and the Maldives— to explore the process and outcomes of using the contextual approach.

1.4.1. The research focus

The use of context-based strategies in the science classroom is relevant to a wide range of educational concerns and issues. The scope of this study was however limited to exploring the use of the contextual approach to the teaching of physics at senior secondary school levels in the Maldives and in New Zealand, and the research study was designed within the following limits and boundaries:

- the contexts investigated in the study were restricted to *everyday technological contexts*;
- the curriculum area was limited to physics; and
- the research samples were limited to Grade 10 and Grade 11 classes in Malé, Maldives, and the corresponding Form 5 and Form 6 classes in Hamilton, New Zealand.

1.4.2. Clarification of some terms

The phrase *everyday technological contexts* may project different images to different educationalists because of the many meanings associated with the concepts *everyday, contexts*, and *technology*. The use of these concepts in this thesis is clarified in this section.

The meaning of the term "context"

Rodrigues (in press) categorised the meanings and shades of meanings associated with the term "context" into three groups:

- *Context as a physical setting* such as the classroom, furniture, displays and other physical aspects;
- *Context as a learning environment.* This view encompasses the social as well as the physical setting in which learning occurs; the classroom, furniture, displays and other physical aspects; the location of the school; the socio-economic backgrounds of students and teachers; the ethnicity;
- *Context as the scenario* or the real-life situation for which the learned skill, behaviour, concept or idea is relevant.

White (1979) considered aspects of the learning environment such as demonstrations and unusual activities conducted by a teacher to be an important part of the context. According to him some images or episodes from the learning environment "act as anchoring posts for knowledge that is linked with them" (p15). A broader view of context was taken by Rogoff (1984). According to her the context of a problem is an integral part of the cognitive activity. "The context includes the problem's physical and conceptual structure as well as the purpose of the activity and the social milieu in which it is embodied" (p 2).

This thesis limits the notion of 'contexts' to scenarios or real-life situations from the *everyday life* of the students for which the learned skill, behaviour, concept or idea is relevant.

The meaning of the term "everyday"

The term everyday is used in sociology, anthropology, philosophy, and history for different purposes and with different meanings. (See Bullock *et al* 1988 for a

condensed overview.) The concept of everyday is associated in this study with the issue of identifying everyday contexts that students may consider relevant. From this perspective, an everyday context is one that is considered common-place by the students in their daily life.

The meaning of the term "technology"

The science taught at school is normally encountered by students in their everyday lives in two forms: as natural phenomena, and as technological phenomena. The most frequently encountered applications in physics appear to belong to the realm of technological applications.

The variety of interpretations of the term technology have been documented by several researchers (for example, see Hodson 1991). For the purposes of this study the definition of technology used by Cosgrove (1989) was adopted. According to him, technology is "the ways humans use their intellectual capabilities and physical resources to solve problems of survival, well-being and quality of life" (p ii).

An everyday technological context, as used in this thesis, could be associated with the use of any application that is designed to solve a problem of survival, well-being and quality of life that the students may consider relevant to them. It must also be noted that a technological application may solve more than one problem and may be used in more than one scenario or real-life situation. Therefore, a given application may have more than one context associated with it (Jones *et al* 1993).

1.5. AIMS OF THE RESEARCH STUDY

The purpose of the research study was to explore the process of contextual teaching and its outcomes. Hence, the study was designed to achieve the following aims:

- to explore student interests in technological contexts that they consider relevant in New Zealand and the Maldives;
- to use the above information for designing classroom interventions that may be used for contextual teaching;

- to conduct the classroom interventions in mixed-ability physics classrooms in the two countries;
- to monitor the process and outcomes of using these interventions; and
- to monitor any cultural and gender differences in the above outcomes.

Student interest in relevant technological contexts was investigated by studying their interest and ideas in an area of technology common to the Maldives and New Zealand. Telecommunications was chosen as the common area of technology for the initial exploration as it spans the cultural and socio-economic boundaries of the two societies. Although the cultural and socio-economic contexts of these two societies are enormously different, telecommunications facilities are comparable in the two towns where this study was conducted—Malé in the Maldives and Hamilton in New Zealand. International Direct Dialling telephone services, card-phones, coin-phones, satellite TV in addition to local TV, local radio broadcasting on FM and AM, and facsimile are a few examples of common public services available in the two towns. Hence, telecommunications constitute a significant part of the everyday life experiences of the learners who were targeted in this study.

Telecommunications is also an area identified by the New Zealand and the Maldivian curricula as providing relevant and meaningful applications of physics. The new draft curriculum statement in physics for New Zealand identifies telecommunications as providing useful learning contexts (Ministry of Education, NZ, 1993b). The London GCE A'level syllabuses for physics, used at grades eleven and twelve in the Maldives, have telecommunications as a unit for extending the material of the basic syllabus and to stimulate student interest in the social and economic implications of applications of physics in society (ULEAC 1993)

The other aims were achieved by conducting classroom interventions based on technological contexts and the contextual approach to teaching. The research questions addressed during this study are specified next.

1.6. THE RESEARCH QUESTIONS

Two groups of research questions were formulated for achieving the aims of the study. The initial set of research questions explores student interest and ideas in telecommunications—the common area of technology. The final set explores the process of contextual teaching and learning.

Research questions about relevant technological contexts:

1. What applications of telecommunications interest Grade 10 and Grade 11 physics students in the Maldives and the corresponding Form 5 science and Form 6 physics students in New Zealand?
2. What reasons do students suggest for their interest in these applications?
3. What cultural and gender differences are observed in the above?
4. How do the above interests and ideas inform the process of contextual teaching and learning in physics?

Based on student interest and ideas classroom interventions were developed. The following research questions are about the use of the contextual classroom interventions at senior secondary school physics classrooms in the Maldives and in New Zealand.

5. How do teachers and students respond to contextual learning and teaching strategies advocated by the interventions?
6. What difficulties do teachers and students face in using the contextual learning and teaching strategies?
7. What are the affective and cognitive outcomes of using the contextual learning and teaching strategies in mixed-ability classrooms?
8. What cultural and gender differences are observed in the process and outcomes of contextual teaching?

Details of the research design and methodology are provided in Chapter Three and in subsequent chapters. An overview of the remainder of the thesis is now provided.

1.7. OVERVIEW OF THE THESIS

Chapter Two reviews the literature to clarify the concept of teaching and learning physics in contexts that are relevant and meaningful to the learner, and to develop the contextual approach to teaching and learning outlined in Chapter One. Chapter Three outlines the research design and the methods used for collecting data.

Chapter Four describes the design, process and outcomes of the research conducted during its first phase of the study to compare student interest and ideas in an area of technology common to New Zealand and the Maldives. The implications of the research outcomes on the contextual approach to teaching and learning are discussed.

Chapters Five, Six, and Seven report the research conducted during the second, third, and fourth phases of the study respectively. Each chapter describes the design, process, and outcomes of the research conducted during the relevant phase of the study. During the second phase of the study initial classroom interventions to study the process and outcomes of contextual teaching were conducted in the two countries. During the third phase of the study classroom interventions were repeated in the two countries. The last phase of the research, also conducted in the two countries, concentrated on the reactions of teachers to the use of the contextual approach to teaching.

Chapter Eight reviews the outcomes of all the phases of the study, explores how far the research questions were answered, and discusses the implications for further research.

CHAPTER TWO

LITERATURE REVIEW OF TEACHING AND LEARNING IN A TECHNOLOGICAL CONTEXT

The purpose of this chapter is to clarify the contextual approach to teaching and learning outlined in the previous chapter by reviewing the literature related to teaching and learning physics in contexts that are relevant and meaningful to the learner.

In this chapter the following areas of literature are reviewed:

- the main traditions of psychology that influence current research into learning and teaching;
- social and cultural influences that may influence the learning and teaching process; and
- some context-based teaching strategies that have been used in the science classroom.

The main findings of the chapter are summarised at the end of the chapter, with a special focus on how they inform learning and teaching physics in a technological context.

2.1. CONTEXTUAL LEARNING AS INFORMED BY LEARNING THEORY

In the previous chapter it was maintained that engaging learners with relevant and meaningful contexts makes physics accessible for more learners and enhances the quality of their learning. However, learning itself is a concept that has several meanings associated with it. Different traditions of psychology project different images of human learning and different views on how best to facilitate learning.

This section reviews learning as interpreted in the main traditions of psychology and clarifies how technological and other everyday contexts may be used to make the teaching and learning of physics relevant and meaningful to the learner.

The traditions in psychology that are most often cited in current research into human learning (Lederman *et al* 1993, Osborne and Wittrock 1985, Driver 1982) include the following: the developmental tradition; the behaviouristic tradition; personal constructivist and social constructivist traditions. These traditions are explored below.

2.1.1. Contextual learning from a behaviourist view

Wheldall and Merrett (1984) defined the behavioural approach to teaching in terms of five "general assumptions" (p 14-15)

- Teaching is concerned with the observable. What goes on in the minds of the students can not be observed and hence is of no consequence.
- All classroom behaviour is learned either inside the class or outside.
- Learning involves change in behaviour and the only way to know that learning has taken place is to look for a change in the learner's behaviour.
- Behaviour change depends mainly on consequence.
- Behaviours are influenced by the contexts within which they occur. Children learn to perform certain behaviours when and where they are appropriate.

The concept of learning hierarchies is central to the behaviourist psychology of learning (Gagné 1970). According to the concept of learning hierarchies, prerequisite concepts and ideas need to be learned in order to learn a more complex concept or idea. In other words, instruction should be sequenced so as to teach the prerequisite ideas before introducing new ideas.

In applying the concept of learning hierarchies to learning in context, the relevant real life application would be presented only after the teaching of the skills, concepts or ideas necessary to understand the context. This reduces contextual teaching to the normal classroom practice of focusing only on the physics of the application and neglecting its ever-day aspects.

Although most curricula are still written in behaviourist terms, according to some educationalists and researchers, behaviourism provides a narrow view of learning (von Glasersfeld 1992, Driver 1982). Behaviourist instruction programs are considered more appropriate to the teaching of observable skills rather than to "the teaching of any material which has a significant conceptual component since it takes no account of the conceptual framework the learner brings to the situation" (Driver 1982, p 73). For facilitating conceptual understanding, the teaching process is required to focus beyond the observable behaviour of learners and attempt to understand the cognitive process associated with understanding.

2.1.2. Contextual learning from a developmental cognitive view

The most influential theory of cognition of the century, was proposed by Piaget (Lefrancois 1994). His theory of cognition is also considered developmental in that it imposed age-related restrictions on what a child could learn, and viewed human development as occurring in terms of age-defined stages (Lovell 1980). Based on his observation of children from birth to 16 years old, Piaget proposed that the mental structures that process the incoming messages develop as the child grows, and the complexity of the information these structures can process depends on the complexity of the structures themselves (Shayer and Adey 1981).

Piaget also proposed one of the most influential (Meadows 1983) stage theories that relates intellectual development to age. According to his stage theory, senior secondary school students (16 years and over) will have fully developed cognitive structures. This implies that learners at these levels will make sense of everyday applications of physics in a manner very similar to adults, and warrants the use of real-life contexts for making physics meaningful and relevant.

Researchers who replicated and expanded Piaget's work found difficulties in applying his stage theory at an individual level (Lefrancois 1994). However, Piaget's theory is considered extremely useful in visualising human development "at a gross level" and in speculating the most likely behaviours of children at different ages (Driver 1982, p72).

Being a biologist by profession most of Piaget's initial work was of a biological orientation. However, his work on human cognition informed modern understandings of the human psychology, and has been expanded by several researchers to study its implications for the classroom. According to Lefrancois (1994), the following ideas have direct implications for teaching:

- Language facilitates and guides thought processes, and children should be given the opportunity to interact verbally with the teacher and each other in the classroom.
- Social interaction is one of the chief factors that makes thought more objective.
- Concepts arise from sensing and acting upon the environment, and children should be involved in numerous real and relevant activities.
- Children interact with the world through two processes called accommodation and assimilation—both of which are always in action in any interaction. Assimilation is the process by which previous learning is used in order to interact with new objects and events. Accommodation is the effort of the learner to fit his or her behaviour to the environment. "Assimilation requires that the situation be somewhat familiar: accommodation will take place only if the situation is, at the same time, somewhat strange" (p 73).

The above view of learning provides several useful insights into designing contextual learning strategies. Activities that attempt to facilitate learning in meaningful and relevant contexts need to start off with situations that are familiar to the learner, in order to ensure assimilation. New and challenging components need to be added to the activity in order to ensure accommodation. Furthermore, the activity needs to include opportunities for engaging in numerous real and relevant activities, and opportunities for interacting verbally with the teacher and each other in the classroom. While the contexts need to have the science required by the curriculum embedded in them, unlike in the behavioural perspective, all the science embedded in the context need not be previously taught in the class.

The notion of starting instruction from situations that are familiar to the learner is also central to the constructivist view of learning that is explored below.

2.1.3. Contextual learning from a personal constructivist view

Constructivist psychology is based on the view that knowledge is a human construction (Driver 1993). That is, knowledge is not passively received, but actively constructed by the learner and the learner's existing ideas are important in this process. Piaget himself is considered a constructivist in that he viewed learners to actively participate in the process of meaning construction. However, constructivists impose no developmental restrictions on learning (Driver 1982).

Personal constructivists picture learning to be a private activity and the process of meaning construction is projected as occurring purely at a personal level (von Glasersfeld[1] 1992). A major focus is given to learner's experiences, ideas and knowledge about scientific phenomena that they bring to the classroom; these ideas may sometimes help or hinder the process of learning (Freyberg and Osborne 1985). The following quotes from von Glasersfeld[2] explain the personal constructivist view of knowledge and learning:

> ...knowledge is a network of conceptual structures and, as such, can not simply be transferred by the use of words because it must be constructed by each individual knower... (1992, p 33)
>
> To guide learning, therefore, the teacher will have to have some notion of the concepts the students already have and how they relate them. (1992, p 33)
>
> [Learning] is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction. Problems are not solved by the retrieval of rote-learned "right" answers. To solve a problem intelligently, one must first of all see it as one's own problem. (in press, p 15-16)

This view of learning reinforces the use of contexts in the learning and teaching of science. As knowledge can not be simply transferred by the use of words, the alternative is to engage the learners with the scientific knowledge and let the learner construct his or her own understandings of the knowledge. This can be facilitated by using everyday contexts in which the scientific knowledge is embedded.

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[1] Von Glasersfeld used the term 'trivial' constructivism to describe personal constructivism.

[2] The quotes are from Von Glasersfeld's explanation of 'radical' constructivism and how it informs learning in mathematics. Von Glasersfeld's radical constructivism is similar to trivial constructivism in its implications for learning in the classroom, but different in its view of reality (Lerman 1989).

The personal constructivist view imposes additional conditions on the contexts that may be used for facilitating relevant and meaningful learning. Basic to personal constructivism are the views that "the individual makes sense of experience in order to satisfy an essential need to gain predicability and control over one's environment" (Confrey 1993, p4), and that "effective motivation to continue learning can be fostered *only*[1]by leading students to experience the pleasure that is inherent in solving a problem seen and *chosen as one's own*[2]" (von Glasersfeld in press, p 16). These views imply that an application that is used as a context must be seen *by the learner* to be relevant to himself or herself and they must have *a need to know* more about the application.

One of the critiques of the personal constructivist view of learning is that it promotes the notion of discovery learning (Driver 1993) and hence limits the role of the teacher in the teaching and learning process. An alternate view (Shotter 1992) is to picture learning as a socially constructed and linguistically sustained process that gives the teacher a larger role in the teaching and learning process. This view is explored below.

2.1.4. Contextual learning from a social constructivist view

Social constructivism[3] moves the focus of meaning construction from the individual to the society. For social constructivists meaning of individual action is not something inherent only in behaviour (as it is for behaviourists) or something inherent only in the mind (as is for the cognitivists and personal constructivists) but is located in the public realm (Olssen 1991).

Based on research into the influence of social processes and language on human psychology, social constructivists view the process of understanding and knowledge construction as a social activity that is influenced by the values and knowledge structures shared by the society, ie., people actively shape each other's knowledge and reasoning process by direct and indirect means (Driver 1993). "Knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared

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[1]My emphasis.
[2]My emphasis.
[3]Some authors (eg., Gergen 1985) prefer to use the term social constructionism in order to separate it from constructivism in art and architecture.

problems or tasks" (Driver 1993, p 70) and are continuously being refined to improve social agreement (Bingle and Gaskell 1994).

The concept of situated cognition proposed by Brown *et al* (1989) is an example of the above view of learning. According to Brown *et al* (1989):

- Conceptual knowledge is a function of the culture and the activities of the community in which the concepts have been developed. Therefore, conceptual knowledge can not be abstracted from the situations in which it is learned and used. It is partly a product of the activity, context and culture in which it is developed and used.
- Conceptual knowledge may be considered as a set of tools. Learning about these tools does not enable the learner to use them effectively. However, learning how to use these tools as practitioners use them requires the learner, like an apprentice, to enter that community and its culture.
- Although at school students are shown the tools used by practitioners (for example scientists), the school culture in which they observe these tools is very different from the practitioners' (scientists') culture and the teacher needs to be aware of these differences.

Learning in science in situated cognition is sometimes viewed as process of cognitive apprenticeship (Brown *et al* 1989) of learners into the culture of science by more experienced members of the scientific culture. "A more experienced member of a culture may support the less experienced member of the culture by structuring tasks, making it possible for the less experienced person to perform them and to internalise the process, ie., convert them into tools for conscious control" (Driver 1993, p 70). Most of the time the teachers play the role of the more experienced members of the scientific culture in the classroom. However, other students too may sometimes play this role and help their colleagues. In this process of involvement in the activities of the scientific culture, students learn to use the various cultural tools—the scientific knowledge.

In a learning activity designed on the cognitive apprenticeship model, the teacher is essentially involved in "providing help in developing an appropriate notion and conceptual framework for a new or complex domain and allowing the learner to explore that domain extensively, then gradually withdrawing support" (Hennessy 1993, p12). Hence the role of the teacher is of providing support as well as empowering the learners to take charge of their own learning.

The above view of learning advocates the use of historical, physical, technological and social contexts that are relevant to the learner in the teaching and learning of science (Hennessy 1993). According to Brown *et al* (1989) the main features of a learning activity designed around the cognitive apprenticeship model include the following:

- Beginning with a task embedded in an activity (context) that is familiar to the learners.
- Using authentic activities that represent the ordinary practices of the scientific culture.
- Allowing students to generate their own solutions so as to familiarise them into the culture of science.
- Facilitating group learning where social interaction and conversation may take place.

The social constructivist view of learning provides a useful theoretical framework that agrees with the contextual strategy advocated in this thesis.

2.1.5. Contextual learning as informed by learning theory

All the traditions of psychology that have been reviewed support the use of applications of science that are relevant and meaningful to the learner in the classroom to promote learning. However, according to the behaviourist concept of learning hierarchies, an application of science can only be presented to the class after the teaching of the skills, concepts or ideas needed to understand it. This view contradicts with the contextual approach advocated in this thesis.

The contextual approach to teaching advocated in this thesis may be grounded in Piaget's cognitive view of learning, or the personal and social constructivist views of learning. These views justify starting off teaching and learning activities with contexts that are familiar to the learner.

Identifying contexts that are relevant to the learners appear to be problematic from a cognitive and personal constructivist view. As relevance is a personal construction, even with extensive research into the learners' existing ideas about a context, the teacher can only speculate on the relevance of the context to the

learner. However, according to the social constructivist view of learning, relevance is a socially constructed concept.

Social constructivists view the processes of understanding and knowledge construction to be social activities that are influenced by the values and knowledge structures shared by the society. Scientific knowledge itself is seen to be a product of the culture of science and the activities of the scientific community; scientific knowledge is the set of tools used by scientists in their work. Teaching science is seen as a process of introducing the learners into the culture of science where they learn how to use the tools (scientific knowledge) as practitioners (scientists) use them. This requires a clarification of the cultural influences on knowledge-production and learning. These influences are explored in the following section.

2.2. SOCIO-CULTURAL INFLUENCES ON CONTEXTUAL LEARNING

The social constructivist view of learning explored in the previous section highlighted possible influences of culture on the generation of knowledge and on learning. It is generally agreed that culture influences thinking (Ingle and Turner 1981), perception of reality (Porter and Samovar 1991), framing for meaning in daily communication (Porter and Samovar 1991, Erickson 1987, Bell and Freyberg 1985), and the behaviour (Brislin 1990) of an individual.

This section reviews some concepts of culture in order to identify cultural elements and issues that may influence teaching and learning physics in contexts that are relevant to the learners.

2.2.1. A definition of culture

Anthropologists have widely disagreed over a definition of culture, providing a range of "fuzzy" conceptions (Erickson 1987, p 12, Milner 1991).

In its most popular usage, "culture refers to widely shared ideals, values, formation and use of categories, assumptions about life, and goal directed

activities that become unconsciously or subconsciously accepted as right and correct by a group of people who identify themselves as members of a society" (Brislin 1990, p 11). These values and beliefs are shaped by "a complex web of linguistic, social, political, economic, philosophical and religious factors" (Wilson 1981, p 28-29). Features of a culture include "both visible and physical elements, such as houses and superhighways as well as less visible norms ... [like] ... who is allowed to build houses, taboos that determine how houses are built and used ..." (Brislin 1990, p 12).

The concept of culture as social behaviour and artefacts, describes the values, norms and beliefs of a society. However, this conception of culture is limited in that it can not be easily used to define the culture of smaller social units like the school or the classroom. In studying the culture of a small scale social unit like the school or the classroom, the concept of culture as a shared way of making sense or as "a constructive frame for reality" (Cusick 1987, p 6), is often used. This concept is explored further.

2.2.2. Culture as shared ways of making sense

Based on the discussions of D'Andrade (1984) on culture theory, Erickson (1987) reviewed three conceptions which project culture as shared ways of making sense. The three conceptions are as follows:

- *Culture viewed as knowledge bits* "that are stored in a large pool of information within the bounded social group. No single member of the group has learned all of the knowledge that is possessed within the group as a whole. The amounts and kinds of information known are seen as varying widely across individuals and subgroups within the total population." (Erickson 1987, p 13)
- *Culture as conceptual structures* or "central organising constructs" that constitute what is taken as "reality" by members of a group. "Within the group routine ways of acting and making sense repeat the major framing patterns again and again, as within a musical composition many variations can be written on a few underlying thematic elements" (Erickson 1987, p 13).
- *Culture as political struggle* where social structure and culture are treated as intertwined with strong patterns of differential sharing of cultural knowledge in the social unit. This view encompasses both the notion of culture as bits of

> information differently distributed among subgroups of society and the notion of culture as a set of central organising constructs shared widely in a particular society. Erikson (1987) suggests this conception to be the most comprehensive of the three. In this notion of culture, "cultural difference is seen as tracing lines of status, power, and political interest within and across institutional boundaries found in the total social unit, by analogy with the ways in which differences in air pressure or temperature are displayed as isobars on a weather map." (Erickson 1987, p 13-24)

The concept of culture as shared ways of making sense suggests the existence of smaller social groups within the larger society. While sharing the values, norms and beliefs of the larger society, each social group is bonded by a sub-culture with its unique knowledge bits, conceptual structures and political struggles. Several of these sub-cultures may interact in any given social institution; especially in the school system which shapes the future generations of the society.

Applying the above concept of culture, several cultural influences may be identified within the science and physics classroom. In addition to the values, norms and beliefs of the larger society, the culture of the scientific community, as well as the culture of school science will influence the learning and teaching processes. These cultures are examined in the following sections.

2.2.3. The culture of science and the culture of school science

Definitions such as the following have been accused of providing an incomplete and a selective picture of science to the public (Chalmers 1988).

> Science [is] a branch of knowledge conducted on objective principles involving the systemised observation of and experiment with phenomena, especially concerned with the material functions of the physical universe. (Oxford 1990, p 1081)

Although providing an all-encompassing definition of science is extraordinarily difficult, scientific activities are certainly not always systematic, nor are they always based on objective principles (Charlesworth 1982). Claxton (1991) summarises "the nature of science proper" (p 80), highlighting some features of the scientific culture that do not appear in the public image of science (see also Chalmers 1988, Charlesworth 1982).

> ... At the centre [of science] is the attempt to generate comprehensive accounts of phenomena in the natural world which would give rise to accurate predictions, and therefore to the possibility of greater control, within particular domains. This attempt is embedded, however, within a context of personal psychology and social influence, which renders it fallible and slow. Scientific knowledge is actually an intricate body of relatively successful ideas, and could therefore not get off the ground without human faculties that are non-logical, intuitive and reflective. ...
>
> But equally the faculty of 'straight thinking' is needed, in order to devise ways of telling the successful from the unsuccessful ideas. 'Creativity' throws up candidate hypotheses; 'rational problem solving' and 'hypothetico-deductive thinking' sort out the wheat from the chaff. This recursive act of threshing leaves behind it an untidy pile of 'unconscious presuppositions', 'self-evident truths', 'disputed facts', and 'bold conjectures', and lets the wind carry away the disproved claims and the misconceptions. At each stage in the development of scientific ideas, what is 'obvious' today was 'ridiculous' yesterday and will be 'false' tomorrow. (Claxton 1991, p 80)

Science education at school, with its responsibility for preparing future scientists, is often responsible for propagating the false image of science (Fletcher 1979, Claxton 1991). This may be because, unlike scientists who are actively involved in shaping the discipline of science, science teachers themselves have very little knowledge of the culture of science. Science teachers are busy shaping a completely different discipline that constitutes a culture of its own; the discipline of teaching science.

According to Nadeau and Desautels (1984), traditional school science can develop or reinforce incorrect beliefs about the culture of science as reflected by the following:

- that science develops in a linear, logical fashion, rather like the table of contents in a book;
- that advances in science are the result of the periodic efforts of men, and occasionally women, acknowledged to be in the genius category;
- that the scientists are motivated essentially by the ideal associated with the development of knowledge;
- that science evolves independently of the socioeconomic and the cultural context of the time (p 41).

School science is urged to project a more realistic image of science, by including some of the controversial findings (Nadeau and Desautels 1984) of science that

illustrate the role of speculation and institution (Fletcher 1979), to change the "almost idolatrous attitude" (Nadeau and Desautels 1984, p 56) of students towards science. Including the history of science in the curriculum, where the sociopolitical and cultural contexts of some major scientific achievements are considered, is seen as a means of inculcating in the students a critical approach to scientific activity (Nadeau and Desautels 1984).

Bridging the gap between scientists' science and the way it is represented in schools is an area of major international research. As is typical of any social change, educational reform is a slow process. The transfer of the outcomes of research in science education to the classroom involves funding, resources and expertise. Consequently the traditional culture of school science still prevails; especially in the under-developed world.

2.2.4. Science in non-western societies

The traditional image of science, with its "hard mechanistic model of the world in which human appetites and weaknesses are out of the picture" (Christie 1991, p 27), has been at the forefront of western development and economic supremacy. Since the mid-1960's many under-developed countries have invested in science education to bridge the gap between them and the technologies of the developed world (Ingle and Turner 1981). With modernisation equated to westernisation (Hewson 1988), western-style science education is seen as a stepping-stone (Tan 1988) for the western technology and western scientific know-how considered essential for development in the modern world.

The direct adaptation of western science curricula, in non-western countries, continues to serve well in meeting the initial requirement of producing a relatively small number of highly qualified personnel in the area of science and technology required for national development (Ingle and Turner 1981). However, with the growth of schooling, and the drive towards *science for all* (Fensham 1988a), western science curricula were considered "cultural misfits" (Ingle and Turner 1981, Wilson 1981) in some non-western countries.

According to Baimba, in most black African (Baimba 1991) countries traditional cultural practices are in conflict with the Western cultural practices through which science has evolved (Baimba 1992).

> School science represents knowledge imposed on traditional students who come to school with a wealth of beliefs about the world around them. These traditional beliefs, which makes sense of the world to the traditional students, often conflict with what is taught in science lessons. Hence, for the majority of these students, the meaningless information given to them in science lessons is shelved, to be used only for the purpose of passing school examinations. Once outside it is the traditional knowledge which they use to make sense of their world. (p 28)

Similar research conducted in Samoa (Moli 1991), Australia (Ritchie and Kane 1990), Botswana (Prophat 1990), the Caribbean (George and Glasgow 1989), Nigeria (Okebukola and Jegede 1990), USA about American Indians (More 1987) and UK (Chamberlain 1986, Tunnicliffe 1986) documents how the beliefs, norms and values of students from non-western cultures are in conflict with the beliefs, norms and values projected by western science.

Maddock (1981) suggested that the shared knowledge, myths, legends and superstitions of indigenous people, which are based on experience and fashioned by reason, constitute an alternative science to western science in explaining the functions of the physical universe. With western science being projected as a western construct (Ogawa 1989), the concept of ethnoscience (Knight 1977), often referred to as indigenous science (Linden 1991), is appearing in modern epistemology.

Ethnoscience appeared in recent curriculum initiatives, only as a "help to the teaching of modern science" (Maddock 1981, p 15) by linking the world of western science to the world of the non-western student. Today, as more and more elements of indigenous cultures are being discovered by the west, *science proper* itself is being described as the ethnoscience of the western civilisation (Ogawa 1989). Furthermore, as some elements of indigenous science and technologies are proving to be kinder to the environment than its western counterparts (Linden 1991, Christie 1991), ethnoscience is being offered an equal status to western science by a few scientists (Christie 1991).

2.2.5. Socio-cultural influences on contextual learning

The school is an important social institution for sustaining culture, as well as for initiating and passing on cultural change. Through formal and informal processes of schooling and everyday life, learners develop and constantly modify cultural lenses that are used to perceive what happens in their everyday life. These lenses influence what the learner may perceive to be relevant and meaningful, and are shaped by several, often dynamic, cultural elements or sub-cultures that operate within the society.

The sub-cultures that may interact within the physics classroom include:

- *the culture of the society* (the culture of the learners) with its political struggles, minority groups and the resulting dynamics that operate, often unnoticed, to restructure the norms, values and beliefs of the society;
- *the culture of science* and its role in the progress of the society; and
- *the culture of science projected in the science curriculum* that is shaped by the norms, values and beliefs of the school system reflected by the politics of the system and the official and unofficial aims of science education.

These sub-cultures may directly or indirectly influence classroom processes. The socially-constructed perception of what it means to be a learner, or the perception of what type of activities are appropriate in the science classroom may impede or even help a teacher use contextual teaching strategies.

The sub-cultures that interact inside the classroom also dictate the technological and other everyday contexts that may be used in the classroom. For the context to be relevant and meaningful to the learner, it needs to link to the everyday culture of the learner. For it to be useful for learning the prescribed science content, it needs to relate to the curriculum that reflects the culture of school science. Furthermore, in order to give the learners the true picture of science, the context should pertain to the culture of science. This inter-relationship is illustrated by Figure 2.1.

An example of a context that pertain to all these interacting sub-cultures in a physics classroom is telecommunications. Aspects of telecommunications belong to the culture of science and the culture of the learners, and can also be explored within the school physics curriculum (the culture of school science).

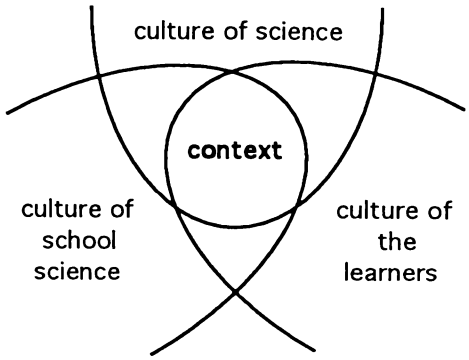


Figure 2.1. The cultural position of a relevant and meaningful context

2.3. CONTEXTUAL TEACHING AS INFORMED BY CLASSROOM-BASED STUDIES

There is little disagreement among science educators about the need to make the teaching and learning of school science relevant and meaningful to the needs of the learner. However, science educators have varied views on how to achieve this efficiently and economically in the classroom. These views are sometimes based on particular views of learning, while sometimes these views are only influenced by the socio-political and economic factors that shape education.

This section reviews some strategies currently being used to make classroom science meaningful and relevant to learners and their needs in society, and proceeds to explore how these strategies may inform learning physics in a technological context. The following areas of curriculum development and classroom-based research were reviewed:

- The development and use of curriculum material for secondary school science and physics based on science-technology-society issues and themes.
- Research into the use of contexts for teaching secondary school science and physics.

2.3.1. Use of science-technology-society issues

In the mid 1970's several industrialised countries experienced immense political and economic pressure to re-shape science education to meet societal needs which were increasingly dependent on applications of science and technology. This led to an increased emphasis on including the interrelationships between science, society and technology in the science curriculum.

The main drive of the Science-Technology-Society (STS) movement was based on the belief that by including scientific and technological issues that are important to society (STS issues) in the teaching of science, science education would cater to the needs of students in scientifically- and technologically-orientated societies. As a result science would become more meaningful even for those who may have little interest in the subject for its own sake (Holman 1988).

Among intense debate on what scientific, technology and society issues (STS issues) are important enough to be included in the curriculum (Bybee 1987) and on how STS issues may be incorporated to the teaching of science (Solomon 1988a), a variety of curriculum materials emerged.

According to Fensham (1988b) the curriculum materials that were produced under the STS umbrella consisted of resource material that:

- provided descriptive accounts of technology in action at the beginning and throughout the learning of a science topic as a motivational aid to learning;
- included brief and factual reference to randomly-chosen technological applications that involve the concepts of the science topic;
- made factual reference to selected examples of technology based on a social issue, that involve the concepts of the science topic.
- were organised along a technological theme or a socio-technological issue;
- used the construction of a technological model or the practice of a technological process;
- incorporated a technological theme or a socio-technological issue organised along a science topic;
- focussed on the detailed science that is important to the construction and operation of a technology or an a socio-technological issue, or to;
- involved the systematic learning one or more social aspects of a major technology or a broad field of applied science.

The science content in most of the initial STS material was determined by traditional science (Solomon 1988a), and this was mainly because the material was designed for highly prescribed traditional curricula that did not reinforce the learning of the STS issues (Fensham 1988b). The next section studies a STS-type project in order to identify some of the difficulties encountered in using STS material in the classroom.

2.3.2. Use of science and technology in society

According to Hunt (1988), the Science and Technology in Society (SATIS) project was established in 1984 within a climate of national curriculum reform leading to the introduction of the national GCSE schemes in 1986 in UK. Sponsored by the Association for Science Education, one hundred STS-type teaching units were published for use by the 14-16 age range.

The units are short (about 75 minutes of classroom time each) and are designed to be used as resource material with existing science programmes. "Each unit relates to a major topic in the science syllabuses while exploring important social and technological applications and issues" (Hunt 1988, p 411). According to Hunt (1988), SATIS units introduced some new learning strategies that most science teachers may not have considered using before. These include the following strategies:

- *discussions* where students are guided by the teacher through a coherent debate about relevant issues after they have informed themselves with relevant knowledge;
- *role-plays* that emphasise on bringing out the various viewpoints of the interest groups represented;
- *surveys* conducted by the learners to collect data about relevant issues for their own analysis;
- *reflective reading* of material on relevant issues.

Almost all units were written by teachers in the SATIS Central Team with co-operation from experts in industry, agriculture, higher education or public services (Hunt 1988).

The findings of a study conducted to evaluate the use of SATIS units, reported by Walker (1990), include the following:

- Teachers tended to use SATIS units with upper and middle ability students. A substantial number of units were considered too difficult for low ability students.
- Most teachers did not use a unit unless it had a direct link to the GCSE syllabus.
- Nearly all of the more popular units were exam orientated. These units had straight science topics with SATIS elements used to add contemporary relevance to the topic.
- The least used teaching/learning methods were role-playing, discussing and debating ideas. The most used methods were data-management and case studies.
- Most pupils enjoyed the SATIS units in general. The less popular units were those that mostly involve reading and writing without much teacher or student interaction. However, over 80% of the teachers considered the reading activities to be most effective in their classrooms!

According to Fensham (1988b) even when the curriculum supported STS-type learning, most science teachers were not prepared to teach STS issues. Most STS issues involved science from a number of traditional scientific disciplines that do not normally appear in a school science course, and in many countries science teachers were very specialised in their science disciplinary background. The societal aspects of an STS treatment involved a number of other non-science disciplinary fields such as sociology, economics, politics, religion, that teachers normally did not have the confidence to do cognitive justice. Furthermore, an undergraduate education in science rarely allowed teachers to be aware of the controversial nature of science itself or the various arguments, debates and controversies on the impact of science and technology on society.

The need to spend time in subject areas other than science also had another drawback (McFadden 1991). It was argued that if STS issues were to be taught in science, without loss of attention to the development of science concepts and skills, the whole school curriculum needs to be reformed towards a de-compartmentalised, coordinated school curriculum with no subject boundaries and team teaching. The lack of substantial research indicating enhanced learning

outcomes also made teachers reluctant to use STS-units in their teaching of science (Solomon 1988b, Hart and Robottom 1990).

The experiences gained by using STS-type curriculum material, resulted in some curriculum innovations. The PLON curriculum development project that is discussed below is an example.

2.3.3. Use of thematic curricula

Although the PLON[1] project team recognised the importance of separate STS courses, they felt that individual courses on STS themes were not enough to address some of the difficulties faced by physics students at school (Eijkelhof and Kortland 1988). "This feeling has led to the development of physics curricula in which a specific integration of physics, technology and society was striven for: curricula based on both the good features of an academic course in physics and of STS courses about the impact of science and technology on society" (Eijkelhof and Kortland 1988, p 285). According to Eijkelhof and Kortland (1988), the PLON project developed teaching material that:

- contain physics (basic concepts and skills) which is useful in everyday life regarding decision making situations on a personal and social level, *and — at the same time —* which is essential for those who continue studying physics in tertiary education;
- present an authentic view of physics, by paying attention to the history, the nature and the methods of physics;
- recognise the differences among the students in interests, abilities and plans for the future;
- stimulate students to be actively interested in experiments, literature, investigations, data retrieval and analysis, etc. (Eijkelhof and Kortland 1988, p285)

Thematic teaching units were based on everyday phenomenon like weather changes, traffic, electrical machines and were designed for use at different levels at secondary schools. Each thematic teaching unit was structured into five stages (Eijkelhof and Kortland 1988, Lijnse *et al* 1990):

- An *orientation* stage where the students are shown the relationship between a specific physics domain and the everyday life context. "The relationship is reflected in a *central question* which sets the scene for the unit.... Ideally this central question should have relevance for students. It should be broad

[1]PLON is a Dutch acronym for *Physics Curriculum Development Project.*

enough to meet the differences in interests and should provide the possibility of being translated into a variety of suitable student activities" (Lijnse *et al* 1990, p 98).

- A stage where some *basic knowledge and skills* concerning the topic are taught "preferably in the form of various student activities which stimulate independent learning in small groups" (p 98).
- A stage where students work on different *options* in parallel groups.
- A stage where students report back their findings to the rest of the class, aimed at broadening and deepening their knowledge.
- Optional sessions at the end of the unit where the students may further explore the area depending on their interests.

Eijkelhof and Kortland (1988) highlighted the following problems and issues that surfaced during the process of developing and evaluating the PLON units:

- In choosing the contexts (the themes and central questions) a compromise between desirability and feasibility had to be made. Ideally, the contexts that were incorporated into the curriculum should have only been influenced by the differences in interests, abilities, plans for the future among students and by long-term developments in society. In reality, certain other factors like the existing nationwide examination programmes, preparedness of teachers to adopt and implement innovative material, had to be taken into consideration.
- The contextual knowledge that incorporates the physics/technology or physics/society components, ie., the central question, had to be very closely connected to the physics content. If various chapters of the unit were loosely connected to the central question, teachers tended to concentrate only on the traditional physics aspects, neglecting the innovative chapters.

A major difference between the STS courses and the PLON curriculum units was the use of everyday experiences of the learner as the starting point of instruction by the latter. Real life applications were presented to the students in their full complexity before teaching prior concepts and knowledge required to understand them. This reflects the constructivist strategy of making use of the student's prior knowledge in teaching.

The constructivist view of learning has also been used by other educationalists and researchers. The Iowa STS programme that is discussed in the next section is an

example of a research programme that advocated constructivist strategies for using STS-issues in the classroom.

2.3.4. Using student-generated contexts

The Iowa STS programme, conducted by the University of Iowa, USA, was established in 1983 in an attempt to help teachers remedy the alienation of many students, specially females and minorities, from science by using approaches advocated by the STS-type curricula (Yager and Tamir 1993). Yager and Tamir (1993) described the STS approach advocated by the programme as:

- student centred;
- individualised and personalised and recognising student diversity;
- using a variety of resources;
- being based on cooperative work on problems and issues and considering students to be active contributors to instruction;
- building on student experiences;
- assuming that students learn best from their own experiences;
- based on planning the teaching around problems and current issues.

The new approach advocated by the Iowa STS approach was based on constructivism. This can be seen in the exemplar of their approach provided by Yager and Tamir (1993) that illustrated how a teacher at Grade 9 level used students' ideas about what was wrong with the stream in their town for teaching concepts of acids and bases. The stream was something that the students were familiar with and they were aware of the pollution of the stream caused by the coal mine upstream. Their ideas about the reasons for pollution were used by the teacher to direct the students to explore the concepts of acids and bases leading to the study of hydronium and hydroxide ions that was required by the curriculum.

In this approach "the teacher was the decision maker about curriculum framework and teaching strategies, students were the decision makers regarding issues and questions, how to pursue them, how to get information, how to use information, and what actions to take" (p 638). Moreover, the students had a reason, other than passing the exam, for studying about hydronium and hydroxide ions. Their reason was to find out what was wrong with their stream.

Through workshops, short courses and interim communications, the programme provided in-service support for over 300 teachers. The in-service work with the teachers helped them teach towards enhancing achievement in five major domains (Yager and Tamir 1993):

- *Concept domain* that focused on the more conventional content of science courses.
- *Process domain* that encompassed the skills associated with exploration and investigation.
- *Applications domain* that focused on the transfer and use of information, skills, and attitudes across contexts.
- *Creativity domain* that developed students' abilities for visualising, imagining and combining ideas and objectives in new ways.
- *Attitude domain* that influenced student motivation.

In a recent study (Yager and Tamir 1993), 15 teachers who were considered experienced in using the contextual style of teaching, taught 30 classes and 720 students over grades 2 through to grade 9. Each teacher taught two classes. In one class the teacher used the contextual approach and in the other the teacher used a traditional teacher-centred approach directed by text books and direct instruction. Standardised post-test and pre-test items were used to test the students' learning in all the five domains.

According to Yager and Tamir (1993) the major findings include the following:

- With experienced, high-quality teachers, using the new approach did not produce more *concept learning* compared to using a traditional approach.
- With respect to process skills, creativity skills, and in the applications of concepts and processes to new situations, the new approach was more effective in all students.
- When the new approach was used with low ability students, they developed more positive attitudes towards science.
- In using the new approach, older students showed marked improvement in their skills of applying concepts and processes to new situations, while younger students improved more in their process skills and creativity skills.
- Regardless of the instruction approach, high ability students gained more than low ability students.
- The only gender difference found was in case of attitudes. Positive attitude change towards science was observed in females in both treatments.

> However, in the more student-centred treatment, the greater positive attitude change in females was observed.

Other researchers too reported similar results of using contextual approaches in the teaching and learning of science. Rodrigues (1993), in studying the role and effect of context in the learning of form-six (Grade 11) oxidation and reduction concepts by female students in New Zealand, reported enhanced cognitive and affective outcomes when a constructivist approach was used. Jones (1988) and Cosgrove (1989) reported similar results in using technological contexts from the everyday-life experiences of learners in the teaching of physics concepts for both girls and boys.

Although the use of student generated contexts produces enhanced affective and cognitive outcomes, researchers attribute different characteristics to contexts that are relevant and meaningful to learners and use different strategies for choosing and identifying them. Some of these characteristics and strategies are explored below.

2.3.5. Identifying relevant contexts

According to Rodrigues (1993), if the students are unable to provide some expertise in the context, it does not exist for them.

> This expertise would stem from the student's existing experiences and the links they have made between the new experience and their existing experiences.... This expertise characterises context lessons and is illustrated by students who are confident, assertive, questioning and volunteering information. In addition, conversation in context lessons reflect normal patterns, rather than classroom teacher orchestrated talk. (p 22)

However, finding such suitable contexts was considered by Rodrigues (1993) to be a dilemma. Students are often unable to identify their existing experiences that are pertinent to a given concept and teachers may have to use a variety of strategies to find out students' existing experiences that may be used to build a context.

According to The Cognition and Technology Group at Vanderbilt (1990) contexts need to be shared by the learner and the teacher. They used random access videodisc environments that allowed teachers and students to share and mutually

explore contexts or events. Depending on student interest, a particular section of the video may be played and re-played and students may engage in solving problems based on the section of the video that interest them. Their videodisc technology has been used successfully for teaching language, social studies and mathematics.

Dawson (1994) developed similar video-disc environments coupled with interactive computer programs for the teaching of mechanics. In one of his interactive units, random access video clippings of a roller coaster ride were used to develop students' existing experiences about how it feels to ride a roller coaster into concepts of acceleration, kinetic energy, and potential energy. This is facilitated through interactive computer-based environments that allowed students random access to technical and physics information of the roller coaster: the motor that drives the coaster, its power, energy stored, speed and kinetic energy, acceleration, etc. The interactive environment provided activities that allowed students to design their own roller coaster and also allowed them to see on the screen, how the modified system may work. Most of the time the computer played the role of the teacher.

Jones (1988) and Cosgrove (1989) proposed that technological applications and issues from the learners' culture provide relevant contexts for teaching and learning physics. If the technological contexts are from the everyday life of the learners they will be able to provide the expertise about the context that Rodrigues (1993) demands. Furthermore, these applications may be mutually explored and shared by teachers and students as required by The Cognition and Technology Group at Vanderbilt (1990).

The use of technological applications and issues from the learners' culture as contexts fits in to a social constructivist framework discussed previously and is explored below.

2.3.6. Technological contexts for making physics relevant

In his study of using technological contexts for teaching concepts of capacitance and doppler effect at form seven (Grade 12) levels in New Zealand, Jones (1988) used the following criteria for choosing the technological contexts:

- Relevance in terms of human relationships and everyday life.
- Relevance to the student's interests and existing knowledge, with particular reference to gender differences. For example, it has been found that girls preferred medical examples of technology, whereas boys were more interested in technical aspects of devices.
- A range of applications based on the same physical principle or concept. With individual differences in existing knowledge, this will enhance the probability of each student generating a number of meaningful links.
- Suitability for introduction at the beginning of the lesson with background material and physics concepts directly accessible.
- Availability of experiments that can be carried out to further explore and test student's ideas.
- Development of a theme for the next few lessons so that new ideas can be related back to existing ideas, further reinforcing the physical concepts. (Jones and Kirk 1990, p 483)

Jones also explored the technological contexts that were considered relevant by sample of senior secondary school students in New Zealand. Based on his findings, Jones suggested that students found the following types of technological applications generally relevant to them:

- applications which directly involved people;
- applications within their environment, e.g., home, school, society;
- applications which correspond to their intended careers and anticipated needs;
- medical applications (particularly girls); and
- modern technological devices (particularly boys).

According to Jones, students did not appear to be interested in:

- domestic appliances apart from new technology like microwave ovens;
- remote industrial applications; and
- school physics type activities.

Jones also suggested that there were sex differences in what students preferred to learn. For example, more girls preferred medical applications, and more boys were interested in technological devices. Boys were also more interested in the technical aspects of devices.

In his unit on capacitance, for example, Jones (1988) used social issues and applications that involved principles of capacitance in their basic design. The first group of lessons were based on a camera flash unit. By building models of the camera flash unit, and through discussions about students' ideas about the

working of the model, the basic concepts of capacitance were developed. The second group of lessons extended the students' developing concepts of capacitance by looking at other applications that they were interested in finding out more about. These applications included earthquake monitors, altitude monitors, baby breathing monitors and microphones that were designed around principles of capacitance. The third group of lessons were based on looking at the social issue of cot-death and how the baby-breathing monitor saved the lives of small children.

All the lesson groups were structured into five stages (Jones 1988):

- a focusing stage designed to focus students' attention on the learning situation or context;
- an exploration stage designed to provide students the chance to explore the context;
- a reporting stage where students report their findings to the class and discuss them;
- a formulation stage where the teacher and the students use the information gained in the previous stages to develop physics concepts and to write them in a formal physics manner; and
- an application stage where students carry out further investigations, attempt traditional physics and other technological applications.

The units of capacitance and doppler effect were trialed by "expert teachers" who were "sympathetic to the alternate approach to teaching physics" (Jones and Kirk 1990, p 485). Enhanced cognitive and affective outcomes without a significant gender bias, and positive responses from the majority of the teachers involved in the research were reported.

In a study conducted in New Zealand to teach 11-15 year-olds electric current using technological applications from their everyday life, Cosgrove (1989) used a teaching unit structured into three phases: a familiarisation phase, a challenge phase, and an application phase.

- In the familiarisation phase students were given many simple practical experiences involving electric current and the teacher encouraged the students to work on their own, without offering the 'right' answer to the practical exercises. The students were encouraged to suggest answers to their questions. The main aim of the familiarisation phase was to allow the students to formulate their own ideas about electric current.

- In the challenge phase students' ideas about electric current were explored and by using analogies and experiments, students' alternate conceptions about electric current were challenged.
- In the application phase students were required to solve practical problems based on real world events and their interests. Solving these problems allowed the students to apply their current ideas about electric current and enabled the teacher to intervene when and where appropriate to help students understand the scientist's view of electric current. The problems that students had to choose from, included the following:
    - Why is it when one light goes out in a set of Christmas tree lights, all of the light bulbs go out?
    - Designing a warning system to avoid train accidents inside the very long Kaimai[1] tunnel.
    - Designing traffic lights.
    - Changing the speed of an electric motor.

In the classroom trials, Cosgrove monitored the ideas of students as they followed the course of study. His research showed that as early as the familiarisation phase some students changed their thinking about electric current towards the scientists' notion. However, some of them who initially adopted the scientist's view shortly regressed to their early views. Significant changes towards the scientists' view of electric current were observed in many students after going through the challenge phase and the applications phase. Cosgrove contended that it was unlikely that students would develop a view of electric current consistent with scientific ideas at first contact, and the challenge phase and the application phase provided the necessary period of time for these ideas to gradually develop.

Based on the varied reactions from the different teachers who were involved in trialing the unit of work, Cosgrove decided that "extensive teacher education would be necessary before the package was implemented" (p 109). However, the difficulties faced by teachers in attempting to use the approach were not further explored.

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[1] A tunnel, about 7.5 km long, through the Kaimai mountain ranges in the North Island, New Zealand.

2.3.7. Structure of context-based teaching strategies

The lesson structures used by Jones (1988) and Cosgrove (1989) used the generative learning model of teaching as a basis (Cosgrove and Osborne 1985). According to Cosgrove and Osborne (1985) the generative learning model of teaching has a three-stage structure common to many other teaching sequences:

- the teaching sequence of Renner (1982) that facilitated learning through experience, interpretation, and elaboration;
- the teaching sequence proposed by Karplus (1977) which was based on exploration, explanation, and application;
- the teaching sequence proposed by Nussbaum and Novick (1982) that comprised exposing alternative frameworks of students, creating conceptual conflict, and encouraging cognitive accommodation;
- the teaching sequence proposed by Erickson (1979) that facilitated learning through experiential manoeuvres leading to anomaly manoeuvres and to restructuring manoeuvres.

The generative learning model of teaching proposed a focus phase, a challenge phase and an application phase. It also added a preliminary phase to the three-stage structure that requires the teacher to prepare for implementing the three stages. A similar lesson structure is also used by the PLON curriculum material discussed above (2.3.3).

The generative learning model of teaching was derived from a personal constructivist view of learning (Cosgrove and Osborne 1985).

2.3.8. Contextual teaching as informed by classroom-based studies

The STS experiences indicate that it may be difficult for some teachers and students to use the contextual approach advocated in this thesis. However there is a basic difference between the initial STS material and the contextual approach. The initial STS material was based on concepts of physics and science. However later material was designed on themes and required students to engage with examples and applications before the teaching of the relevant theory.

Most of the teaching material reviewed in this section introduced the context before teaching the physics. These studies yielded enhanced learning outcomes, and hence provided support for the main contention of this thesis. However, there were different views about how contexts that are relevant to the learners may be chosen. The implications of these findings, as well as the findings from the other parts of the literature review reported in this chapter, are discussed in the next section.

2.4. IMPLICATIONS FOR CONTEXTUAL TEACHING AND LEARNING IN PHYSICS

The traditions of psychology that have been reviewed, except the behaviourist concept of learning hierarchies, support the contextual approach to teaching that is advocated in this thesis.

Identifying contexts that are relevant to the learners appears to be problematic from a cognitive and personal constructivist view. As relevance is a personal construction, even with extensive research into the learners' existing ideas about a context, the teacher can only speculate on the relevance of the context to the learner. The social constructivist views relevance as a socially constructed, and socially negotiated concept. If relevance is socially negotiated then it may be speculated that the teacher is in a better position to assess what may be relevant to the students. This speculation is based on the fact the teacher and the students share the same sub-culture—the culture of the classroom. The social constructivist view of relevance is adopted for the purposes of this study.

If the concept of relevance is socially constructed then it may be influenced by the various forces that shape the social norms and beliefs of the science classroom—the classroom culture. The literature review of socio-cultural forces that may shape the classroom culture revealed the following to be the most influential in a science classroom: the culture of science, the culture of the learner, and the culture of school science.

The above findings imply that the context chosen for contextual teaching has to be relevant to all the three cultures that interact inside the science classroom. If the

context belongs only to the culture of science, the learners may not find it meaningful. If the context belongs only to the culture of the learner, there may be no educational value in using it in a science classroom. Furthermore, even if the context is relevant to the learners and to the culture of science, its use must be warranted by the science curriculum and by acceptable school and classroom practice. The values, norms, and beliefs projected by the science curriculum and school practice constitute the culture of school science.

Technological applications from the culture of the learners have been used for teaching of secondary school physics in some research studies (Jones 1988, Eijkelhof and Kortland 1988, Lijnse *et al* 1990, Cosgrove 1989). These applications appear to provide contexts that belong to the culture of the learner, the culture of science, and the culture of school science in the western countries the studies have been conducted. It remains to be seen whether technological applications from the everyday life of Maldivian students provide contexts that they consider relevant to themselves. This question is explored further in Phase One of the research study.

The outcomes of the studies mentioned above support the principal contention of this thesis that the use of the contextual approach to teaching enhances the learning outcomes. However, all of these studies were conducted in western societies using teachers who were considered to be experts in using the contextual approach to teaching that is advocated in this thesis. As reported earlier (Chapter One, section 1.4) this raises two questions: Can contextual teaching and learning be used in non-western cultures? What problems may be faced by some teachers who attempt to use contextual teaching? These questions are explored further in the Phase Two, Phase Three and Phase Four of this research study.

The research conducted during the four phases of the study is reported after discussing the research methodology and design in the next chapter.

CHAPTER THREE

RESEARCH METHODOLOGY AND DESIGN

This chapter describes the methods used for collecting data, the strategies employed to ensure the validity of the data collection procedures, and a description of the steps taken to enhance the reliability of the data collected.

The chapter outlines the different phases of the study, the main research activities conducted, and the participants involved in each phase. Full details of the different phases of the study are provided in later chapters.

3.1. RESEARCH METHODOLOGY

Classroom-based educational research employs quantitative methods, qualitative methods, or a combination of both. Quantitative methods are used to measure a process and the factors that influence the process in terms of quantity, amount, intensity or frequency (Denzin and Lincoln 1994). Their strength is in their ability to quantify generalisable variables (Tesch 1990). Qualitative methods do not quantify generalisable variables, and are used to collect descriptive and interactive data (Smith 1987, Sowden and Keeves 1988, Denzin and Lincoln 1994).

This study was designed (1) to compare the interest and ideas of a sample of secondary school students from the Maldives and New Zealand in an area of technology that is common to the two societies, and (2) to explore the process and outcomes of teaching physics in technological contexts that were relevant and meaningful to the learners in the two societies. For these purposes a combination of qualitative and quantitative strategies was employed for collecting data. The following qualitative strategies were used:

- structured open-ended interviews;

- informal conversational interviews; and
- qualitative classroom observation.

The following quantitative methods were used, in conjunction with informal conversational interviews:

- questionnaires;
- concept mapping; and
- pre- and post-tests.

Table 3.1 summarises how these data-collection methods were used in the study.

Table 3.1: Data-collection methods used in the study

Data-collection methods	Used for:
• structured open-ended interviews	exploring student ideas about telecommunications— an area of technology common to the Maldives and New Zealand.
• informal conversational interviews • qualitative classroom observation • pre- and post-tests • questionnaires • concept mapping	monitoring the process and outcomes of learning and teaching physics in a technological context in the two societies.

The strategies for collecting data and their particular use in this study are explored further in the following sections.

3.1.1. Interviews

Interviewing is one of the most powerful tools used in attempting to understand the points of view of the interviewee (Fontana and Frey 1994). In its basic form an interview is a conversation between two people (Posner and Gertzog 1982). However, many forms of interviews are used by researchers.

Because of its interactive nature, interviewing has many advantages over other types of strategies for collecting qualitative data. These advantages include the following (from Best and Kahn 1993 and Cohen and Manion 1994)

- People are usually more willing to talk than to write, specially in providing certain types of confidential information.
- The interviewer can interact with the interviewee and clarify misunderstandings.
- Interviewing allows the probing of particular knowledge domains in greater depth than with other methods of data-collection.
- The same information may be obtained in several ways during the interview. This allows the interviewer to check the truthfulness of the responses.
- Interviewing allows the probing of unexpected and revealing remarks made by the interviewee and this helps make private thinking public.
- Interviewing also allows the probing of significant areas of the interviewee's insight into his or her experiences that may result in outcomes unanticipated by the interviewee.

The interactive nature of interviewing also imposes shortcomings on the strategy. In particular the interviewer has to be very sensitive to the following considerations.

- The meaning of a question asked by the interviewer may not be fully understood or even may be misinterpreted (Cohen and Manion 1994). Similarly, the interviewee's response may be interpreted in a sense that was not intended (Bryman 1988).
- The interviewer's preconceptions and feelings may be reflected in the questions, gestures, and other verbal and non-verbal signals that may direct the interviewees responses. These preconceptions may also influence how the interviewee's comments are interpreted (Lythcott and Duschl 1990).
- The interview process may be influenced by the personal characteristics of the interviewer (Fontana and Frey 1994).
- The interviewer has to gain rapport or establish a friendly relationship for the interviewee to provide certain types of information (Spauld 1988).
- Effective interviewing is time-consuming and is one of the most difficult methods of data collection (Best and Kahn 1993).

Because of the interactive nature of the study and the in-depth information required, interviewing was used as the main technique for collecting data throughout the research study. Several strategies were used to minimise the shortcomings associated with interviewing. These strategies include the following:

- all the interviews were audio-taped and most of them were fully transcribed for analysis and coding;
- the interviewees were given the guarantee of confidentiality and anonymity; and
- different types of interviews were used for different situations.

Audio-taping and coding the transcript are considered to be more efficient than note-taking (Miller and Cannel 1988). Note-taking requires the interpretation of the data quite early on (Walker 1985). Instead of concentrating on interpretation of the data the use of audio-taping frees up time during the interview for thinking about the responses and for probing them.

A disadvantage associated with audio-taping and coding the transcript is the amount of labour and time that goes into transcribing (Galton 1988). Furthermore, the delayed interpretation of data may also require certain interviewees to be approached more than once for further clarifications.

All interviewees were guaranteed confidentiality and anonymity. Only those who agreed to the anonymous use of their comments were interviewed. In case of interviewees (such as teachers) who may be identified by their comments, the transcripts, with an indication of the contexts within which the transcripts may be used, were submitted in writing for review. Teachers were requested to exclude sections of the transcript that they were unhappy about.

Two types of interviews were used during the different stages of the study:
- structured open-ended interviews; and
- informal conversational interviews.

3.1.2. Structured open-ended interviews

In structured open-ended interviews (Best and Kahn 1993[1]) two types of questions are used: basic questions and clarification questions. The exact wording and sequence of the basic questions are predetermined. All the interviewees are asked the same basic questions in the same order. Open-ended clarification questions are used to probe responses to the basic questions.

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[1] Best and Khan uses the term standardised open-ended interviews.

The strengths of using open-ended questions in interviewing include the following (Cohen and Manion 1991):

- open-ended questions are flexible;
- they allow the interviewer to probe more deeply or to clear up misunderstandings;
- they allow the interviewer to assess the interviewee's knowledge;
- they allow the interviewer to more accurately assess what the interviewee believes;
- they can result in answers suggesting unexpected or unthought-of relationships or hypotheses; and
- they encourage co-operation and help establish rapport between the interviewer and the interviewee.

When all the interviewees answer the same basic questions the advantages are (Best and Kahn 1993):

- the responses are comparable across interviewees;
- data are complete for each person on the topics addressed in the interview; and
- organisation and analysis of data are facilitated.

Some shortcomings of the use of structured open-ended interviews are:

- they provide little flexibility in relating the interview to particular individuals and circumstances (Best and Kahn 1993);
- the structured wording of the basic questions may constrain and limit the flow of questions and answers (Best and Kahn 1993); and
- the use of open-ended clarification questions may make the coding of the interview difficult (Cohen and Manion 1991).

Structured open-ended interviews were used in this study to explore individual student's ideas about some applications in telecommunications. Stimulus cards were used to focus the interview on the applications. Each stimulus card contained an illustration of the application, and a key phrase about the application. Some applications were similar (e.g., telephones and cellular phones, satellites in weather forecasting and satellites in navigation). Using similar applications allowed comparison of student answers within the interview. Using the same applications in all the interviews facilitated their coding and enabled easy comparison between responses of individual interviewees.

The questions used in the interview were trialed with students at the same school level as those in the selected sample. Based on the outcomes of the trials the questions were modified to increase comprehension and readability.

For facilitating the flow of conversation and to develop rapport the interview schedule was structured into four parts: an introduction; housekeeping; interview about applications; and an ending (Osborne and Freyberg 1985, Jones 1988). The introduction was used to inform the interviewee of the purpose of the interview and to acquaint the researcher with the interviewee. The house-keeping section of the interview was used to collect some background information about the interviewee by asking some questions that can be easily answered. The questions were made simple in order to get the conversation flowing. The interviewee was then questioned about the applications. Further details of the interview schedule are given in Chapter 4.

3.1.3. Informal conversational interviews

Informal conversational interviews or unstructured interviews are conducted without imposing any prior categorisations that may limit the field of inquiry (Fontana and Frey 1994). Informal conversational interviews do not use predetermined questions or structure: the questions emerge from the immediate context (Best and Kahn 1993).

The strengths of informal conversational interviews (Best and Kahn 1993) include the following:

- the salience and relevance of questions are increased as they relate to immediate experiences;
- interviews are built on and emerge from the observations of the interviewer and hence the interview can be matched to individuals and circumstances.

There are some weaknesses of informal conversational interviews:

- Because of the different information collected from the interviewees for the same questions, data organisation and analysis could become quite difficult (Best and Kahn 1993).
- The information given by the interviewee very often depends on trust. Getting the trust of the interviewee may sometimes be difficult (Spauld 1988).

Informal conversational interviews were used in this study with groups and individuals throughout the classroom interventions. These interviews were conducted with teachers as well as with students. Before using informal conversational interviews the researcher spent some time interacting with the interviewees. This helped in establishing rapport and in creating the informal and trusting environment needed for the successful conduction of the interviews.

Other methods of data-collection were used in conjunction with the informal conversational interviews. As most of these methods were structured, their use facilitated the organisation and analysis of data. The methods were:

- qualitative classroom observations;
- concept maps;
- pre- and post-tests; and
- questionnaires.

3.1.4. Qualitative classroom observation

Unlike structured classroom observation that looks for the occurrence of preset processes and patterns of behaviour in the classroom, qualitative classroom observation attempts to identify patterns of behaviour inside the classroom and to look for interactions and relationships as they happen (Adler and Adler 1994, Stallings and Moholman 1988, Galton 1988, Croll 1986).

Qualitative classroom observation was used in the study to observe patterns of teacher-student interactions, student-student interactions, and the various behaviour patterns of students and teachers. It was also used to identify indicators of learning in the classroom. In addition to maintaining field notes, all the sessions were audio-taped and later coded.

A major strength of audio-taping the classroom sessions is that it enables the researcher to review the observation at a later date (Galton 1988) and observe new patterns and categories that may not be apparent initially during the interview (Edwards and Westgate 1987). A major limitation of audio-taping the classroom proceedings is the amount of work and time needed for transcribing (Galton 1988). Hence, during the later stages of the study only the sections of the interviews that were considered to be relevant were transcribed.

Qualitative classroom observation by itself is subject to observer bias and subjective interpretations (Adler and Adler 1994, Croll 1986). During this study, therefore, the observer's interpretations of the classroom observations were clarified through informal conversational interviews with the teachers and students.

For the purposes of the study, the presence of the researcher inside the class was essential. However, the presence of an external observer inside the classroom is considered to influence classroom discourse and behaviour (Edwards and Westgate 1987, Adler and Adler 1994). In order to reduce this influence on the students involved in the study, students were informed of the interventions in advance. The researcher was introduced to the students and spent some time interacting with them and observing some of their sessions before the classroom interventions.

3.1.5. Questionnaires

A questionnaire is a self-report instrument used for obtaining quantitative information about variables of interest to an investigator (Wolf 1988). Questionnaires that are used to collect opinions of respondents are also known as opinionnaires (Best and Kahn 1993).

Questionnaires are used to collect data from a large number of respondents economically and quickly. They have been used to quantify students' attitudes towards various aspects of learning science (Orion and Hofstein 1991).

In this study questionnaires were used after the completion of classroom trials to identify the range of views and opinions among students regarding various aspects of the classroom activities and teaching. These views and opinions were explored further using informal conversational interviews with individual students.

Student responses to the questionnaires were clarified in this study using informal conversational interviews. This required the questionnaires to be traceable to the respondents. Students were encouraged to identify the questionnaires by name in spite of the possibility of restricting the amount of information disclosed (Cohen and Manion 1994). The data collected through the interviews about the

questionnaires were considered more useful than the data that may be lost. Students were also given the opportunity to be anonymous. All the respondents of this study were assured that their responses will not be seen by their teachers or by any staff of their school. Almost all the students involved in the study identified their questionnaires.

The questionnaires used in this study employed some questions that required written answers and some that required students to respond to semantic differential probes (Phillips 1988). The questions were explained before administering the questionnaire. Students were told that they could seek any clarification during the answering process.

3.1.6. Concept mapping

Concept mapping with informal conversational interviews was used during the first stage of the research to monitor the cognitive outcomes of the classroom interventions. Concept mapping requires the student to arrange a set of given concepts and to interlink them. A word or phrase is used at each link between two concepts to explain their relationship. The number of links made between concepts and the nature of these links give information on the quality of the conceptual framework of the student (Novak 1990).

Easily interpreted and quickly administered to a large group of students (Wallace and Mintzes 1990), concept mapping has been used as a research tool to explore meaningful learning (Heinze-Fry and Novak 1990) and to study what students know and how they organise what they know (Novak 1988, Wallace and Mintzes 1990, Roth and Roychoudhury 1992). Concept mapping has also been used as a teaching strategy (Roth and Roychoudhury 1992).

Concept mapping was completely new to the students involved in the study, and they had to be trained to draw concept maps. A brief explanation of concept maps with an example was not enough to teach many students the skills needed for drawing concept maps. Even with more help some students were unable to draw concept maps and the strategy was not used during the later stages. Concept mapping was substituted by pen and paper tests backed by informal conversational interviews.

3.1.7. Pre- and post-tests

Pen and paper tests with informal conversational interviews were used as pre- and post-tests to monitor the cognitive outcomes of classroom interventions. The tests required students to write short answers to questions designed to explore their ability to:

- recall or recognise specific concepts of electromagnetism;
- explain their understanding of these concepts; and
- apply these concepts in familiar and unfamiliar situations.

The pre- and post-tests for a particular group of students used almost identical questions. This strategy enabled easy comparison of student answers before and after the classroom interventions.

Informal conversational interviews were used to clarify the written answers of students because the tests were not standardised and hence may not accurately describe how far the participants have achieved the test objectives (Livingston 1988). The phrasing of the question may not convey the intended message to the student, and the written answer may not convey the intended message to the researcher. The interviews were used to compensate for these shortcomings and if a student was able to give a better oral answer the written answer was ignored.

3.2. STRATEGIES USED TO ENHANCE VALIDITY AND RELIABILITY

Reliability is the degree of consistency that an instrument or data-collection procedure demonstrates, and validity is the quality of a data-collection procedure that enables it to measure what it is supposed to measure (Best and Kahn 1993).

Although quantifying the reliability and validity of a qualitative study is extremely complex (Sowden and Keeves 1988) strategies were employed in this study to enhance the validity of the data collection procedures and to increase the reliability of the data. These strategies were:

- structuring the open-ended interviews that were used for exploring students' ideas about telecommunications; and

- triangulation in monitoring the process and outcomes of classroom interventions in this study.

These strategies and their use in this study are clarified below.

3.2.1. Structuring the open-ended interviews

According to Best and Kahn (1993) the validity of an interview is enhanced when it is based on a carefully designed structure, and the reliability of response may be evaluated by restating a question in a slightly different form at a later time in the interview.

The open-ended interviews used in this study were carefully structured. Each interview was divided into four parts to facilitate the flow of conversation (see section 4.3, p 67). The same predetermined basic questions were asked of all the participants in the same order during each interview. The questions were based on selected applications in telecommunications and had been modified for increased comprehension on the basis of trials with students of similar backgrounds.

The applications selected for the interview included similar items that enabled the interviewer to compare student responses to similar situations and to probe apparent inconsistencies.

In order to focus the interview, particularly the open-ended sections on the applications and the technological contexts associated with them, stimulus cards were used. Each stimulus card contained an illustration showing the application in a particular context. A key phrase highlighting the application and context that was being discussed, was printed on each stimulus card. Details are provided in Chapter Four.

3.2.2. Triangulation

Qualitative instruments were used to monitor the process and the outcomes of the classroom interventions. However, these instruments were not standardised and

their validity can not be estimated. Triangulation was used to increase the reliability of the data.

Cohen and Manion (1994) defines triangulation as the use of two or more methods of data-collection in the same study. Triangulation is used to probe more fully "the richness and complexity of human behaviour by studying it from more than one standpoint and, in so doing, by making use of both quantitative and qualitative data" (p 269).

Triangulation helps compensate for the limitations of the individual data-collection methods, and helps reduce the effect of possible researcher bias in analysing and interpreting qualitative data (Cohen and Manion 1994). Therefore, the use of two or more methods to collect data from the same setting increases the consistency of the data that is being collected.

During the classroom interventions of this study several methods were used to monitor process and outcomes. Qualitative classroom observation was used to monitor classroom process. The outcomes of the classroom interventions were monitored by concept mapping, pre- and post-tests, questionnaires, and qualitative classroom observations. The observations made by the researcher using these instruments were discussed with students and teachers using informal conversational interviews. These interviews were audio-taped and the relevant sections of the tape were transcribed and analysed.

3.3. RESEARCH DESIGN

The research study reported in this thesis was designed in four iterative phases (Sowden and Keeves 1988). The phases are considered iterative because the outcomes of the initial phases influenced the research activities, the participants, and the techniques used for collecting data in later phases. Due to the iterative nature of the study full details of the research activities and the samples are provided in individual chapters that discuss these phases in detail.

This section provides an overview of the research activities conducted during the different phases of the research, outlines the samples involved in these phases, and

sketches a picture of the social, political and economic backgrounds of the schools, teachers, and students involved in the study.

3.3.1. Outline of the research activities

The research study was conducted in four phases. Table 3.2 provides an outline of the research activities conducted during the four phases. The time-lines for the activities conducted during the phases of the study is outlined in Table 3.3.

Table 3.2: Outline of the research study

Phases	Research activity
Phase 1	a) Exploring students' ideas about telecommunications.
Phase 2	b) Designing and developing classroom interventions. c) Initial classroom trials.
Phase 3	d) Developing the teaching resource. e) More classroom trials.
Phase 4	f) Some teachers trying out the resource for the first time.

Table 3.3: Time-line of research

Time-line	Research conducted
July to December 1992	Phases 1 and 2 in New Zealand
December 1992 to March 1993	Phases 1 and 2 in the Maldives
April to December 1993	Phases 3 and 4 in New Zealand
January to April 1994	Phases 3 and 4 in the Maldives

The first phase of the research was designed to explore student interest and ideas about telecommunications—an area of technology that is common to the two cultures in which the research was conducted. A sample of senior secondary school students from New Zealand and the Maldives were interviewed. The outcomes of these interviews were used to identify contexts that were meaningful

and relevant to the students within telecommunications and to gain insights into the factors that made these contexts relevant to them.

During the second phase of the research, classroom interventions for using the contextual approach were designed based on the findings of Phase One. These interventions were used in physics classrooms to teach a topic specified by the senior secondary school physics curricula in New Zealand and in the Maldives. The reactions of the class teachers and the students, and the cognitive and affective outcomes were monitored.

Based on the outcomes of Phase Two a contextual teaching resource was developed. Phase Three researched the cognitive and affective outcomes of using the teaching resource in physics classrooms in the two countries.

Phase Four researched the difficulties teachers may face in starting to use the contextual teaching approach. The sample of students, teachers and schools are outlined next.

3.3.2. Outline of the samples for all the phases of the study

The students, the teachers, and the schools involved in the different phases of the study were selected from Hamilton in New Zealand and Malé in the Maldives. Malé is the capital of the Maldives and Hamilton is the biggest inland city in New Zealand. Table 3.4. (next page) outlines the samples for the various phases of the study. Further details of how the samples were selected are provided later in the chapters that discuss the individual phases of the study in detail.

Most secondary schools in Hamilton and Malé were either government-funded state schools that offer free schooling, or state-subsidised private schools for fee-paying students. The students were selected from a cross-section of private and government (state) schools. Grade 10 and Grade 11 in the Maldives correspond to Form 5 and Form 6 in New Zealand respectively.

The schools, students, and teachers involved in this study from the two societies have many similarities and differences which are rooted in the social, political, and economic scenarios in the two societies. These similarities and differences are

explored further in the next section to provide a background to the samples from the two societies.

Table 3.4: Outline of the participants in the study

Purpose	Participants in New Zealand	Participants in the Maldives
Exploring students' ideas about telecommunications (Phase 1)	A random sample of 32 students at Form 6 and 5 levels from 3 schools in Hamilton.	A random sample of 32 students at grade 10 and 11 levels from 4 schools in Malé.
Initial classroom trials (Phase 2)	The researcher using the intervention at a Form 6 physics class at a co-ed school in Hamilton.	A local physics teacher using the intervention at a grade 11 physics class at a co-ed school in Malé.
Second classroom trials: Student reactions to contextual teaching (Phase 3)	A local physics teacher (who observed the researcher conduct the initial intervention) using the teaching resource at a Form 6 class in Hamilton.	The researcher using the teaching resource at a Grade 10 boys-only class and a Grade 10 girls-only class in Malé. (There are no co-ed classes at Grade 10 in Malé.)
Teachers' use of the contextual teaching strategy (Phase 4)	Monitoring the local physics teacher in Phase 3 use the teaching resource in a Form 6 class in Hamilton.	Monitoring 2 local physics teachers use the teaching resource at a Grade 10 boys-only class and a Grade 10 girls-only class in Malé.

3.3.3. Background to the samples from the two societies

There were many similarities and differences between the two school systems from which the student samples were chosen. The similarities between the school systems from which the student samples were chosen include the following:

- *The medium of instruction in the classroom.* Though not the mother-tongue of Maldivian students and some New Zealand students (from non-English speaking backgrounds), English is well understood and spoken in the classrooms in which the research was conducted.

- *The science/physics curricula.* The school curricula in New Zealand and the Maldives are very different. However, the final years of the science/physics

curriculum in New Zealand and the corresponding GCE O'level and A'level physics curricula in use in the Maldives have a lot in common.

- *The teachers.* Almost all secondary school teachers and supervisory staff, both in New Zealand and in the Maldives are trained in western universities.

Some differences between the educational scenario of New Zealand and the Maldives that may influence the outcomes of this research include the following:

- *The aims of teaching and learning science.* In addition to providing the necessary trainable personnel for science-oriented vocations and research, science education in New Zealand has a general aim of scientific literacy for all students. Scientific literacy is seen to be a requirement for an informed citizenry in the modern New Zealand society which is dependent on science and technology (Ministry of Education, New Zealand 1993). To this effect, science is compulsory for all students up to the tenth year at school..

  In the Maldives education is aimed for training the personnel necessary for national development. Any student who successfully completes secondary education has the guarantee of future employment, often with further training which adds to the associated social status. Science is a compulsory subject up to the seventh year of school.

  One major obstacle to training the personnel necessary for national development is the lack of tertiary education in the Maldives. Existing vocational and occupational training institutes, which provide semi-skilled and skilled labour to some areas of the labour market, are the only gateway open locally for school-leavers. Government scholarship schemes provide the high achievers an opportunity for higher education in areas seen as relevant for national development. Self-funded overseas study is becoming common.

- *Educational opportunity.* Full secondary schooling in New Zealand is available for all interested students. In the Maldives, however, completing secondary schooling is a privilege enjoyed by a small proportion of the school-aged population. Although the Maldivian government spends a large proportion of the national budget on education, the lack of a fully-developed

educational infrastructure for secondary schooling makes it impossible to meet the public demand.

The increased output from a recently universalised primary school system is straining the secondary schools in the Maldives. As only a few secondary schools exist elsewhere, the majority of the students are migrating to the capital, Malé, for their secondary education. For students who wish to continue their secondary education beyond grade 10 levels (O' levels), this migration to Malé is essential as the secondary schools that offer A'level studies in the country are located only in Malé.

The sample from the Maldives included students from the capital and those from other areas of the country who were staying in the capital for their studies. The private school involved in this study had a larger proportion of students staying in the capital for their studies and had poorer laboratory and other teaching and learning facilities compared to the government schools.

- *The teachers.* Due to the sudden growth of secondary schooling, most secondary school teachers in the Maldives are expatriate. Relatively few overseas teachers work at schools in New Zealand. Teachers in New Zealand tend to stay at the same school for a longer time than those in the Maldives.

- *Ethnicity of the student sample.* The population of New Zealand is made up of a rich ethnic mix. The indigenous Maori population makes up about one tenth of the total population of about 3.4 million people. About four-fifths of New Zealanders are of European origin, predominantly of British origin. A minority of Pacific Island Polynesians, Chinese, Indians with immigrants from all over the world contribute to the increasing ethnic diversity of the country (Department of Statistics 1993)

  All Maldivians are considered to be of the same ethnic origin. However the student sample from the Maldives included a student from Shri Lanka—one of the neighbouring countries.

The next chapter explores and compares the interests, ideas, and prior knowledge of some students from the Maldives and from New Zealand in telecommunications.

CHAPTER FOUR

PHASE ONE: RELEVANT TECHNOLOGICAL CONTEXTS ACROSS A SOCIO-CULTURAL BOUNDARY

This chapter documents the research conducted during the first phase of the study to explore technological contexts that may be relevant to senior secondary school students in the Maldives and in New Zealand. The chapter begins with an introduction to this phase of the study, and then details the New Zealand and the Maldives samples and the data-collection procedures. After presenting the data, trends in the data are identified and compared across the two countries. The chapter concludes by summarising the implications of the outcomes of this phase on learning and teaching physics in a technological context.

4.1. INTRODUCTION TO PHASE ONE

Student interest in learning about a range of technological applications has been studied by Jones (1988) for a sample of Form 5 science students from 10 schools in three different regions of New Zealand. Based on his research Jones suggested some categories of student interest in technological applications. These categories provide guidelines for choosing technological contexts that may be relevant to the majority of the learners in science and physics classrooms in New Zealand (see section 2.3.6, p40).

This phase of the study was designed to compare student interest in an area of technology, namely telecommunications, common to the Maldives and New Zealand. This comparison was considered essential as there have been no studies conducted in the Maldives to explore student interest in and ideas about technological applications. Senior secondary school students were interviewed about their interest and ideas about some applications in telecommunications. This

information was intended for use in the second phase of the research when contextual teaching and learning interventions were developed.

4.2. SAMPLE IN PHASE ONE

Senior secondary school students from New Zealand and the Maldives were interviewed about their interest, ideas, and prior knowledge in a selection of applications in telecommunications. The Maldivian sample was selected from Grade 10 and Grade 11 of some schools in Malé, the capital of Maldives. The corresponding sample from New Zealand was selected from Form 5 and Form 6 of some schools in Hamilton, the largest inland town in New Zealand.

A stratified random sample (Best and Kahn 1993) of mixed ability students were chosen from each country. After gaining permission from the school administrators, individual teachers were requested to provide lists of students grouped into three categories: low ability students, average ability students, and high ability students. Student ability was assessed by the teachers based on the records of student performance in class tests. Some teachers chose to provide coded lists instead of a list of names due to privacy requirements. Students were selected at random from all the ability groups by the researcher[1]. Individual students were then approached by the teachers for permission.

4.2.1. The sample from New Zealand

Thirty-two students were selected from two private schools and a state school in Hamilton, New Zealand. The state school was co-educational and had a student population of over 1100. The two single-sex private schools were catering for smaller student populations. The teaching facilities were similar in all the three schools. Further characteristics of the sample are summarised in Table 4.1.

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[1] The sample was chosen to represent the following mix from each school: 25% low ability; 50% average ability; and 25% high ability.

The New Zealand students were interviewed in July and August 1992, which was towards the end of the second term of school. The students were preparing for the following secondary school attainment certificates:

- School Certificate Examination after three years of secondary education (end of Form 5),
- Sixth Form Certificate awarded on a single subject basis after the satisfactory completion of a course of one year beyond School Certificate level.

Table 4.1: Interview sample from New Zealand

school	number of students
girls only, private	5 (fifth-form science) and 5 (sixth-form physics)
boys only, private	5 (fifth-form science) and 5 (sixth-form physics)
co-educational, State	3 girls and 3 boys (fifth-form science) 3 girls and 3 boys (sixth-form physics)

Table 4.2: Interview sample from the Maldives

school	number of students
girls only, State	4 (Grade 10 physics)
boys only, State	4 (Grade 10 physics)
mixed, but boys and girls attend different sessions, private	4 girls and 4 boys (Grade 10 physics)
co-educational, State	8 girls and 8 boys (Grade 11 physics)

4.2.2. The sample from the Maldives

A random sample of 32 students were selected from 4 schools in Malé, Maldives, as shown in Table 4.2.

The students from Grade 10 levels were selected from the GCE ordinary level physics classes of three different types of schools in Malé: a boys-only State school; a girls-only State school; and a private school that held two different sessions for boys and girls. All of these schools were catering for lower secondary levels and had student populations of over 2000 each. The teaching and

learning facilities offered by the State schools in Malé were comparable to those offered by the schools in New Zealand. Teaching and learning facilities offered by the private school in Malé were comparatively less.

The Grade 11 students were selected from the first-year physics classes of a higher secondary college in town. Comprising only Grade 11 and Grade 12, and a small student population, this college was fully funded by the State. Only those who achieved a predetermined academic standard at the GCE ordinary level examinations are normally admitted to Grade 11 and Grade 12 classes in the Maldives. The Advanced Level college offered teaching and learning facilities that were comparable to those at the equivalent levels at the participant schools in Hamilton.

The interviews were conducted in the Maldives in January and February 1993. Students from the Grade 10 physics classes had completed their London GCE Ordinary level examinations and were awaiting their results. The Grade 11 physics students were half-way through their first year of the London GCE Advanced Level physics courses.

All the students were individually interviewed for about an hour each to clarify their interests and ideas about a selection of applications in telecommunications. Details of these interviews are provided next.

4.3. DATA COLLECTION IN PHASE ONE

Structured open-ended interviews were used to collect data on student interests and ideas. The merits and drawbacks of structured open-ended interviews have been discussed in Chapter 3.

The interviews were structured in that:

- the same pre-determined questions were asked of all the participants in the same order; and
- the pre-determined questions were based on a selection of applications in telecommunications.

Student responses to the pre-determined questions were clarified through open-ended clarification questions. The structure of the interview and the choice of the applications used in the interviews are discussed in the next section.

4.3.1. Applications used in the interviews

Thirteen applications from different areas of telecommunications were selected for the interviews. They included the following variety:

- applications that were common to the everyday life of the students, e.g., telephone and radio;
- applications that were not very common, e.g., cellular phones and pagers; and
- applications that students hear about, but were not necessarily from their everyday life, e.g., Instrument Landing System in aircraft and sonar on warships.

A technological application may sometimes have more than one associated technological contexts (Jones *et al* 1993). As it was intended to explore students' reactions to various technological contexts, the applications were selected to provide a wide variety of contexts, e.g. recreational technology, technology in the home and the environment, and technology for travel and transport. Furthermore, a particular technological context of each application was highlighted during the interview. The applications and the context that were highlighted for each application are shown in Table 4.3.

In the selection of applications similar items and contexts were included in order to compare student responses and to probe any apparent inconsistencies in the responses. For example, a student may not be interested in learning about satellites used in Global Positioning System but may be interested in finding about satellites used in weather forecasting. The lack of interest in the application in one context and an apparently inconsistent reaction to the same application in a different context could be explored further.

Stimulus cards were used for drawing the attention of the interviewee to the highlighted contexts. Each stimulus card consisted of a photograph or an illustration showing the particular context associated with the application. A title

related to the context was also printed on each card. The stimulus cards are shown in Appendix A1. Table 4.3 also describes them briefly.

Table 4.3. The applications, the contexts and the stimulus cards used for the interviews. *Comments in italics indicate changes made to the card titles and illustrations for use in the Maldives*

	Title of card indicating the application.	**Illustration used on card to focus on context.**
1.	We in New Zealand [*the Maldives*] are able to see the Olympic games events as they happen in Barcelona..	A man running a hurdles race and a woman performing the high jump
2.	A telephone enables us to talk to people who are far away.	A tone-type telephone
3.	Cellular phones enable 'people-on-the-move' to be contacted wherever they go.	A cellular phone
4.	Warships use special sound waves to 'look' for submarines.	Diagram of sound waves emerging from a warship and being reflected off a submarine
5.	Satellites help us to forecast weather and monitor land and sea conditions.	A weather map showing clouds and isobars
6.	A 'radio doctor' can [*A radio enables us to*] reach out to a large number of people over a large area.	A cassette-radio
7.	Radio transmitters are used to monitor migration of animals.	A photograph of a lion in a thick forest
8.	Doctors 'on call' can be alerted instantly, wherever they are, using pagers or 'bleepers'.	A pager held in a hand
9.	A baby monitor enables the parents to hear the baby wherever they are in the house.	A baby in a cot
10.	Some [*shops and*] homes are protected by electronic burglar alarms.	An bungalow-type house set in a garden *A shopping complex in town*
11.	The crew of NZL-20 in the America's Cup used satellites to find out their position accurate to a few metres. *Ships and boats at sea can use satellites to find out their position accurate to a few metres.*	Photographs of the New Zealand yacht, NZL-20 which participated in the race *A photograph of a small sailing boat used for recreational travel and fishing*
12.	Space probes give us new information about what is beyond our planet Earth.	Illustration showing the path of the Voyager 2 past some planets
13.	The Instrument Landing System can land an aircraft automatically.	A Jumbo Jet in flight

Two changes to the illustrations on the stimulus cards were made because of the following differences between New Zealand and the Maldives. Card number 10 used burglar alarms and the New Zealand card showed an expensive-looking bungalow that was advertised during the interviews as a lucky draw. As bungalows are not common in the densely-populated town of Malé, the alternative card showed a well-known shopping complex in town. Card 11 dealt with the use of satellites in navigation and the New Zealand card showed the New Zealand yacht, *NZL-20* that participated in the America's Cup. Maldives did not participate in the America's Cup and the card used in the Maldives showed a small sailing boat used for recreational travel and fishing.

Titles used on some stimulus cards were also changed to make them relevant to each country. These changes are shown in Table 4.3. The term 'radio doctors' was removed from card 6 as students in the Maldives were unfamiliar with 'radio doctors'. Even with the New Zealand sample, the term 'radio doctors' was often misinterpreted as technicians who repaired radios. This problem was addressed during the interviews by attempting to change the focus of the context to the use of radio broadcasting to reach out to people.

4.3.2. The interview

Each interview was structured into four parts: an introduction; a housekeeping section; a section on interviewing about the applications; and an ending (Osborne Freyberg 1985, Jones 1988). Appendix A2 provides the interview schedule.

The introduction was used to inform the interviewee of the purpose of the interview and to introduce the researcher. Each student was given a guarantee of confidentiality and anonymity, and informed of the possibility of changing any response at any time during the interview. Student questions about the researcher and the research study were also answered.

The 'house-keeping section' of the interview was used to collect some background information by asking questions that could be readily answered. These questions were made simple, and helped to get the conversation flowing. The interviewee was then questioned about the applications using the set of stimulus cards and a

data-sheet shown in Figure 4.1. The data-sheet listed the applications in random order with a five-position scale (Jones 1988) against each application.

Interview code:_____ Date:_____ Time:_____

How interested would you be in finding out more about:	Very interested	Interested	Slightly Interested	Not Sure	Not interested
1. how we, in New Zealand, are able to see the Olympic games events as they happen in Barcelona.					
2. how a telephone enables us to talk to people who are far away.					
3. how cellular phones enable 'people-on-the-move' to be contacted wherever they go.					
4. how war-ships use special sound waves to 'look' for submarines.					
5. how satellites help us to forecast weather and monitor land and sea conditions.					
6. how a 'radio doctor' can reach out to a large number of people over a large area.					
7. how radio transmitters are used to monitor migration of animals.					
8. how doctors 'on call' can be alerted instantly, wherever they are, using pagers or 'bleepers'.					
9. how a baby monitor enables the parents to hear the baby wherever they are in the house.					
10. how homes are protected by electronic burglar alarms.					
11. the crew of NZL-20 in the America's Cup used satellites to find out their position accurate to a few metres.					
12. how space probes give us new information about what is beyond our planet Earth.					
13. how the instrument landing system can land an aircraft automatically.					

Figure 4.1: Data-sheet for recording student interest in New Zealand (reduced by 70%) NOTE: Some titles were modified for use in the Maldives.

The stimulus cards were shown to the interviewee as numbered in data-sheet shown in Figure 4.1. For each of them the title was read out from the card, and the following questions were asked. Further questions were asked to clarify the responses to the questions.

1. How interested would you be in learning more about it?
   [At this point the student was asked to indicate his or her interest on the data-sheet]
2. Can you tell me why you are (not / not very / very) interested in this?
3. Can you tell me how you think this might work?

After all the cards have been considered the student was asked to suggest any other application in telecommunications that he or she would like to find out more about. Any suggested applications were added to the data-sheet and the above questions were repeated. At the end of the interview opportunity for amending any responses was provided.

The interviews were audio-taped and later transcribed. For ease of analysis the interviews were transcribed using a word-processor under the headings shown in Figure 4.2.

no.	Card title	How interested would you be in learning about this?	Can you tell me why you are (very/ slightly/ not) interested in this?	Can you tell me how you feel this might work?
1				
2				

Figure 4.2: Headings of the coding sheet

In the following sections the data collected from the interviews is presented and analysed.

4.4. REASONS FOR STUDENT INTEREST IN APPLICATIONS

Students were interested in the applications for a variety of reasons. These reasons often merge and inter-mingle. However, some reasons were associated more with certain applications than others. This section explores the following reasons suggested by students for their interest in the applications. A students may be interested in an application if:

- it was perceived to be useful to the student's needs (Maldives, 10 boys and 18 girls; New Zealand 16 boys and 11 girls[1]);
- it was perceived to be relevant to a societal concern (Maldives, 7 boys and 9 girls; New Zealand 4 boys and 10 girls);
- it was considered new or modern (Maldives, 10 boys and 9 girls; New Zealand 8 boys and 5 girls); or
- the student was inquisitive about how it operates (Maldives, 10 boys and 6 girls; New Zealand 11 boys and 4 girls).

In the following sections the above categories of reasons are clarified.

4.4.1. Student interest in applications that were perceived to be useful to their needs

Many (86% of all) students were interested in learning about applications that they considered relevant to their needs. These needs spanned a wide range including their social needs, their recreational needs and, their future career needs. Social needs included their need to get in touch with friends and family, to socialise with a particular group, to ensure personal safety and security, and to live up to expectations. Students were also interested in applications used by friends and family.

A Maldivian boy who came to the capital Malé for his studies from a small village was interested in learning about telephones because it enabled him to get in touch with friends quickly:

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[1] A student giving the same reason more than once was counted as one in this classification.

> Those days when we live in our islands we could not hear our friends. But now within a minute we could hear them. (MEM104: Boy, Grade 10, Maldives)

Ensuring security and safety at home made a New Zealand girl interested in finding out more about the burglar alarm:

> Because we need one. We have been burgled once. We didn't have a burglar alarm. And our next door neighbour just recently put in a burglar alarm. (H04f6: Girl, Form 6, New Zealand)

The need to live up to certain expectations made the following student interested in finding out more about cellular phones:

> Suppose somebody buys this [cellular phone] and I am supposed to know some physics. He would think that I would know about these types of things which are taught in physics. He would expect me to know how these things work. (SE101: Boy, Grade 11, Maldives)

A girl who wanted to become a medical doctor was very interested in studying about pagers because she expected to use them one day (D03f6: Form 6, New Zealand). A boy who was interested in a career in electrical engineering was interested in all the applications that had electronics in them:

> I think it has something to do with electronics. I am in engineering next year, so we have to learn electronics ...(H03f5: Boy, Form 5, New Zealand)

The need to know more about what interested some members of their families motivated the following girls to learn about some applications:

> I don't know anything about it [satellites used for weather forecasting]. But when I think about it and I think I would like to find out more about it. [In fact she indicated to be very interested in the application] Because my brother and my uncle all talk about it. They all are in *Dhiraagu* [the Maldives Telecom company] (AM101: Girl, Grade 10, Maldives)

> My dad's got a [cellular] phone actually the same as this [on the stimulus card]. So it's good to find out more about it... so that I can understand when they [her brother and dad] talk about it (D01f5: Girl, Form 5, New Zealand)

> At home my brother used to take apart the radio and try to meddle with it. I sometimes get interested in seeing [how] the voice is transferred from one place to the other. (SF105: Girl, Grade 11, Maldives)

Most (78% of all) students were interested in learning about how the Olympic games were transmitted live from Barcelona because they were sporting fans. Coverage of other events may not evoke the same interest. The following comments illustrate this view:

> Boy: [Interested in learning about how the pictures were transmitted live from Barcelona because] I see them live. We are here so far away and we are able to see the games.
> Interviewer: Had it been a wedding or some other ceremony that is being shown live would you be interested?
> Boy: No. I am interested in sports! (MEM101: Boy, Grade 10, Maldives)

4.4.2. Student interest in applications that were perceived to be relevant to a societal concern

The importance of an application to the society was often a reason for student interest (mentioned by 47% of all students). The following student was interested in the telephone because he considered it to be important to the society:

> [Students] finding out more [about telephones] will help the country to improve in our telecommunications. It might be that we may not be able to live without the telephone. Maldives is forming a lot of foreign relationships and the telephone is a must. We can live without the TV but the telephone is a must. (MAM102: Boy, Grade 10, Maldives)

Overseas relationships are important for the growing Maldivian economy that is highly dependent on tourism for foreign exchange earnings.

Students' interest in finding out about applications related to social issues or concerns that they see as being important was particularly evident in case of applications like the use of baby monitors, and the use of radio-transmitters to monitor migration of animals. A boy in New Zealand wanted to learn about the baby monitor because he related it to a social issue that he considered important:

> It's important to know about these things. You have heard about cot-deaths and that but it's important to hear what's happening with the baby and that from another room in the house. (H06f5: Boy, Form 6, New Zealand)

The issue of cot-deaths was a major focus of the New Zealand media just before the interviews.

The following Maldivian boy did not like the context in which the sonar was presented. However he was interested in learning about the application because he perceived it to be useful to Maldivians who do most of their travel by sea.

> This is war. It is something I dislike very much. War hurts people. It damages town and everything. [But I am interested in the application because] this is useful in detecting shallow water. I mean if the boat uses this to find shallow places or big rocks it helps them to go safely. I am interested in finding out how they do it because it could be used in a useful way. (MEM102, Grade 10, Maldives)

Social issues publicised by the media were often[1] mentioned by students in both countries.

4.4.3. Student interest in new and modern applications

Student interest in applications that they considered new, recent or modern was generally high (50% of all students). It was evident in case of space probes:

> Because it is so great a mystery. Like it hasn't been found out what is beyond space and we are going further and further out to see what is actually out there. I like to see what is out there. That would be interesting. (H02f5: Boy, Form 5, New Zealand)

> Because it [a space probe] gives me new information. Space information is also a very interesting thing to find out. We can compare our planet to other planets. Because of development in science and technology people have gone to the moon and have decided to live in space. This thing gives us new information about space. (MEM102: Boy, Grade 10, Maldives).

Students were most often[2] interested in space probes, cellular phones, and pagers because of their novelty. Students were also interested in these applications because of the technology associated with them.

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[1] About 50% of all students who were interested in an application because of its relevance to a social concern.

[2] About 80% of all students who were interested in the particular applications were interested in them because they were new.

4.4.4. Student interest in the technology associated with an application

Some students (48% of all) were interested in finding out about the technological aspects of an application. The following quotes are from students interested in learning about the applications in order to understand how they were used to solve the particular problems:

> [About the use of radio transmitters for detecting migration of animals] It's interesting how they can do that, but I think it's done on sound. Or I don't know how they move. It's not really really interesting like it's not amazing, but I can imagine it being done but it is still quite interesting because I don't know how they keep them out in the bush. How they can keep the radio transmitters and them out of the bush without the animals detecting it. (H01f6: Girl, Form 6, New Zealand)

> How can these things [satellites] give information about things in outer space? I want to find out. Is this a kind of a satellite? .... (SE106: Boy, Grade 11, Maldives)

While some[1] students wanted to know the general strategies used to solve a problem, some[2] were interested in the technical details of the application.

> [I am interested in finding out about telephones because] I've heard of the new fibre optic cables that are in. I'm not clear about how they work or what they do and I like finding out about things and how things work. I like pulling things apart and hearing about new things that come in. I like watching 'Beyond 2000' for its new ideas that come out. (J03f6: Boy, Form 6, New Zealand)

A few[3] students were very explicit in their interest in the technical aspects. The following comment illustrates this:

> If it was taught to you how the telephone enables us to talk to people who are far away it would be interesting. If they talked about how the message is sent and not if they broke it into like labelling the telephone, the cables and all that kind of things. More explaining how the message was sent. Not like, how this bit does this without actually going into details of actually what it does. Instead of saying what it is and what it is for actually saying what it does. (H01f5: Boy, Form 5, New Zealand)

Many (about 80% of) students interested in the technical aspects of the applications had some prior knowledge or had used the application personally. For example,

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[1] 16 students.
[2] 15 students.
[3] 2 boys in New Zealand and 3 boys and 4 girls in the Maldives.

the following girl was interested in finding out more about applications seen in her everyday life.

> "The things I have put very interested are things I can relate to like I know about bleepers and that I think it's really interesting that they can just go off when they are needed. [*Things you can relate to... could you elaborate a little on that?*] Things like that I have experienced in my life like things that I'm used to, like I'm used to having a bleeper 'cause my mother and father have one, my brother has one, so it's something that I've been brought up around so it's something I'm used to so that's something I'm used to interested in the workings of what goes around me. (H01f6: Girl, Form 6, New Zealand)

There were students interested in the technological aspects of all the applications. However, student interest in technical aspects of the Instrument Landing Systems on aircraft and cellular phones were particularly notable[1]. Students also expressed interest in learning about the TV, the telephone, the radio, the fax machine, and the computer, some of which were not in the interview list.

In both countries more boys than girls were interested in the technical aspects of the applications. About 66% of boys and 30% of the girls expressed their desire to explore the technical aspects of one or more of the applications[2]. No trends across cultures were observed.

4.4.5. Student interest and their ideas about the working of the applications.

Except for those students who expressed an interest in the technical aspects most students did not have an in-depth knowledge of the working of the applications. Rather, many students had a modular view of the operation of an application. They analysed the application into small modules, and associated some functions with these modules, without providing details. This is illustrated by the following examples:

Girl:	[About satellites are used by boats for navigation] They use radio waves and by an aerial on the boat connected to a transmitter will send a code.
Interviewer:	Where does the satellite come in?

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[1] About 75% of all students interested in the applications expressed an interest in the working of these applications

[2] 21 out of 32 boys and 10 out of 32 girls from the total sample.

Girl: It transmits the waves back to the ship.(AM101: Grade 10, Maldives)

The student was able to breakdown the application into two modules—the transmitter on the boat and the satellite. She was also able to connect these two modules by radio waves. She also attempted to provide some details of the modules, and associated an aerial to the transmitter, a code to the radio wave, and a transmitter to the satellite. A modular approach to explaining how radio transmitters detect the migration of animals was used by the following boy:

Boy: [About the use of radio transmitters to detect the migration of animals] When an animal moves that will probably send a beep or something and from the distance away, like how long it takes to travel or something like that. No. Actually yeah. It is pretty interesting to find out how they would monitor the animals moving.
Interviewer: You were telling me about the beep.
Boy: Whatever they do. I don't know how they would do it.
Interviewer: Where would the transmitter be?
Boy: I've sort of seen in documentaries and stuff they might inject it underneath the skin or on a collar or something like that. The thing that will be interesting is finding out how they can find where the animals are in a certain area. How it actually works is that they can actually locate the animals or could be done by the same thing as how they find the battleship the submarine. (H01f5: Form 5, New Zealand)

Students used ideas from their science lessons, from books and articles, or from TV programmes to generate their views of how an application works. The following student used many school physics ideas in her explanation of how space probes work:

Girl: It's got a camera attached to it. I know that much, so they can see what's on it but it gets launched off like another rocket or something and it increases speed until it reaches the solar system where gravity no longer holds it down and because of its speed it just goes on and a uniform speed around and it carries on going because it's got no gravity to hold it down and stop it and no friction to slow it down so it just carries on drifting in space and must have a speed to carry on going. But it just keeps on drifting and it's happen that past all those planets and...
Interviewer: How would this information be received by Earth?
Girl: Must send back relay messages through sound, not sound, through waves ... that can go through any hemisphere or atmosphere or anything like that.

> 'Cause it's out there in space and it must be able to travel undeterred until it gets to its actual base or otherwise it would be all the different conditions out there would change it so it must be a medium it carries on going through everything until it reaches its receiver. (H01f6: Form 6, New Zealand)

When students were unable to explain how an application worked they were asked to speculate. Most students suggested how the applications might work. The few[1] who opted out were high achievers. This was the only feature of student interest or ideas about the applications that distinguished high-achievers from the other students.

4.4.6. Reasons for lack of student interest in applications

The number of students who were not interested in the applications was small compared to those who were interested. Students were generally not interested in applications that did not have the features they considered interesting. Therefore, a students may not be interested in an application because:

- it was not perceived to be useful to the student's needs;
- it was not perceived to be relevant to a societal concern;
- it was not considered new or modern; and
- the student was not inquisitive about how it operates.

The reasons for student interest discussed above are compared across the two countries and across gender in the next section.

4.5. STUDENT INTEREST ACROSS THE TWO COUNTRIES AND GENDER

This section identifies the general trends and patterns in student interest in the applications and explores these further on the basis of the most commonly associated student reasons for their interest in the applications. Possible reasons for the trends and patterns are also suggested by the researcher.

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[1] 2 boys in New Zealand and a boy and a girl from the Maldives

In the last section it was observed that students were interested in the applications for a variety of reasons. Table 4.4 summarises the reasons that were most frequently associated with the applications.

Trends in student interest across culture and gender are identified in the next section.

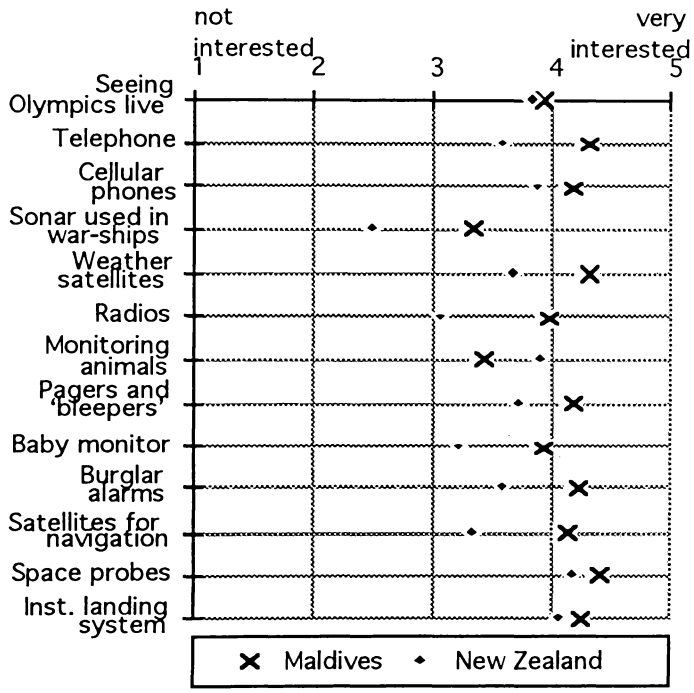
Table 4.4: Reasons that were most frequently associated with the applications

	application	Most students interested in the application because they perceive it to be: useful to their needs	relevant to an issue of concern	a remarkable technological achievement	new or modern
1	Seeing Olympics live	✓			
2	Telephone	✓			
3	Cellular phones				✓
4	Sonar used in warships[1]		See footnote		
5	Weather satellites	✓			
6	Radio	✓			
7	Monitoring animals		✓		
8	Pagers and 'bleepers'				✓
9	Baby monitor	✓	✓		
10	Burglar alarms	✓	✓		
11	Ships using satellites for navigation	✓			
12	Space probes			✓	✓
13	Inst Landing System	✓		✓	

[1] Out of the reasons suggested by those who were interested in the application no particular reason was prominent. The mean interest of the total sample was lowest (2.9) for this application. See Figure 4.3 (next page).

4.5.1. Trends in student interest

Data about student interest in the applications as recorded on the data-sheets were processed to identify possible trends. The five-point scale used was assigned ratings from 1 to 5. One was assigned to the not-interested end of the scale and 5 was assigned to the very-interested end. The mean score given to each application by all the students in each country was calculated. Similarly the interests of girls and boys in each country were compared. Numerical and statistical details are provided in Appendix A3. Figure 4.3 compares the mean interest of students in the Maldives and in New Zealand in learning more about the applications. The significance of the difference between the means of the two samples for each application was calculated using a *t-test.*



The differences in interest indicated are not significant at 0.05 level

Figure 4.3: Comparison of student interest between the two samples in New Zealand and in the Maldives

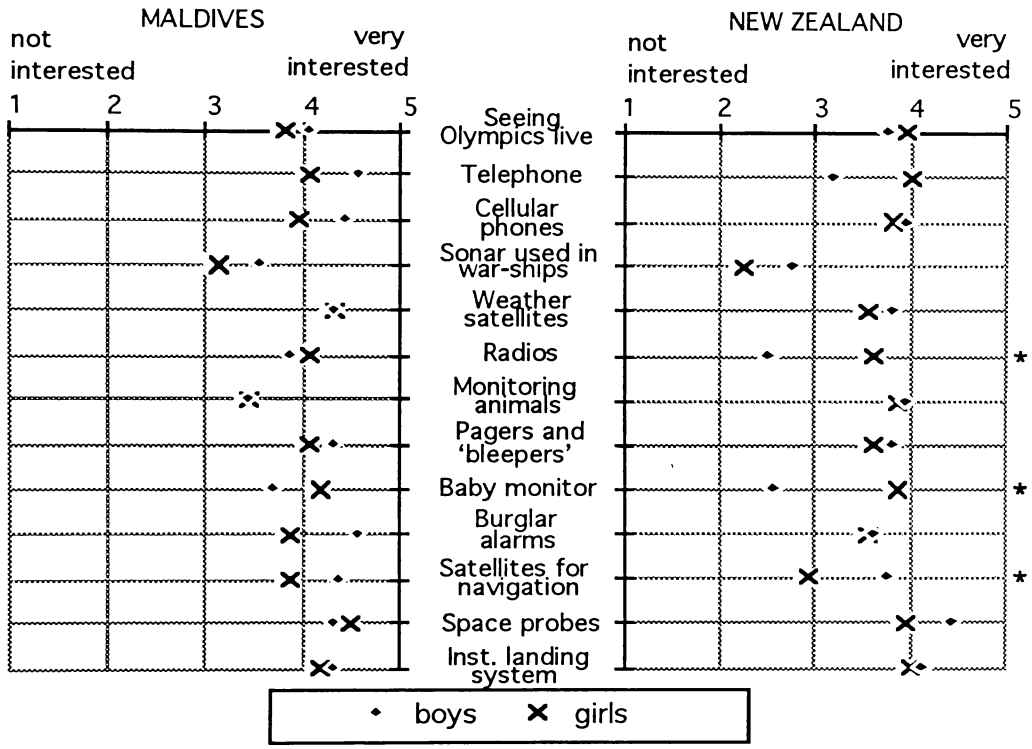
The following trends can be seen from Figure 4.3:

- Students interest in the applications was relatively[1] higher in the Maldives than in New Zealand.

[1] Mean interest level for all the applications in New Zealand was 3.6 (corresponding to a half-way position between slightly interested and interested on the interest scale) while for the Maldives it was 4 (which corresponds to the interested position on the scale). This difference was significant at 0.05 level

- Student interest in the live telecasting of the Olympics, cellular phones, pagers, space probes and the Instrument Landing System was high in both samples.
- In both samples, there were relatively few students interested in the use of sonar in warships.

These observations can also be seen in Figure 4.4 comparing the interest of girls and boys in the two samples.



* The differences in interest indicated are significant at 0.025 level.
The differences in the Maldives sample are not significant at 0.05 level.

Figure 4.4: Comparison of student interest between boys and girls in the two samples

The following observations may be made from the Figure 4.4:

- Girls were more interested in baby monitors and radios than boys in New Zealand. There were no significant differences in the Maldives.
- Boys were more interested in the use of satellites in navigation in New Zealand. There was no significant difference in the Maldives.
- Girls appeared to be more interested in learning about the telephone in New Zealand than boys. However, boys appeared more interested in learning about the telephone in the Maldives.

- The difference between the interest of girls and boys in the New Zealand sample appeared greater than that in the Maldives sample.

4.5.2. Possible reasons for the trends in student interest

The trends in student interest may be explained in terms of the students' reasons for their interest in individual applications, and the socio-cultural differences between the two countries. As identified earlier (in Section 4.4) a student may be interested in an application if:

- it was perceived to be useful to the student's needs;
- it was perceived to be relevant to a societal concern;
- it was considered new or modern; or
- the student was inquisitive about how it operates.

Most of the applications have become widely available in the Maldives during the last decade. Hence, they were relatively new to the everyday life of many students who were interviewed. The novelty of the applications may be responsible for the higher interest. The possibility that the novelty of an application increases student interest is supported by the higher interest in the more recent applications like cell phones, pagers, space probes, and Instrument Landing Systems in both samples. Applications like telephones, weather forecasting, and burglar alarms have been used in New Zealand longer than in the Maldives, and student interests were generally lower for these applications in New Zealand.

In spite of its novelty, fewer students from the Maldives were interested in the use of radio transmitters for monitoring animals. Students indicated that there were no animals that needed monitoring in the Maldives. For them the application was neither useful nor relevant to the society. Land-based wild-life is almost non-existent in the small islands of the Maldives. The following comment makes this very clear:

> It is quite an interesting topic had it been another country. But there aren't a lot of animals to migrate here. So this sort of thing will not be very useful. (MA102: Boy, Grade 10, Maldives)

Many students in the Maldives found the use of satellites for navigation to be interesting because of its relevance to their needs. Most internal travel within the

islands nation of Maldives is by sea, and the importance of accurate navigational aids were mentioned by many students. In New Zealand students were interested in the application because of the sporting context associated with it. Furthermore, the New Zealand yacht *NZL-20* that participated in the America's Cup received considerable media attention just before the interviews.

Fewer students from New Zealand were interested in baby monitors. The increase in interest in the Maldives was due to the greater number of boys interested in the application together with girls. The interest of boys in baby monitors was significantly smaller than that of girls in New Zealand. The care of babies was mentioned by more boys in the Maldives than in New Zealand. This may be because of the social practice of extended families living under the same roof in the Maldives.

Students appeared to be generally interested in those issues that were publicised by the media. Conservation of wild-life is a much-publicised issue in New Zealand, but receives much less publicity in the Maldives. More than half of the students interviewed in New Zealand expressed an interest in the conservation of wild-life, and many students made their love for animals very clear. Although some students from the sample in Maldives expressed their concern for conservation of wild-life, many were interested in the application for other reasons.

The apparent influence of media on student interest may be used to explain some differences in student interest across the two samples. Many students in both samples expressed a dislike towards learning about sonar used in warships, because of the association with war. "It is war [and] war is not humane and civil" (MAM104: Grade 10) declared a Maldivian boy. However, several students in the Maldives expressed a liking towards the application because it was something to do with the military and hence drove the general interest level higher in the Maldives. During the interviews in the Maldives there were radio and TV programmes targeting school-levers for recruitment into the military forces.

The issue of cot-deaths received a lot of publicity in New Zealand just before the interviews. This issue was raised by several students in New Zealand as their reason for being interested in baby monitors. Cot-deaths were not a social concern in the Maldives.

In addition to informing students about the current concerns of the society, the media appeared to inform students of developments that were significant and topical. For example, the interest of students in applications like space probes and satellites that were uncommon to their everyday life were often related to television programmes that they have seen.

4.6. IMPLICATIONS FOR THE USE OF TECHNOLOGICAL CONTEXT IN CONTEXTUAL TEACHING OF PHYSICS

The reasons suggested by students for their interest in the applications in this study were similar to the outcomes of the study of student interest in a wide range of technological applications in New Zealand by Jones (1988). The compatibility of the outcomes indicate a consistency in student interest in technological applications at senior secondary school levels in New Zealand.

The categories of student interest were similar across the student samples from New Zealand and the Maldives. Students were interested in applications that they considered to be related to their recreational and other needs. Student interest in new and modern applications was high in both the samples. Students were also interested in the technical aspects of the applications. This indicated that in spite of socio-political and economic differences between the countries student interest was similar in a common area of technology.

No significant gender differences were noted in student interest in the Maldives sample. However as noted by Jones (1988) boys appeared to be more interested in technical contexts in the two countries.

Differences in student interest between the samples were also seen. This difference was notable for applications related to issues that received media publicity. Students appeared to be interested in the social debates specific to the country, so that applications related to issues of concern to the society were more popular with students from that country.

Student interest in a given technological context may be affected by more than one reason. These reasons sometimes enhance the interest of the student in learning

about an application. For example a student may find an application to be interesting because it is modern and also because it is related to his/her recreational needs. Sometimes these reasons may work against each other. For example a student who found the sonar interesting for its usefulness to travel may not want to learn about the application because it is used in warships. By considering the categories of student interest that conflict and support each other, technological contexts relevant to the majority of the learners in senior secondary school physics may be chosen by a teacher.

While a single context may not be relevant to all the students in a classroom, it can be argued that the use of several inter-related contexts will be more likely to interest all the students.

Students who were interested in the technical aspects of the applications had some prior information about these aspects. Furthermore when asked how an application works students with some background information about the application readily speculated on how the application might work. This may suggest that if opportunities for learners to explore the technical aspects of a context are provided in the teaching and learning process, an interest in the technical aspects may be developed in most of the students. Student interest in the technical aspects of the applications is useful in the teaching of physics as most of the physics concepts are associated with the technical aspects.

The above analysis assisted in developing classroom interventions for teaching senior secondary level physics during the second phase of the research study. The next chapter reports on the development of these classroom interventions and their use in contextual teaching during Phase Two of the research study.

CHAPTER FIVE

PHASE TWO: INITIAL CLASSROOM INTERVENTIONS

This chapter documents the development, use, and outcomes of the initial classroom interventions. The chapter begins with an introduction to this phase of the study, and then describes the process of designing the classroom interventions for use in the two countries. The New Zealand and the Maldives samples and the data-collection procedures are described, and the process and outcomes of the interventions are documented. Trends in the outcomes are identified and compared across the two countries, and the chapter concludes with a discussion of the implications of the outcomes on the rest of the study .

5.1. INTRODUCTION TO PHASE TWO

The first phase of the study explored student interest and ideas about an area of technology common to the Maldives and New Zealand, and clarified students' reasons for their interest in technological applications. These reasons provided insights into technological contexts students in the two samples considered relevant to them.

During Phase Two of the study the outcomes of Phase One were used as a framework for designing classroom interventions using the contextual approach to teaching. An area of the senior secondary school physics curriculum common to the two countries was identified and the interventions were trialed in physics classrooms in the two countries. The process and outcomes of the interventions were monitored.

Phase Two of the study constitutes a pilot study for further classroom interventions in Phase Three and Phase Four of the study.

5.2. DESIGNING THE CLASSROOM INTERVENTIONS

Speculations about the use of technological contexts in contextual teaching and learning were made based on the research findings reported in Chapter Four. These speculations are as follows:

- As a given technological context may not be relevant to all the students in a classroom, several inter-related contexts need to be used in contextual teaching and learning.
- When opportunities for learners to engage with the technical aspects of a context are provided early in the teaching and learning process, interest in the technical aspects may be developed in most students.
- Technological contexts relevant to the majority of the learners in senior secondary school physics may be chosen by considering the categories of student interest that conflict and support each other.
- In spite of socio-political and economic differences between New Zealand and the Maldives student interest in the area of telecommunications was similar in the two countries.

Based on these assumptions classroom interventions were designed to teach a common curriculum area in senior secondary physics in New Zealand and in the Maldives.

5.2.1. Choosing the common curriculum area

The curriculum area was decided mainly by the timing of the classroom interventions. Sixth-form electromagnetism was scheduled to be taught in the school in New Zealand during the period allocated for the classroom intervention. The choice of electromagnetism was made possible by the physics teacher and the administrators of the school in the Maldives agreeing to re-schedule their teaching sequence.

The electromagnetism curricula for Form 6 in New Zealand and the corresponding Grade 11 in the Maldives (Appendix B1) require students to learn the following concepts:

- magnetic fields and magnetic field lines;

- magnetic field due to current in a wire;
- force on a current carrying wire in a magnetic field; and
- laws of electromagnetic induction.

5.2.2. Learning outcomes targeted by the interventions

The interventions were designed to meet the syllabus requirements for electromagnetism in the two school systems. The learning outcomes targeted by the interventions are stated below[1].

By the end of the interventions students can:

1) describe the influences of some everyday physics-based technologies on their everyday lives;
2) explain how developments in some physics-based technologies have changed society;
3) develop and use the principles, concepts and models of electromagnetism to explain appropriate physical phenomena;
4) carry out practical investigations to explore some relationships in electromagnetism; and
5) describe and explain how the principles of electromagnetism are used in applications.

These learning outcomes are based on the curriculum requirements of Form 6 physics in New Zealand and Grade 11 physics in the Maldives (see Appendix B1). However, the depth of treatment required in the two countries differs considerably.

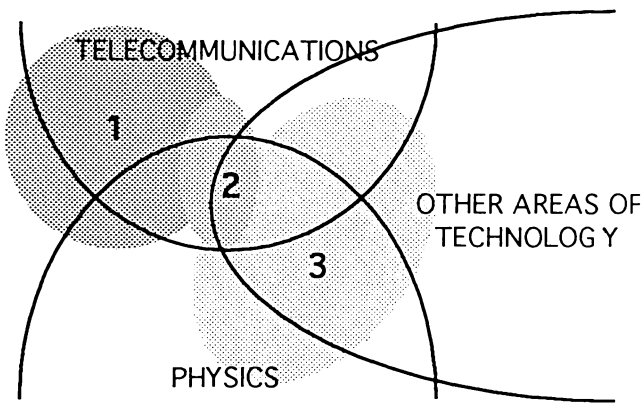
The following sections describe the structure of the interventions designed to target these outcomes.

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[1] The outcomes are stated using the language and the format used in the draft document, *Physics in the New Zealand Curriculum,* (Ministry of Education, NZ, 1993b).

5.2.3. Choosing technological contexts for the interventions

An introductory 'macrocontext' and several 'microcontexts' were used to design the classroom interventions for teaching electromagnetism (The Cognition and Technology Group at Vanderbilt 1990). 'Sound transfer in telecommunications' was chosen as the introductory macrocontext. It is considered a *macro*context because it has several microcontexts embedded in it. 'Everyday use of some applications in the transfer of sound' was used as the initial microcontext. Microcontexts outside the domain of telecommunications were used later. These contexts and their relationships are shown in Figure 5.1.



KEY

1	*The macrocontext:*	transfer of sound in telecommunications and its implications for everyday life
2	*The initial microcontext:*	everyday use of some applications for the transfer of sound
3	*Other microcontexts:*	other applications that use electromagnetism

Figure 5.1: Contexts used during the interventions

The initial microcontext was expected to lead to the moving coil speaker and the dynamic microphone that make use of electromagnetism. A speaker and a microphone are essential elements in any device used in telecommunications for

the transfer of sound and the choice of the specific applications was left for the students and the teacher.

The concepts of electromagnetism that were introduced using the initial microcontext were revisited by engaging the students with additional microcontexts outside the area of telecommunications. These microcontexts were decided by the teachers and the students.

The combination of the introductory macrocontext, initial microcontexts, and the other microcontexts were expected to encompass a variety of everyday contexts relevant to most, if not all, students in physics classes at senior secondary school levels in the Maldives and New Zealand. The organisation of these contexts into a teaching unit is discussed next.

5.2.4. The teaching unit

The three-phase framework proposed by Cosgrove and Osborne (1985) was used for designing the teaching unit for the interventions. The framework, which includes a focus phase, a challenge phase, and an application phase, was used to compile sub-units for the teaching unit.

The focus phase of each sub-unit was used to engage students with the relevant contexts through classroom discussions and experimentation. The challenge phase was used to engage learners with specific aspects of the contexts. The application phase was used to formally direct students' attention to the physics concepts and to apply them, particularly in other contexts.

Classroom activities were outlined for the sub-units which were arranged into a unit of work as shown in Figure 5.2. The outline of classroom activities[1] developed for use in New Zealand is shown in Table 5.1. The same outline of activities was used in the Maldives with slight changes. As the Grade 11 physics syllabuses required a more in-depth treatment of the physics concepts Sub-unit 2 and Sub-unit 3 were modified for use in the Maldives as shown in Table 5.2.

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[1] These activities may be further clarified by referring to Appendix C1 which contains the teaching resource developed for use in the Phase Three of the study. The resource was based on the outcomes of this phase of the study.

In subsequent sections the use of the classroom activities and their outcomes are documented. The samples from the two countries and the data-collection procedures are described next.

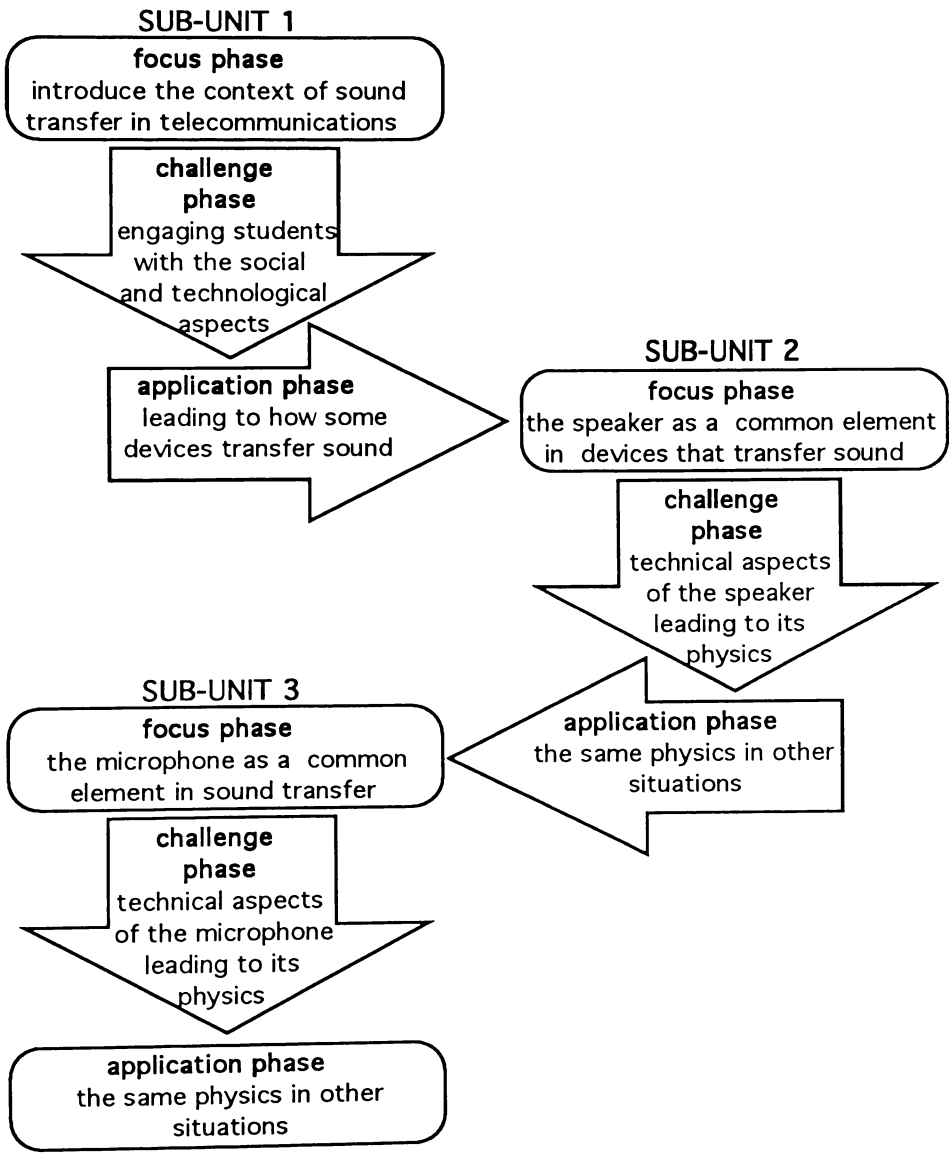


Figure 5.2: Structure of the unit of work

Table 5.1: Outline of activities developed for use in New Zealand.

Sub-units	Theme	Activity
1a Introduction: Sound transfer in telecom-munications	• Impact of Telecommunications on society. **(1 session)**	• Making a list of applications in telecommunications used in everyday life. • Classroom discussions about how some of these applications have changed our way of living (e.g., life before and after the telephone, how a baby monitor may change the lifestyle of a parent).
1b Some devices that transfer sound	• How do they work? • The physics behind the devices. **Note**: some of these devices must use speakers and microphones, e.g., baby monitors, walkie-talkies, telephones, ... **(1 session)**	• Looking at (and if possible opening up) some devices and identifying some main components used in them. • Discussing in groups to produce block diagrams showing how the devices may work. • Classroom discussions about the block diagrams. • Demonstrating the conversion of sound to electric signals and back to sound by microphones and speakers respectively.
2a Converting signals into sound: The speaker	• What are speakers made of? • Building a speaker in the laboratory. **(1 session)**	• Opening up a speaker and identifying the various parts. • Designing and building a speaker from everyday material. • Testing the speakers.
2b Physics of the speaker **2c** Exercises	• Let us talk about how a speaker works. • How do scientists and engineers describe it? **(4 sessions)**	• Class discussion on students' ideas about how a speaker works. (Directing the student's attention to the need for a generally understood terminology to describe the physics). • Permanent magnets and magnetic domains. • Magnetic fields and field lines. • Magnetic fields due to steady currents in straight wires and solenoids. • Force on a current-carrying conductor in a magnetic field. • Some exercises for studying electromagnetism in other applications.
3a Converting sound into signals: The microphone **3b** Physics of the microphone **3c** Exercises	• What are microphones made of? • Let us talk about how they work. • How do scientists and engineers describe them? **(3 sessions)**	• Class discussion on students' ideas about how a microphone works. Direct the student's attention to the need for a generally understood terminology to describe the physics. • Electromagnetic induction. • Faraday's and Lenz's laws. • Some exercises for studying the above concepts in other applications.

Table 5.2: Sub-units 2 and 3 modified for use in the Maldives.

Sub-units	Theme	Activity
2b Physics of the speaker **2c** Exercises	• Let us talk about how a speaker works. • How do scientists and engineers describe it? **(6 sessions)**	• Class discussion on students' ideas about how a speaker works. (Directing the student's attention to the need for a generally understood terminology to describe the physics). • Permanent magnets and magnetic domains. • Magnetic fields and field lines. • Magnetic fields due to steady currents in straight wires and solenoids • Force on a current-carrying conductor in a magnetic field. • Some exercises that look at electromagnetism in other applications. • The exercises must include the derivation of BQV from BI/.
3a Converting sound into signals: The microphone **3b** Physics of the microphone **3c** Exercises	• What are microphones made of? • Let us talk about how they work. • How do scientists and engineers describe them? **(5 sessions)**	• Class discussion on students' ideas about how a microphone works. Direct the student's attention to the need for a generally understood terminology to describe the physics. • Magnetic flux and flux linkage. • Electromagnetic induction. • Faraday's and Lenz's laws. • Some exercises that look at the above concepts in other applications. • Some applications that look at r.m.s. and peak values for sinusoidal signals.

5.3. SAMPLES IN PHASE TWO

Schools at Form 6 levels in New Zealand and the corresponding Grade 11 levels in the Maldives were approached. With the permission of the administrators informal communications were made with a physics teacher from each country. Two teachers who readily expressed interest were selected for the interventions. The teachers, in consultation with their students, heads of the departments, and the school administrations decided the classes to be used for the research.

The intervention was conducted first in Hamilton, New Zealand. The school had a student population of over 1100 with classes Form 3 to Form 7. The trial class

was one of three Form 6 physics classes at the school. The student sample consisted of 5 girls and 10 boys. The intervention was conducted by the researcher with the class teacher observing all the sessions. The male physics teacher had a university degree in mechanical engineering, and teaching qualifications. He was a senior teacher at the school.

The intervention was conducted next in Malé, Maldives. The school consisted only of Grade 11 and Grade 12, and the trial class was one of three Grade 11 physics classes. The student sample consisted of 5 girls and 10 boys. The physics teacher who normally taught the class conducted the intervention. The teacher was a Maldivian woman with a university degree in pure physics and teaching qualifications. Her initial training was in primary teaching and it was her second year in secondary teaching. The researcher observed all the sessions.

The intervention in New Zealand began on 12 October 1992, immediately after a major test in physics contributing to the Sixth Form Certificate. The intervention proceeded for 10 one-hour sessions until 20 October 1992. Two weeks later all sixth-form physics students had a unit test which contributed to their Sixth Form Certificate marks in physics.

The intervention in the Maldives proceeded from 1 February 1993 for 14 one-hour sessions until the end of the month. The intervention was conducted immediately after the mid-academic year holidays for the school[1]. The school closed immediately after the intervention for the annual Muslim fasting season of 'Ramadan'. The last session of the intervention was attended only by 5 girls and 5 boys. After the month-long season of Ramadan the school re-opened and a unit test was conducted for all Grade 11 physics classes.

5.4. DATA-COLLECTION IN PHASE TWO

As stated in Chapter 3 several strategies were employed for collecting data about the process and outcomes of the interventions. Table 5.3 summarises the use of these strategies during the interventions.

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[1] The academic year of the particular school started from June.

Table 5.3: The use of data-collection instruments with the two samples

instrument	New Zealand		Maldives	
	used	sample size	used	sample size
concept-mapping	before unit[1]	15	-	-
with informal conversational interviews	after unit	15	-	-
pre-and post-tests	-	-	before unit	15
with informal conversational interviews	-	-	after unit	10
observation of classroom sessions	during all sessions	15 (average[2])	during all sessions	15 (average)
questionnaire with informal conversational interviews	2 weeks after unit, and before unit test	15	last day of unit, and 2 days before post-tests	15
unit test conducted by the school	3 weeks after unit	15	a month after the unit	15

5.4.1. Instruments used for monitoring learning

Concept mapping together with informal conversational interviews were used before and after the intervention in New Zealand (Section 3.1.6). This was expected to provide information about students' prior knowledge before the intervention, and their learning during the intervention. The worksheet used to introduce the concept-mapping activity before the interventions is in Appendix B2. A similar worksheet was used to introduce the concept-mapping activity after the interventions.

For reasons that will be explained later, concept mapping was substituted by pen and paper pre- and post-tests in the Maldives. The same questions were used in both tests, and the question paper used as the pre-test is in Appendix B3. Each test required students to write short answers to four questions designed to explore their ability to recall or recognise specific concepts of electromagnetism, explain these concepts, and apply them in some situations. The first two questions, based on past examination papers at Grade 10 levels, were structured and guided. The

[1] The term unit indicates the unit of work covered during the classroom interventions.
[2] The term 'average' indicates that some students were absent for some sessions.

last two questions were unstructured and required the students to explain the working of some devices.

Responses to the pre- and post-tests were clarified through informal conversational interviews with individual students. If a student provided a better answer in the interview the written answer was neglected and the oral answer was considered in marking the test. Student learning indicated by the concept-mapping exercises and the pre- and post-tests was also compared to the results of the unit test, given to the whole of the Form 6 and the Grade 11 after the completion of the unit on electromagnetism, and to their average performance in class tests and assignments.

5.4.2. Instruments used for monitoring affective outcomes

A questionnaire used after the completion of the classroom trials explored opinions of students about the classroom activities and teaching (Appendix B5). These opinions were explored further through informal conversational interviews.

The questionnaire required students to write answers and to respond to ten semantic differential probes (Phillips 1988). Each probe used a pair of words or phrases that required students to compare aspects of the classroom activities during the unit on electromagnetism to other units of work. Each pair was separated by a seven-point scale for students to mark their responses. The questions and semantic differential probes were explained before administering the questionnaire, and opportunities were provided for further clarification during the answering process.

5.4.3. Instruments used for monitoring teacher reactions

Although the researcher suggested the framework of the interventions the classroom activities evolved through a process of negotiation with the teachers. Several informal conversational interviews were held with the teachers before the interventions. The class teachers were interviewed after almost every classroom session. Records of the classroom proceedings and the researcher's reactions were used during the informal conversational interviews with the teachers.

All interviews were audio-taped, transcribed and reviewed by the teachers. Few sections of the transcripts that teachers found inappropriate for use in the study were edited out.

5.5. TEACHERS' REACTIONS TO THE INTERVENTIONS

As mentioned earlier, the researcher taught the trial class in New Zealand with the class teacher observing all the sessions. In the Maldives the class teacher taught the trial class and the researcher observed all the sessions. All the sessions were audio-taped and transcribed.

The activities used in the classroom sessions were mainly teacher-moderated classroom discussions and group work. In some sessions the teachers made use of the contexts more than in others. Based on the use of contexts by the teachers, the sessions may be divided into three different types:

- *Context-only sessions* where the contexts were explored without much emphasis on the physics aspects of it. The focus phases of all sub-units were generally context-only sessions.
- *Physics-only sessions* where the physics concepts were discussed without much emphasis on the contexts. Some application phases of the Sub-unit 2 and Sub-unit 3 were physics-only sessions.
- *Mixed mode sessions* where aspects of physics and the contexts were explored with frequent cross reference. The challenge phases of all sub-units were mostly mixed-mode sessions.

The teachers noted that the combination of context-based, physics-only and mixed-mode sessions were essential to achieving the learning outcomes. However, they felt that the activities during the application phase could have been made more interactive by making the sessions more context-based.

5.5.1. Some difficulties in using the contextual approach

The teacher in the Maldives noted that she was unable to make some sessions as student-centred and context-based as she wanted to. According to her this was due to some closely related reasons including the following:

- an initial reluctance on the part of the students to participate in the classroom discussions;
- her previous style of teaching that she was used to; and
- her doubts about how students may respond to the new style of teaching.

She speculated that the initial reluctance on the part of some students to discuss their own ideas and to participate in the sessions may be the result of her previous method of teaching. She clarified her view as follows:

> In a way I think it's the previous teaching method that's making them reluctant. In this class they have been used to me teaching... They have not seen me in that role as being a listener rather that being the contributor. So they are not prepared to come out to me.

She did not observe the initial reluctance from the students of a parallel class she started teaching that term. She said:

> The other class have not seen me as that [the contributor] or me being the talker... [They] have had a very ... let us say ... out-of-control teacher. The teacher did not have a tight control on the class. The children will talk as much as they like and whether the teacher talks or not. So that class is used to arguing with the teacher in a way. So that class comes up with more ideas than this one. This one is not prepared to come out with their ideas to me. That's I think from previous experiences of the class. The other class haven't had the experience of me....

Context-based teaching often required her to be the "listener" rather than the "contributor". She said:

> And it's hard for me also to sit back and let them do the teaching. Let them teach each other in a way.

The teacher in the Maldives initially felt that students would be reluctant to engage with the contexts because they would consider classroom discussions and activities about the contexts to be out of their syllabus. She said:

> They will be thinking that this is not in the syllabus. It's going to be a bit of a motivation problem for them. They are too used to

> working for the syllabus. For some of them they will be thinking that this is a waste of time.

Her initial fears about how students may respond to the new style of teaching turned out to be unwarranted.

5.5.2. Comments about student motivation and enjoyment

Throughout the intervention in New Zealand and the Maldives the teachers felt that students were enjoying the new style of teaching and learning more than other physics classes. The teachers noted a marked increase in the motivation of weaker students. According to the teacher in the Maldives her students would normally rush out of the classroom at the end of a session. After most context-based sessions she noted many students to stay back for further discussion and made the following comment:

> Students were more interested. I saw that when it was time to leave they were not that keen to jump and go as they normally are. It took them a while to get settled and to leave. It showed that they were keen. And then it was very different from the classes I normally have; more interaction between the students and me rather than me giving everything to them.

The New Zealand teacher wanted to try out the intervention in the following year in his physics classes. This was particularly because of the increased student motivation:

> I would say that this particular method has been a lot better for the weaker students and the less motivated students than other topics taught by the traditional methods. I am certainly convinced of that.... I am interested in this method of teaching, not so much for the actual test exam results we get, but in terms of motivating the kids and generating interest in the subject and topics. I think you have been valuable for that.

5.5.3. Comments about student interest in the technical aspects of the context

Both teachers felt that more students were interested in the technical aspects of the speaker after building the model. Describing how building the speaker engaged

students with the technical aspects, the New Zealand teacher made the following comment:

> I was impressed that a very very simple form of technology actually was demonstrated to work very quickly. When it [the model speaker] came to work the kids actually realised that just with a coil wire and a cardboard and a very weak bar magnet they could actually turn an electric current into sound. I think it was surprising for me that it actually worked so well. It's so easy and it's very crude. They also learnt a few other things like a number of them forgot that the wire might have an insulating coat on it, you know. The need to scratch the wire and check that. Some of them forgot to put a decent resistance in the circuit, the current's too high and you know all these sorts of things happen normally but it is good that they got to practice with using this sort of equipment. And then moving on from that to testing with more sophisticated supply like the signal generator—they are able to vary the frequency so that they can hear it and get different sounds— is good. They heard sounds using microphones. They were convinced that their speakers worked.

Similar comments were made by the teacher in the Maldives about the increased student interest in the technical aspects of the speaker after building the model. According to her the prior investigations gave the students a reason for learning about the physics of the speaker.

Both teachers felt that using the contexts gave the students a reason to study the concepts of electromagnetism other than for passing examinations, and intrinsically motivated students to study the physics associated with the contexts. The teacher in the Maldives felt that exploring the contexts before teaching the theory "forced" some students to "actively think". The New Zealand teacher considered the contextual strategy to be more effective in motivating the students to engage with the physics aspects than his usual method of teaching. According to him the students picked up a lot of information about the physics aspects without any formal teaching and hence made the teaching more effective and interesting. He further explained this view by referring to the session exploring student understanding of the physics of the model speakers they have built:

> The student's seem to have picked up a lot of information about magnetic fields and how they react together from their own models and without having had very much straight teaching about it and certainly they seem a lot more interested in the topic and in finding about it than the other class where I am teaching in a more formal way. So I think it's such a good way of getting them interested in and getting them into a stage where you need to learn some school

> type physics or book type physics, rules and so on because really they are coming up with these problems themselves. I think it's getting them much more reason to learn the more formal aspects of it which is good rather than saying these are the rules, you have got to learn because we'll be tested in them.

5.5.4. Comments about student learning

According to the teachers some classroom behaviours that they consider to indicate student learning were more frequently observed during the interventions than in other sessions. These behaviours include:

- student-initiated questioning about applications of different physics concepts;
- student-initiated questioning about different physics ideas; and
- students exploring certain aspects of physics in greater depth.

Students were noted by the class teacher to ask more in-depth questions during the interventions than in other sessions. More students were noted to ask questions relating to the physics concepts and their applications. Some of these questions even challenged the teachers' understanding. The teacher in the Maldives explained this by referring to an incident when she was unable to answer a question, that initially appeared trivial to her, to the student's satisfaction. She noted that it was the first time she had ever thought about the particular question in such depth and said:

> It's the lack of understanding of the topic. It's like when you are at college you get taught something and it just stays in the mind. OK the forces act this way, that way. You never think of like having to explain to someone this is how it works to a newcomer who isn't used to it.

In teaching the class in New Zealand the researcher faced similar situations. For example, a couple of students insisted on finding out why electrons in motion produce magnetic fields and were unhappy with the answer provided by the researcher. The researcher realised that the students were asking a question that was neither answered by school physics text books nor by the university physics courses taken by the researcher in his under graduate study in pure physics. However, once the student's questions were answered after some background reading by the researcher, they, as well as the researcher, understood the unity of the several rules used in electromagnetism to find out the direction of the magnetic

field near current-carrying conductors of different shapes, and the rules that provide the direction of the force on a current-carrying conductor in a magnetic field. A few students[1] were able to find out the directions of these forces using only first principles and without using the standard rules.

The teachers felt that the style of teaching used during the interventions was most effective for the weaker students in the class. The students who achieved high marks in the class continued to perform well and enjoyed the classes. The New Zealand teacher made the following comment illustrating this view:

> I don't know that the majority of those students have gained marks or gained understanding particularly different to what they would have done the normal way except that a particular girl was very noticeable because she is quite weak in terms of science ability and certainly she has obviously got a lot more out of this topic than she does most of the others. The rest of them, the marks certainly are as good as, if not better.... Oh, there is another student who has done very well compared to one other test. G[2]. So A and G who are weaker students in test conditions have done much better.

The exam that was being referred to was the common sixth-form test on electromagnetism. A and G who were considered very weak students scored their highest ever marks in physics in the test (see Figure 5.6, Section 5.6.2).

5.6. COGNITIVE OUTCOMES OF THE INTERVENTIONS

The data collected by monitoring the cognitive outcomes of the interventions are discussed next.

5.6.1. Cognitive outcomes indicated by concept-mapping in New Zealand

No particular pattern in cognitive outcomes was generated by the concept mapping exercises before and after the classroom interventions. The interviews about the concept maps revealed that many students did not have a clear idea of how to

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[1] Two boys in New Zealand and a girl in the Maldives.
[2] Name of student abbreviated for anonymity.

construct concept maps. Hence, most concept maps did not reflect the students' understanding of the concepts.

Concept mapping was completely new to the students involved in the study in New Zealand. The explanation of concept maps was not enough to provide the skills needed for drawing them, and the strategy was substituted by pre- and post-tests during the intervention in the Maldives.

5.6.2. Cognitive outcomes indicated by pre-test, post-test, and unit tests

The pre-tests were administered for all the 15 students in the Maldivian sample. Four students were absent from the post-tests. A partially-completed answer-script from a boy was not included in the analysis. Figure 5.3a and Figure 5.3b show the performances of the remaining students in their pre- and post-tests. In these figures students are arranged according to their average performance in class tests and assignments. Detailed marks are provided in Appendix B4.

The charts in Figure 5.3 indicate the performance of students in the pre-test to reflect their average performance in the class. However, this pattern was not seen in the post-tests. A boy, m5, who performed poorly in class tests and in the pre-test made notable improvement in the post-tests. Similar improvement was made by the girl, f5, who normally did not perform very well in class tests.

The informal conversational interviews, conducted after each test with individual students, attempted to clarify their written answers. Students had no difficulties understanding the questions, and their written answers appeared to reflect their understanding of physics. However, m3, a boy in the Maldives, misunderstood a question in the pre-test, and the answer he suggested during the interview was used instead of his written answer. Students who performed poorly in the pre-test appeared more confident in defending their answers in the post-test.

The increased confidence of those who performed poorly in the pre-test could be due to their increased familiarity with the researcher. The enhanced achievement of the students in general could also be due to the post- and pre-tests being

identical. The tests did not examine some of the new concepts that were introduced during the teaching.

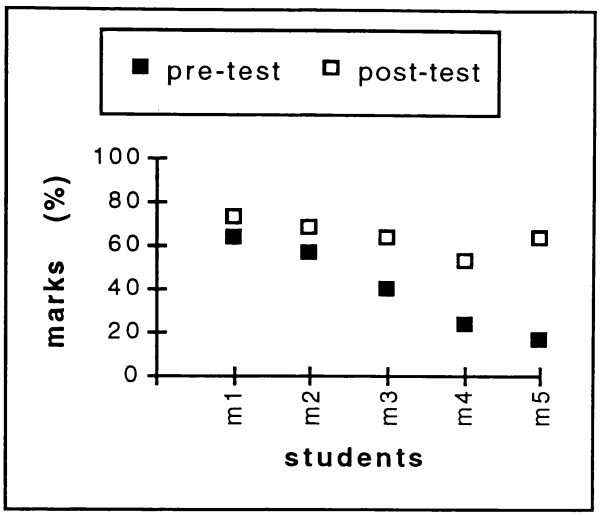


Figure 5.3a: Pre-test and the post-test performances of boys in the Maldives

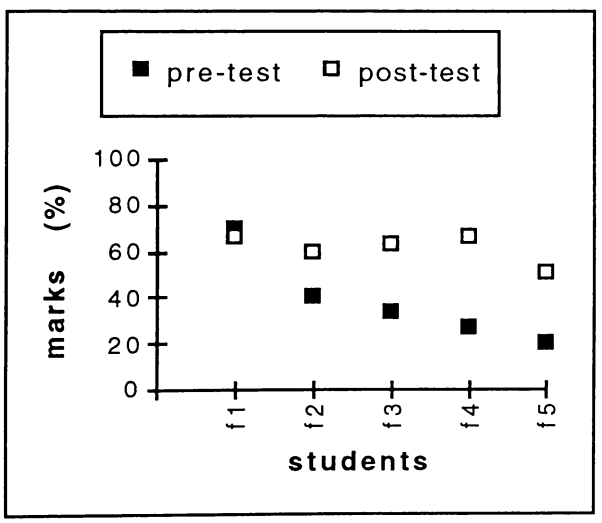


Figure 5.3b: Pre-test and the post-test performances of girls in the Maldives

A month after the intervention a test on electromagnetism was given to all the Grade 11 physics classes in the Maldives. The pattern in student achievements indicated by the post-tests was also reflected by the scores in this test. Students m5 and f5 who normally scored lower marks in class tests and assignments scored

higher marks in the unit tests. Figure 5.4a and Figure 5.4b compare the achievements of the ten students in this test with their average performance in the tests and assignments in previous six months of study in Grade 11 physics.

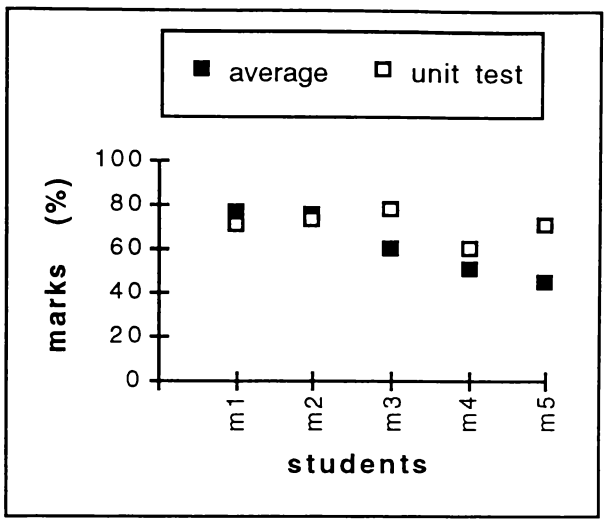


Figure 5.4a: Average performance of boys in the Maldives over the first term compared with performance in the unit test

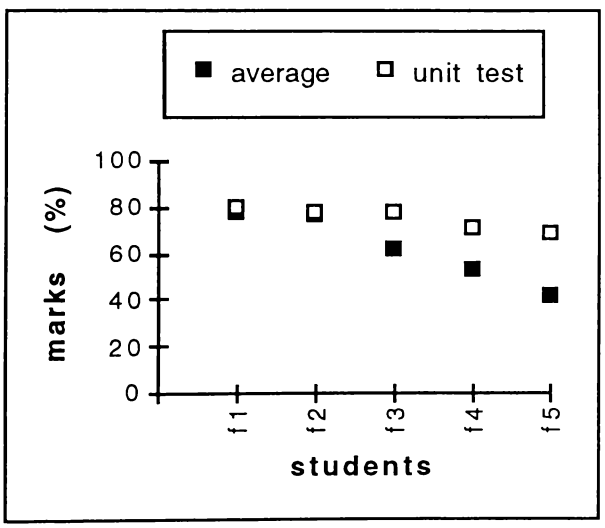


Figure 5.4b: Average performance of girls in the Maldives over the first term compared with performance in the unit test

The trend indicated by Figure 5.3a and Figure 5.3a is repeated in Figure 5.4a and Figure 5.4b. Students who performed poorly over the year performed better in the

test on electromagnetism and students who performed well during the year continued to perform well. The same trend was also observed in the New Zealand sample. Figure 5.5a and Figure 5.5b compare the performance of students in the test with their average performance in the class tests, assignments, and practical work.

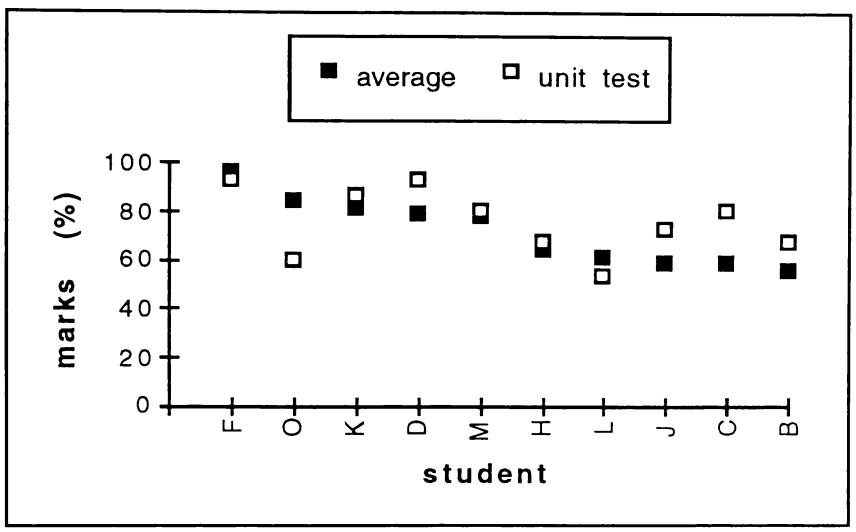


Figure 5.5a: Average performance of boys in New Zealand over the year compared with their performance in the unit test

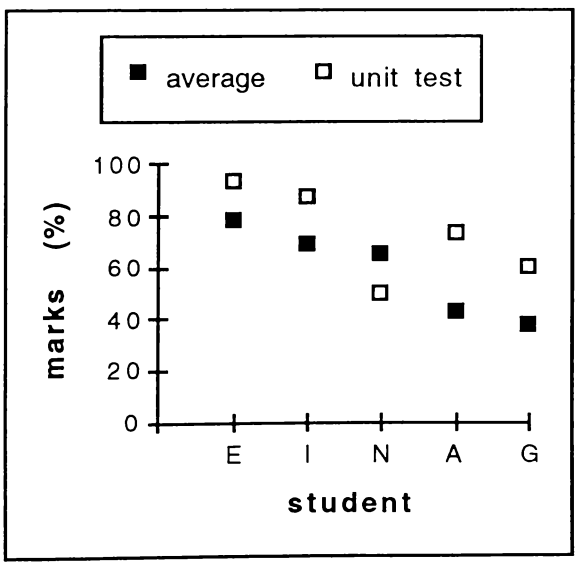


Figure 5.5b: Average performance of girls in New Zealand over the year compared with their performance in the unit test

Figure 5.5a and Figure 5.5b indicate that students in the New Zealand sample who performed poorly over the year also performed better in the test on electromagnetism. The average performance of the class was high throughout the year and girls A and G who were low achievers performed noticeably well in the test on electromagnetism.

A few students in the two samples achieved marks below their average for the year. This difference is notable in case of boy O and girl N in New Zealand who were normally high achievers. When asked about their results, boy O indicated that he did not know what to study for the test in the unit. The girl N commented:

> I know I did bad in it but it is just because I forgot everything. I think I understand it. It is just that when I got in there I forgot everything... I had another test on the same day and so I studied for that and I forgot everything.

5.7. AFFECTIVE OUTCOMES OF THE INTERVENTIONS

The affective outcomes of the interventions are reported in this section. An overview of student reactions to the interventions is initially provided in and these reactions are discussed later in detail.

5.7.1. An overview of student comments

Student responses to the semantic differential probes used in the questionnaire give a general profile of student views about the interventions. The probes required the students to compare the unit on electromagnetism to other units that they have covered during the academic year. These responses were rated on a -3 to 0 to +3 scale. The mean rating for each pair of words and phrases that described the classroom activities was calculated for each sample.

Figure 5.6 compares the mean ratings given by students in New Zealand and in the Maldives. When the differences in the comparisons are significant the levels of significance are provided[1]. Numerical and statistical details are provided in Appendix B6.

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[1] The nonparametric median test was used (Siegel and Castellan 1988).

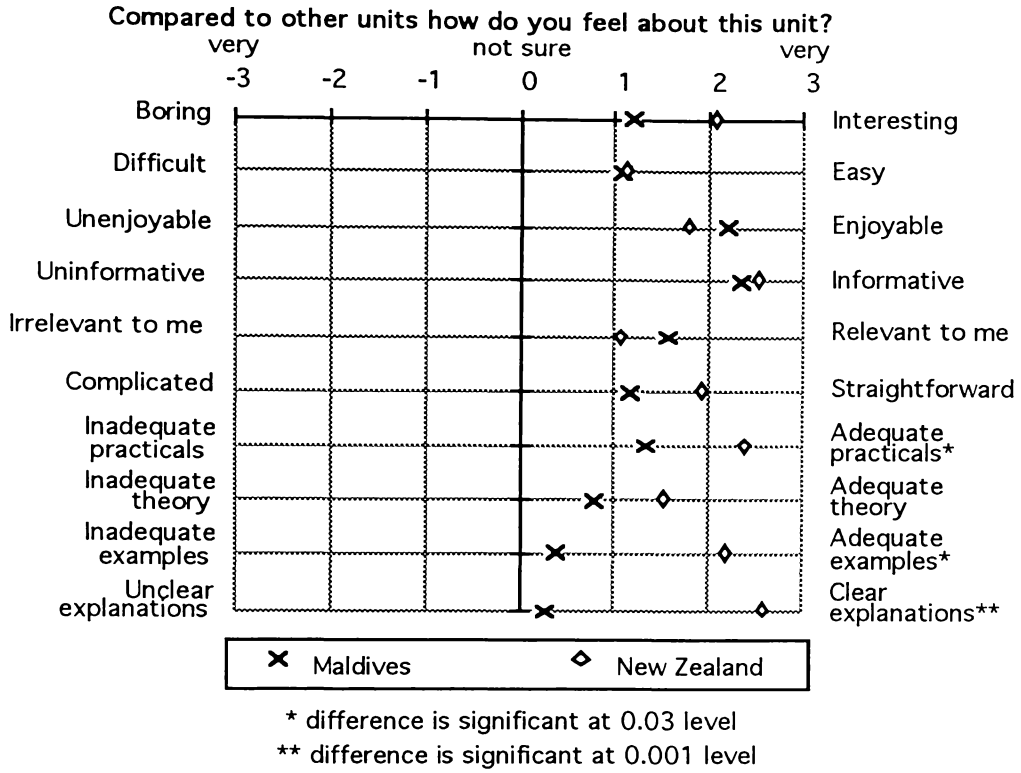


Figure 5.6: Mean ratings given by students in New Zealand (n=15) and in the Maldives (n=15)

Figure 5.6 shows that students in the two samples had positive attitudes towards the unit. They found the unit on electromagnetism to be more enjoyable and more informative than other physics units. Students, particularly those in the New Zealand sample, found the unit to be more interesting than other units in physics. Students in the two samples, particularly those in the Maldives considered the unit on electromagnetism to be relevant to their everyday life.

Students in the two samples had different views on the new teaching style. Students in New Zealand considered the teaching to be straightforward, with adequate practicals, adequate examples and clear explanations. Although, students in the Maldives did not consider the practicals, the examples, and the explanations to be unclear or inadequate, they gave significantly lower rating to these aspects of teaching than students in New Zealand. In order to clarify these views further the opinions of girls and boys in the two samples are compared in the following figures. Figures 5.7 and 5.8 compare the mean ratings to the semantic differential probes given by girls and boys in the New Zealand and the Maldives.

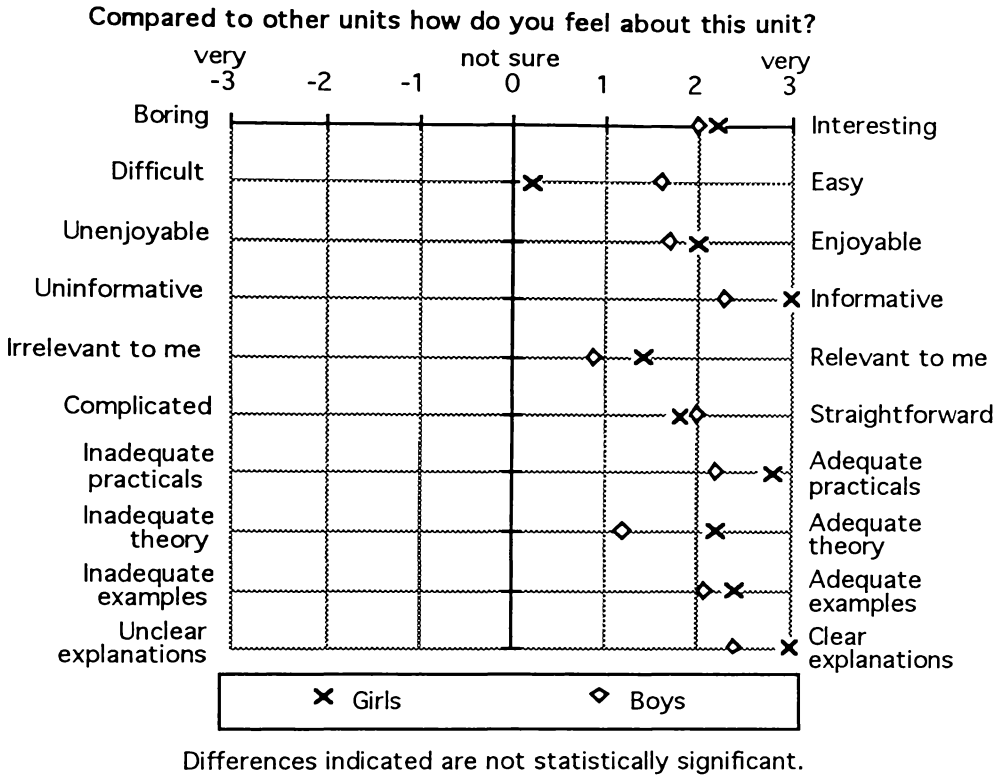


Figure 5.7: Mean ratings given by girls (n=5) and boys (n=10) in New Zealand.

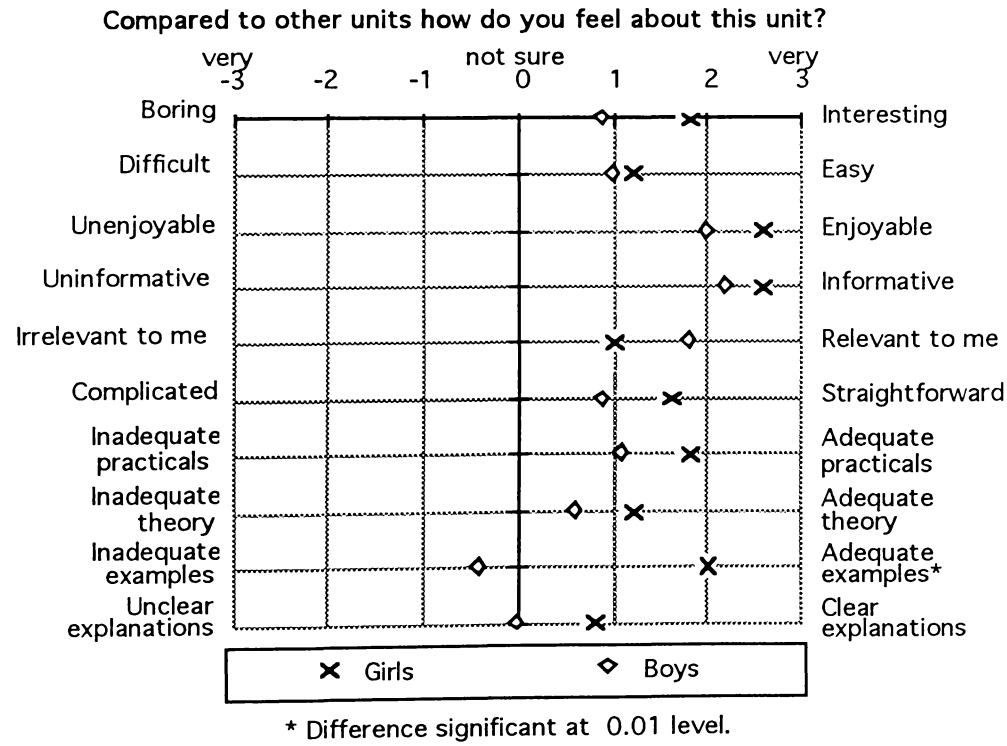


Figure 5.8: Mean ratings given by girls (n=5) and boys (n=10) in the Maldives.

Figure 5.7, and Figure 5.8 reflect the trends observed in Figure 5.6. There were no significant gender differences observed in the New Zealand sample. However, girls in the Maldives appeared to have a more positive attitude than boys towards the teaching style used by the teacher. For example there was a significant difference in the views expressed by boys and girls about the amount of examples used in the teaching.

Compared to other physics units, students in the two samples generally considered the unit on electromagnetism to be more interesting, easier, more enjoyable, more informative, more relevant, and more straightforward to them. Students in New Zealand found the unit on electromagnetism to be taught with clear explanations, adequate practicals, theory and examples. Students in the Maldives did not share the view.

The high level of student interest in the unit on electromagnetism may be because the topic is more interesting than other topics. It may also be because of the new style of teaching. In order to clarify this students were asked to write down their reasons for the views expressed in the questionnaires. These views were further explored through informal conversational interviews about student responses in the questionnaires. In the following section the reasons students suggested for their views about the interventions are explored.

5.7.2. Aspects of the interventions students liked

Most students in the two samples found the unit to be generally interesting. Twenty-one of the thirty students considered the unit of work to be the most interesting unit they have covered in physics that year. Many reasons were suggested by students for their interest. Some typical responses follow:

- The use of everyday applications made the unit relevant to some students. (7 students from the Maldives, 9 students from New Zealand)

  > It [the unit] shows very clearly how electromagnetism is used in everyday life. (Boy, m4, Maldives)

  > It was kind of things like, you can use telephones every day which is quite relevant and you use motors and everything so it is quite interesting to learn about things you are going to use all the time. (Boy, J, New Zealand)

> Sort of all of the other units we have done this year ... we have written it up on the board and it hasn't really been explained to us and we haven't worked through things in a systematic order like we did in this unit. So it has made it really, really difficult to understand and what we have done, so far this year, it doesn't seem to have really applied to anything and it is sort of way over my head really. But this has all seemed really applicable to things in our own life. (Girl, A, New Zealand)

> Most of the things covered in the unit are so common and very easily can be prepared like electromagnets, motors, speakers, etc. (Girl, f4, Maldives)

- The use of applications before the theory enabled some students to understand the theory better. (4 students from New Zealand, and 2 students from the Maldives)

> Because you kind of explained, like, the speakers which I thought was interesting and you kind of brought up more practical sides of things, like, instead of just telling us that electromagnetism, you kind of told that like in the telephone we used it and you told us we could use it in some other things, electric motors and things. (Boy, F, New Zealand)

> Here we are sort of working, trying to come up with notes but we can come up with those basically through experimenting with different things, sort of talking about it. If we had been just given the theory and you had to accept it, you had to learn it and apply it. This way you have to, it is like you are writing your own notes more in this, trying to get the right ideas and that sort of thing. It really makes you think about it. Whereas with notes you don't think about it, you just write them, you read them, you remember them and that is it. You are just regurgitating what you learn, not really, you are not really getting the depth of what you are actually doing. (Boy, D, New Zealand)

- The use of applications before the theory motivated some students to study the physics behind the applications. (2 students from New Zealand, and students 3 from the Maldives)

> We started off with telecommunications. We actually saw the uses and the benefits obtained by using the theory of electromagnetism. I wanted to find which law or principle was applied in the things we used everyday after I find out how important the basics were in our everyday life. (Girl, f4, Maldives)

> It kind of made you work harder, it made you want to know more things and stuff. (Boy, C, New Zealand)

- The group-work and the discussions made some students think more about the theory and gave some students confidence. (2 student from New Zealand, and 4 students from the Maldives)

> But you were learning it as you were doing it because you had to, like every time we came here we did something and then we talked about why it was doing things and stuff like that. So you had to think about it instead of just writing about it. So in that way it was good. (Girl, E, New Zealand)

> It also made me confident. Confident in the sense that I could explain things to others, often understanding them better [in the process]. (Girl, f1, Maldives)

> When you are just working by yourself you are sometimes not quite sure. You ..... a little part of a problem, is that what happens. But when you are in a group you can sort of discuss it and come to a conclusion and be a bit more confident about it really. (Boy, M, New Zealand)

- Some students found the unit to be more enjoyable than the other units. (3 students from the Maldives, and 1 from New Zealand)

- A few students commented that the method of teaching used in the interventions empowered them. (1 girl from the Maldives and 1 girl from New Zealand)

> Because you went around and you sat down and talked to individual people and it made them more aware that they were able to discuss with other people as well. (Girl, G, New Zealand)

5.7.3. Students' views about the most interesting activity of the interventions

Apart from two boys and a girl in the Maldives all the students interviewed (n=30) found the most interesting activity to be building the speaker. Students identified the following reasons for their interest:

- Making speakers that work helped them understand the physics better. (7 students from New Zealand, and 5 students from the Maldives)

> When you can make something yourself it helps you to understand really clearly how it works rather than pulling something apart and seeing how someone else has done it. So it is just for better understanding, I think. (Boy, K, New Zealand)

> It shows a lot about the forces acting on it and why it acts like that and vibrates. (Girl, f1, Maldives)

- The speakers they made from everyday material actually worked. (10 students from New Zealand, and 8 students from the Maldives)

> Meaning that it actually worked... Well it was, like, using cardboard and just normal copper wire and things like that. You sort of think that the speakers that you actually see in the household appliances are sort of high technological sort of things that you can actually do yourself. So I thought that was really good. (Girl, I, New Zealand)

- Speakers were part of their everyday life. (2 students from New Zealand, and 4 students from the Maldives)

> I like speakers and things and I have always wanted to know how to make them, kind of thing. I have always been interested in that kind of type things... When I was a little kid I used to pull things to bits and stuff and so I think making speakers. I have always wanted to know how they work because you always seem to hear them working but you don't know why, kind of thing. (Boy, M, New Zealand)

> Well it is something that you use all the time and, I don't know, it is something that I have always wondered how it worked. When you are little kids you always think there are little people in the speakers playing music and then as you get older you think 'well that is not quite right' and it is just something that I have always wanted to work out. (Girl, f3, Maldives)

Although students generally liked the classroom activities conducted during the interventions some students commented on difficulties encountered.

5.7.4. Aspects of the interventions students did not like

A few high achieving students (f1 and m2 in the Maldives and C in New Zealand) considered the new approach to be slow and time-consuming. Although they enjoyed the sessions C and m2 considered the style of teaching to have unnecessarily complicated an otherwise simple and straightforward piece of physics teaching. One boy, m2, in the Maldives claimed that he could not follow the teacher's explanation because the theory was not presented before the applications:

> Actually the topic is interesting, but I couldn't follow the teacher's explanation. I couldn't concentrate on the activities... The teacher must explain the theory at the beginning of the lesson. (Boy, m2, Maldives)

When faced with difficulties some students did not want to inquire publicly about their difficulties. This reluctance was mainly due to two reasons: some students, particularly girls, were shy of expressing their problems in public; and some students, particularly some weaker students, have already given up hope. A high-achieving girl in the Maldives, f2, was too shy to ask for help because she was afraid of making a mistake in public. A girl in New Zealand, G, who labelled herself to be the 'dud of the class' and considered physics to be 'beyond' her and felt intimidated by physics (see comment made by G at the end of Section 5.7.2), made significant improvement. Although she considered physics to be too difficult and initially was not interested in the classroom activities, she eventually started participating. When questioned about her change she made the following comment:

> Sort of all of the other units we have done this year ... we have written it up from the board and ... we haven't worked through things in a systematic order like we did in this unit. So it has made it really, really difficult to understand and what we have done, so far this year, it doesn't seem to have really applied to anything and it is sort of way over my head really. But this has all seemed really applicable to things in our own life (Girl, G, New Zealand).

G claimed that the new style of teaching made her aware that she knew more physics than she ever thought. Her increased confidence may have made the physics easier for her to understand. She got her highest ever score in physics in the test. A similar transition was made by a boy, m5, in the Maldives who initially remained silent in the class because he had given up hope in physics.

Some high-achievers in the Maldives (2 boys and a girl) felt that the teacher did not go into sufficient depth in certain areas. According to a girl the theory was too specific and kept to the syllabus. She wanted the teacher "not to be too guided by the syllabus".

The next section compares the data collected from students and teachers in the two countries and discusses the outcomes of this phase of the study.

5.8. OUTCOMES OF PHASE TWO AND THEIR IMPLICATIONS

Using technological contexts for the teaching of senior secondary school electromagnetism in the two countries produced similar cognitive and affective outcomes. The students and teachers enjoyed the contextual approach to teaching and learning, and a marked increase in the motivation of weaker students were observed. The weaker students participated more in the classroom activities during the interventions. All but a couple of high achievers in New Zealand performed well in the tests after the intervention. Students who normally did not perform well in class tests performed considerably better.

The similar outcomes of the interventions in the two countries may be explained in terms of the technological contexts used. All the contexts used in the teaching were common to the two countries, particularly the macrocontext— sound transfer in telecommunications. Students as well as teachers in the two samples felt that the use of technological contexts helped to increase cognitive and affective outcomes.

Engaging students with the technical aspects of the contexts motivated some students to explore these aspects further, intrinsically motivating them to learn about the physics. Some students were noted by the teachers to have well-developed physics ideas before the formal teaching of the physics associated with the contexts. Some students claimed that the introduction of the applications before the theory enabled then to understand the theory better motivating them to study the physics associated with the applications.

The teacher in the Maldives faced initial difficulties engaging some students in classroom discussions. In her opinion the reluctance of some students to initially participate in the discussions and classroom activities may be due to the abrupt change in her teaching style. The set of behaviours perceived by a group of students to be appropriate with a particular teacher is difficult to change for students when the teacher changes hers. The students may need to experience the new style of teaching and may need time to alter their existing values, beliefs, and norms of behaviour in the teacher's presence. This view is supported by the fact that the new teaching style of the same teacher was well received by a parallel class she started to teach that term. The researcher faced no difficulties in engaging

students in the activities from the New Zealand class. This may be due to them having no pre-conceived view of the teaching style, or to a greater flexibility of the New Zealand students.

Students as well as teachers require time to adjust to a new style of teaching. In spite of her desire to change her teaching, the teacher in the Maldives recognised that she often switched back to her usual style of interacting with the class. A few students, particularly some high achievers, felt that the new style of teaching was complicated and unnecessary. However, they too enjoyed the sessions.

The outcomes of this phase of the research were similar to those of the studies reported in Chapter 2, and support the thesis that contextual approaches to teaching and learning enhances the affective and cognitive outcomes for the majority of the learners in the classroom. This phase of the research also showed that contexts from common areas of technology may be used in a similar manner in a western and a non-western culture to obtain enhanced cognitive and affective outcomes. Furthermore, the outcomes of this phase provided some insights into the difficulties teachers may face in beginning to use contextual approaches to teaching.

The next part of the study was designed to explore further the process of contextual teaching and it was decided to conduct two more phases of the study. Phase 3 was designed to study the classroom processes associated with contextual teaching and to identify the features of contextual teaching that may enhance learning outcomes. The interventions were conducted by teachers who were familiar with the contextual approach to teaching. Phase 4 was designed to research in detail teachers' reactions to the new strategy of teaching, particularly the difficulties faced by teachers using the strategy for the first time. It was also decided to develop a teaching resource from the material used during the classroom interventions and to use it during Phase 3 and Phase 4.

The research conducted during Phase 3 is reported in the next chapter.

CHAPTER SIX

PHASE THREE: PROCESS AND OUTCOMES OF CONTEXTUAL TEACHING

This chapter documents the process and outcomes of the classroom interventions in New Zealand and the Maldives during the third phase of the research study. The chapter begins with an introduction to the third phase, and outlines the development of a teaching resource for the classroom interventions. The samples and the data-collection procedures are then described, and the process and outcomes of classroom interventions are documented. The chapter concludes by summarising the outcomes of this phase of the study.

6.1. INTRODUCTION TO PHASE THREE

During the second phase of the research classroom interventions based on contextual teaching strategies were used in physics classroom in New Zealand and in the Maldives. The teachers considered the strategies to have enhanced the affective and cognitive outcomes, particularly for the weaker students in the classes. The test results and the opinions of the students appeared to be in agreement with the views expressed by the teachers. However, the teacher in the Maldives faced some difficulties in using the new approach.

This phase of the study was designed to further clarify contextual teaching by focusing on the classroom processes, and identifying aspects of contextual teaching that help enhance learning outcomes. The difficulties faced by teachers in using the new approach to teaching were investigated later in Phase Four, reported in the next chapter

6.2. THE TEACHING RESOURCE

A resource for teaching electromagnetism at secondary school levels in New Zealand and the Maldives was developed from the material used during the initial classroom interventions. The contexts, the structure of the unit of work, and the three-phase framework of the individual sub-units were used unchanged. Notes on possible classroom activities, aspects of practical and theoretical physics, and context-based exercises and problems were developed.

Although the initial classroom intervention in the Maldives was conducted in a Grade 11 class, the teaching resource was targeted for Grade 10 classes in the Maldives. This change was necessary for using the same resource in the two countries. The syllabus requirements in electromagnetism for Grade 11 in the Maldives and the corresponding Form 6 in New Zealand were found to be too diverse and the teaching resource was targeted for Form 6 in New Zealand and Grade 10 in the Maldives where the syllabus requirements in electromagnetism were almost identical.

Slightly different versions of the resource were developed for use in the two countries. The differences between the two versions were in the introductory comments and in the order of some exercises. The introductory comments were based on the curriculum used in each country. The version of the resource used in the Maldives is shown in Appendix C1, and the introduction to the version used in New Zealand is shown in Appendix C2.

The teaching resource was designed as a unit of work with the following sub-units:

1. *Telecommunications:* Getting the message across
2. *The speaker:* Converting signals into sound
3. *The Microphone:* Converting sound into signals

The sub-unit on telecommunications introduced the macrocontext (sound transfer in telecommunications), the initial microcontext (some equipment used in the transfer of sound), the speaker, and the microphone. The sub-unit on the speaker introduced magnetism, magnetic effect of current, and force on a current-carrying conductor in a magnetic field, and explored the application of these concepts in

other microcontexts. The sub-unit on the microphone introduced electromagnetic induction, and explored the application of these concepts in other microcontexts.

All three sub-units of the resource were used with the New Zealand sample. However, only the first two sub-units were used with the Maldives sample. The Grade 10 electromagnetism syllabus in the Maldives was divided into three sections: magnetism and magnetic effect of current; force on a current-carrying conductor in a magnetic field; and electromagnetic induction. The first two sections were scheduled for the latter half of the first term. The section on electromagnetic induction was scheduled for the second term. As the section on electromagnetic induction corresponded to the third sub-unit of the resource, and as adequate data for the purposes of this phase of the research were expected to be generated without it, the third sub-unit was not used in the Maldives.

In using the unit in the two countries the classroom processes followed very closely the activities outlined in the teaching resource.

6.3. SAMPLE IN PHASE THREE

The resource was used in a Form 6 coeducational class at a large state school in Hamilton, New Zealand. The class consisted of 8 girls and 16 boys. The sessions were regularly attended by 7 girls and 9 boys. Some students were involved in other school activities and had to be excused during some sessions.

As there were no Grade 10 coeducational classes in the Maldives, the resource was used in two single-sex classes from a private school in Malé: a boys-only class of 33 students, 28 of whom attended all sessions; and a girls-only class of 20 students, 18 of whom attended all sessions. The boys and the girls had their classes during the morning and the afternoon sessions respectively.

The classroom intervention was conducted in October/November 1993 in New Zealand by the class teacher as the final teaching unit of the academic year. The students had completed 95% of the assessment for the Sixth Form Certificate. Results of a unit test after the intervention was to make up the remaining 5% of the assessment. The teacher had previously observed the researcher teach his classes

during the initial classroom intervention in October 1992 and was confident about using the new teaching strategy. The researcher helped the teacher in preparing for some classroom sessions, and observed all the sessions.

The classroom intervention was conducted in April 1994 in the Maldives by the researcher who was familiar to the two groups of students. The researcher taught the two classes for 3 weeks during February 1993, and for an additional 3 weeks immediately before the intervention. During the former sessions the researcher used traditional teaching strategies.

The students in the two samples had been previously taught some basic concepts of electromagnetism. Students in the New Zealand sample were taught basic concepts of electromagnetism in Form 5 science, during the latter part of the previous year. The students in the Maldives sample have had a less formal exposure to electromagnetism three years back, in their Grade 7 science.

6.4. DATA COLLECTION IN PHASE THREE

The data collection strategies used in this study have been discussed in Chapter 3. Table 6.1 summarises the use of these strategies during this phase of the study.

Table 6.1: Data-collection instruments with the classrooms

Instrument	New Zealand		Maldives	
	use	sample size	use	sample size
pre-and post-tests with informal conversational interviews	before unit and after unit	18 girls and 16 boys 7 girls and 8 boys[1]	before unit and after unit	33 boys and 20 girls 28 boys and 18 girls
classroom observation with informal conversational interviews	by researcher (class teacher teaching)	attention given to all students	by researcher (researcher teaching)	attention given to all students
questionnaires with informal conversational interviews	after unit	7 girls and 11 boys	after unit	33 boys and 18 girls

[1] Total number of boys who attended the post-test was 9. However, the answer script of one boy had to be excluded as he joined the class after completing a higher-level physics course overseas.

The following sections describe the instruments and their use during this phase of the study.

6.4.1. Pre-and post-tests

Pre-tests and post tests were conducted with each group of students before and after using the teaching resource. The same questions were asked during the pre- and post-tests in each country. The question papers used in the Maldives and New Zealand are in Appendix C3 and Appendix C4 respectively. Student responses to the tests were clarified through informal conversational interviews with individual students shortly after each test. During the interviews students were asked to reflect on their written responses and to suggest alternate answers to those they may consider incorrect. Any suggested answers were recorded on their answer scripts. When students were able to give a better oral answer the written answer was neglected. All the interviews were audio-taped and some were transcribed for further analysis.

6.4.2. Classroom observation

All the classroom sessions in New Zealand were observed by the researcher, and the teacher was interviewed after all but one classroom session. The teacher was requested to report any observed changes in the behaviour of individual students during the use of the new strategy. As the researcher was familiar with all the students in the Maldives sample, he was able to detect any changes in the behaviour of individual students during the use of the new strategy.

All classroom sessions were audio-taped, and some classroom observations were reviewed by listening to the audio-tapes before the next session. For example, if a student who was normally silent in class was observed to ask questions, the nature of the questions and the context within which the questions were asked were reviewed by listening to the tapes. Some of these observations were explored further through informal conversational interviews with the students in the two samples, and with the class teacher in New Zealand.

Informal conversational interviews with individual students and with groups of students were sometimes conducted during the classroom sessions and sometimes outside the classroom. Some of these interviews were transcribed for further analysis.

6.4.3. Questionnaires

A questionnaire was used after the completion of each classroom trial to identify the range of views and opinions among students about various aspects of the classroom activities. The questionnaire used in the Maldives (Appendix C5) was slightly different from that used in New Zealand (Appendix C6), but they explored the same aspects. These aspects included the relevance of the classroom activities to them, their interest in the classroom activities, their participation in classroom activities, and their perception of the amount of learning during these activities. The questionnaires required students to compare the unit on electromagnetism to other units of work in physics. These views and opinions were explored further through informal conversational interviews with individual students.

The questionnaires were derived from that used during the initial classroom intervention and included modifications that were based on student responses. It required students to write answers and to respond to semantic differential probes. The phrasing of the questions and the format of the questionnaires was changed. More categories of semantic differential probes were used and a focus statement was added to each probe in the modified questionnaire.

The questions and the probes were explained before administering the questionnaire. Opportunities for further clarification during the answering process were provided.

6.5. CLASSROOM OBSERVATIONS DURING THE TEACHING PROCESS

The class teacher in New Zealand and the researcher in the Maldives used similar classroom strategies during the interventions. As explained earlier all the three

sub-units of the teaching resource were used in New Zealand and only the first two sub-units were used in the Maldives. The main activities conducted during the interventions are outlined in Table 6.2.

Table 6.2: Classroom sessions and activities.

Sessions	**Activities** (with approximate duration)
1. Talking about telecommunications	• Class discussion about equipment and services in everyday telecommunications. (1 hour)
2. Finding out how some applications work	• Investigating student's ideas about how some applications like the baby monitor, the walkie-talkie, and the telephone may transfer voice. (1 hour) - Identifying the speaker and the microphone as essential elements. - Looking at different types of microphones and speakers by opening up some devices.
3. Making a speaker	• Making a working model of a speaker using everyday material. (1 hour)
4. Looking at the physics of the speaker	• Exploring students' ideas about how speakers work. (1 hour) • Looking at how scientists and engineers talk about speakers. (3 hours) - Permanent magnets; - Magnetic fields due to currents; - Force on a current-carrying conductor in a magnetic field. • Exercises, and looking at the above concepts in other relevant applications.
5. Looking at the physics of the microphone (NOTE: These sessions were not conducted in the Maldives.)	• Exploring students' ideas about how dynamic microphones work. (1 hour) • Looking at how scientists and engineers talk about dynamic microphones. (2 hours) - A dynamic microphone as a speaker in reverse. - Electromagnetic induction. • Exercises, and looking at electromagnetic induction in other relevant applications (2 hours).

Certain student behaviours normally associated with learning were observed more frequently during the interventions than in other physics sessions. These observations included the following:

- Students appeared to participate more in classroom activities during the interventions;
- Students were observed to ask more in-depth physics questions during the interventions;
- Some weaker students appeared more confident about their learning; and

- More debate about physics-related issues was observed inside the class.

The above observations are clarified further in the following sections.

6.5.1. Student participation in classroom activities

A student was considered to participate in classroom activities if he or she was observed:

- to make use of opportunities for clarification;
- to do practicals without being urged by the teacher;
- to volunteer answers to questions;
- to volunteer information; and
- to work through exercises without being forced to.

In all physics sessions some students, mostly those who normally performed well in the class, were eager to participate in the classroom activities. During the interventions many students who normally appeared uninterested in physics classes were observed to participate in classroom activities in a similar manner. This change in behaviour was observed mostly in girls in New Zealand. The change was also observed in the Maldives, but generally in weaker students, and there appeared to be no gender bias. The lack of a gender bias in the Maldives may be due to the intervention being conducted in single-sex classes.

In New Zealand the teacher noted that boys normally monopolised the equipment, teacher's time, and attention. According to him girls usually allowed the boys to dominate. He explained this observation as follows:

> Unfortunately, the boys monopolise time, equipment, teacher's attention and we find that throughout the years at the school. Unfortunately, I think girls learn to just let them get on with this. They don't push themselves. They don't want to be noticed so much. The boys don't mind if they [the boys] say something that's wrong or incorrect. They are willing to have a discussion about something and make silly comments, just throw ideas around in a way to be noticed. Girls generally won't do that. So they tend to sit quietly. They won't offer views unless they think they are right. They sit quietly, or get on with the work quietly by themselves without wanting to draw attention to themselves. (T26/10)

However, during the intervention, particularly towards the later sessions, many girls were observed to participate fully in classroom activities.

6.5.2. Student questioning

Some students were noted for their interest in physics and for their in-depth questions. In both samples, these were mostly students who were considered bright by their teachers. During the contextual teaching unit students who were considered weak in physics were observed to ask in-depth physics questions. This change was noted mostly in the Maldives.

Student questions also provided valuable information about contexts that interested them. For example, the period after the researcher had discussed the concept of force on a current-carrying conductor in a magnetic field, a boy M1[1] in the Maldives, had a question to ask. M1 was a weak student and came very prepared for his question.

M1:	[Producing a small cathode-ray tube from eye-piece of video-camera] Sir! I have a question.
Researcher:	Yes?
M1:	I took this TV tube out and did not see any magnets?
Researcher:	So?
M1:	There must be magnets? [Students start laughing. M1 was standing up with the cathode-ray tube held out.]
Researcher:	[To M1 who was looking worried] Okay. What would be the purpose of the magnet in there.
M1:	To move the electron rays. Because the electron rays are also like the electrons inside the wire... [stops]
Researcher:	The electron rays are also like the electrons inside the wire. You are absolutely right. [more students in the class start to listen] Could you explain a little bit more?
M1:	I read about this .....

M1 had a considerable amount of information about 'TV tubes' and the majority of the students were interested in it. The TV tube was considered an additional microcontext and most of the period was spent on discussing how the deflection coils in a TV tube move the electron beam to produce pictures on the screen. In the process exercises on how to deflect the beam in particular directions were

[1] The codes M1 means male student 1. The same code is used for the same student throughout the chapter. The code F1 means female student 1. The sample is always identified as either Maldives or New Zealand.

worked out by the class. Other related contexts were suggested by students. For example, one student suggested how when a magnet was brought near the screen of a colour TV the colours became distorted. Exploring the physics behind this observation further strengthened the concept of the force on moving charges in a magnetic field.

Some microcontexts that were investigated in detail because they were suggested by students, and because of their relevance to the topic, include the following:

- the TV-tube
- magnets distorting the TV picture
- the VCR head
- Hard-Disks
- Floppy-Disks.

The weaker students continued to be reluctant and had to be provided with support. As illustrated in the above example M1 sought help from the teacher to express his ideas in front of his friends. The teacher had to help clarify M1's question, and had to create the opportunity for him/to share his views. As in any other teaching session, this required the teacher to give weaker students more attention and to spend relatively more time with them.

The additional help and support given to weaker students worried some high achievers. This view was made very clear by the individual comments of two high achieving boys (M15, M2) and a high achieving girl (F3) in the Maldives urging the researcher to proceed with the teaching without wasting too much time. According to them attempting to answer student questions was a waste of time especially when the GCE examinations were so close. M2 even accused the weaker students to be "deliberately having fun and wasting classroom time".

Irrespective of the teaching approach used providing additional help and support to weaker students is expected to motivate them to participate in classroom activities. However, in using the contextual approach the teachers found it easier to provide this support.

6.5.3. Student confidence about their understanding

In normal classroom practice the high achieving students were usually confident about their knowledge and often volunteered to help others. During the interventions some who would normally be considered weak students also expressed confidence in their knowledge, sometimes challenging their 'brighter' friends.

The following conversation between some students in the New Zealand class illustrates the above view. The conversation was about how to draw magnetic field lines around a bar magnet . F1 and M4 wanted to help F5, considered a weak student, 'correct' the magnetic field lines she had drawn around a bar magnet. Some of her field lines were going into the sides of the magnet and F1 and M4, who were the top students in the physics class, considered this to be incorrect. They wanted all the field lines to emerge from one pole and to go into the other pole[1]. However F5 was confident about her drawing and was not ready to change her view:

F5:	This is what *I* observed with *my* compass and *my* magnet. [referring to a diagram she has drawn showing the field around a bar magnet]
M4:	That should be straight. [referring to a field line along the side of the magnet]
F1:	You shouldn't be so hard [on her].
Researcher:	[to M4] You are saying that it should be straight?
F5:	[interrupting] You get a compass and a magnet and I prove you wrong.
M4:	The points from that point should be about there and that point should be about there. [He was trying to make the field line emerge from one end of the magnet and to go into the other end.]
Researcher:	Why are you saying that?
M4:	Because it is going into the poles. Along here the actual field lines should travel around and go into the poles at this point. [The field line drawn by the girl was going into the side of the magnet and the boy was unhappy about it. He wanted the line to go exactly into the end of the magnet.]
F1:	Oh maybe it should be around a little bit like that and it doesn't matter.
M4:	Yeah, yeah.

[1] This is not correct for a bar magnet with its poles at the ends. While most of the field lines will emerge from one end (the north pole) of the magnet and will go into the other end of the magnet, some may emerge from the sides close to the end.

F5: So this one be on a separate field? Mr Mohamed please answer this question. [She is not convinced and seeks help.]

F1: And this one on a separate field line, say out here and this one would be like on another one. [She supports M4]

F5: But it is basically the same. You have got the same pattern going around like that. [F5 was not convinced.]

Similar instances were frequently encountered during the interventions in New Zealand and the Maldives.

6.5.4. Debate about physics-related issues inside the class

In the two classes observed during this phase of the study debate about physics-related issues were normally initiated by the teacher in physics classrooms, and only rarely did students engage spontaneously in such debates. During the contextual teaching unit groups of students approached the researcher on several occasions to clarify disputes among themselves regarding theoretical aspects of physics. Some of these debates were about issues like the role of electrons in producing magnetic domains that was not required for the tests. Some of these debates were related to experimental observations, or the application of theory. Similar instances were noted in all the classes, and the students who were engaged with these debates were not only high achievers.

In the Maldives and in New Zealand students met the researcher outside the class to discuss physics-related topics. Students in the Maldives wanted to hold extra classes during the week-ends for these purposes. Some high achieving students in the Maldives suggested that 'proper physics teaching' may be conducted during the regular classes and 'issues that interest us' can be discussed during the extra classes. This response from the students may be a result of the researcher frequently approaching them to clarify their ideas and views about classroom activities. This view is supported by the fact that students did not approach the teacher in New Zealand for clarifications any more than they would during other sessions. However the fact that students wanted to discuss physics during these interections with the researcher may be an indication of their intrinsic motivation.

6.5.5. The teacher's use of the new approach in New Zealand

The timing of the intervention was not very favourable for the teacher in New Zealand. He was busy with pressing administrative commitments, and was unable to concentrate on using the new method to his satisfaction. The teacher had previously observed the researcher use the contextual approach in one of his Form 6 physics classes. However, his other commitments reduced the effort he was able to put into using the new style of teaching. He made the following comment:

> I enjoyed it. I think on the whole the students would have enjoyed this approach to electromagnetism rather than the more traditional approach. I think the problems we[1] had were to do with logistics. Basically with the time of the year we were doing it. I think it would have been better to try it during a different time of the year and ... [we are] certainly going to change the time of the year that we do this unit for this reason next year. So that I think that will help solve some of the problems we have had. Basically we have been very rushed towards the end and weren't able to spend enough time with students doing practical exercises themselves and discussions with individual students and working with them on preparing presentations and giving presentations. That was all rather disappointing and rushed because we had a deadline to meet in terms of assessments and marks. And I think that had badly affected the outcomes of your trial. (A1/19/11)

A1 was a very experienced teacher who had been involved in other research studies. He was very enthusiastic about the use of the new strategy and was disappointed in his problems with engaging fully with using it. Despite these personal concerns the teacher became a secondary school science adviser and he encouraged teachers to use contexts as a starting point for teaching physics.

The reactions of teachers and the difficulties they faced in using the new style of teaching are documented in the next chapter.

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[1] All other Form 6 physics teachers at the school also made use of the teaching resource. However their use of the resource was not monitored by the researcher.

6.6. STUDENT REACTIONS TO THE CLASSROOM INTERVENTIONS

Questionnaires were used after the interventions to explore the affective outcomes. Student responses to the semantic differential probes in the questionnaires are used in this section to provide an overview of their reactions to the new style of teaching in the two countries. The trends and patterns that appear in the overview are then explored.

The semantic differential probes used in the questionnaires required students to compare the unit on electromagnetism to other units in physics, and to indicate their views about the main activities conducted during the interventions. These responses were rated on a 1 to 7 scale, and the mean rating for each pair of words and phrases that described the classroom activities were calculated for each sample. Figure 6.1 compares student responses in New Zealand and the Maldives to the semantic differential probes comparing the unit to other units in physics. The figure is based on the means of ratings given by all the students in each sample for each probe. When the differences in the comparisons are significant the levels of significance[1] are provided. Numerical and statistical details are provided in Appendix C7.

The following trends can be seen in figure 6.2:

- Students, particularly those in the Maldives, considered the classroom activities used during the interventions to be different from normal classroom practice.
- Students, particularly those in the Maldives, perceived to have participated more in classroom activities during the interventions than during normal classroom sessions.
- Students considered the teaching approach used during the interventions to be different from normal classroom practice.
- Students considered the interventions to be more informative, more relevant more interesting, and more enjoyable than other physics units (mean scores for the whole sample are less than 3 for each observation).

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[1] The nonparametric median test was used (Siegel and Castellan 1988).

- Students in New Zealand did not perceive to have learnt any more than in other physics units during the interventions (mean score is very close to 4). However, students in the Maldives felt that they were learning more.
- Students appeared to consider the unit on electromagnetism to be as difficult as any other unit of work (mean score for the whole sample is very close to 4).
- No significant gender differences were observed in the opinions expressed by the students comparing the classroom activities during the interventions to those in other physics units.

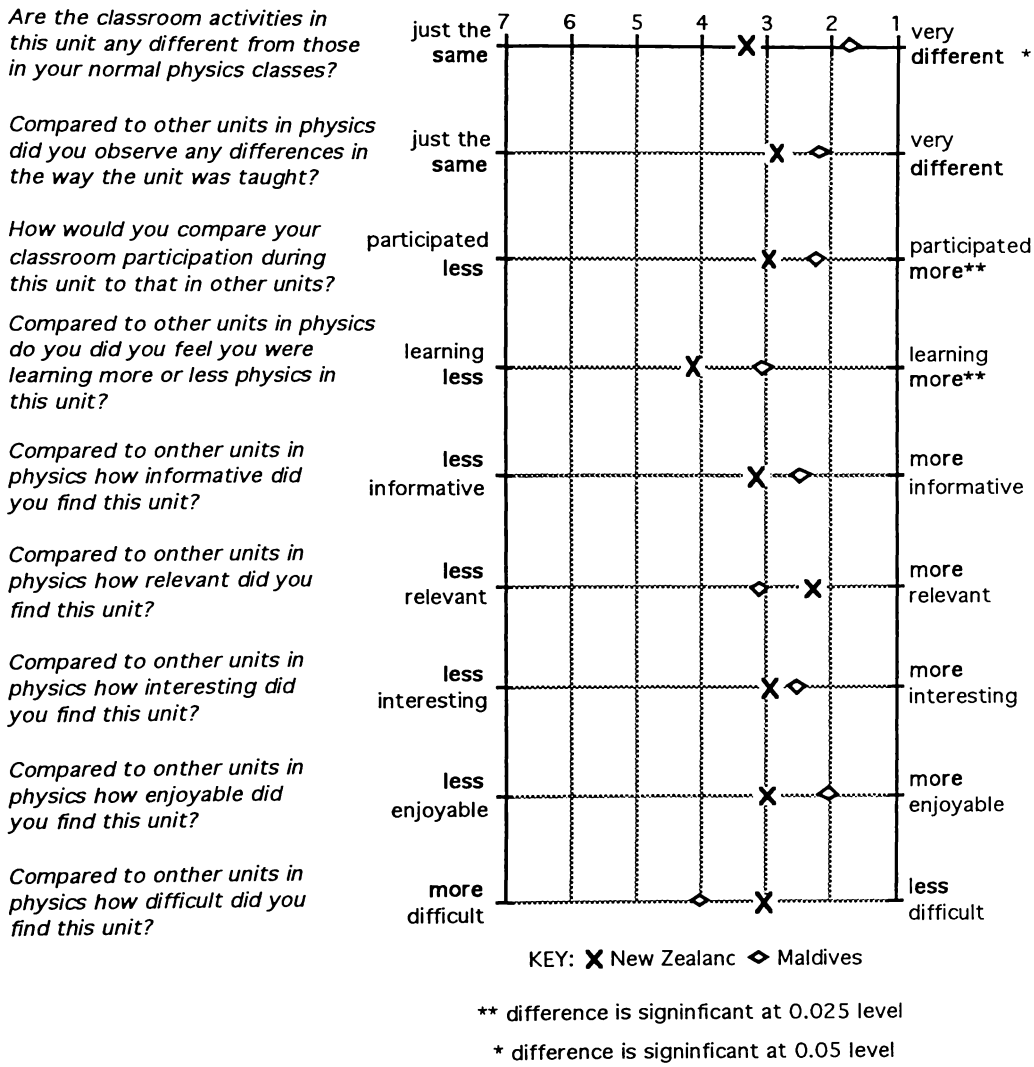


Figure 6.1: Mean ratings of students in New Zealand and the Maldives to the semantic differential probes

The opinions of students expressed in the questionnaires were explored using informal conversational interviews. The most frequently suggested reasons for

their increased motivation during the contextual teaching unit include the following:

- the interactive nature of the activities;
- the hands-on nature of the activities;
- the use of everyday applications to introduce the theory; and
- the every-day nature of the contexts.

These reasons are clarified in the following sections.

6.6.1. The interactive nature of the activities motivated students

Almost 33% of the students in the two samples described normal physics classes as boring because they would normally sit silently in the classroom, listening to the teacher, and taking a lot of notes. The interactive nature of the activities during the interventions was considered a change from normal classroom practice and hence motivated many students who normally were not very interested in the classroom proceedings. This view is reflected by the following comments:

> The teacher paid more attention to my ideas and gave me more help (F3, girl, Maldives).

> The teacher required me to answer questions and that made me think (M7, boy, New Zealand).

All the girls in New Zealand liked the new style of teaching. According to F6, a girl in New Zealand, the teacher was giving more help and attention to weaker students like her during the intervention:

> I enjoyed this unit. It was taught well. The teacher has a habit of talking only to the students who understand physics. ... he is more interested in the intelligent students than he is with students who do not understand. Instead of helping them he taught the intelligent ones harder stuff. (Girl, F6, New Zealand)

The increased teacher-student interaction may have made it easier for many students to participate in the classroom activities and may also have motivated many who needed the extra attention from the teacher to engage them with classroom activities.

6.6.2. The hands-on nature of the activities motivated students

The hands-on nature of the activities included in the interventions motivated students to participate in the classroom activities. A boy (M1) from New Zealand made the following comment:

> I am a student who would do practical experiments rather than just copy notes and diagrams. So I really enjoyed making the speaker, looking at magnetic fields, etc. (M1, New Zealand)

Many students in the Maldives (39% of girls and 33% of boys) noted that they rarely did practicals during their physics sessions and the inclusion of practicals with the teaching motivated them to participate in the activities. A girl (F15) from Maldives made the following comment supporting this view and pointing out that the practical activities during the intervention were different from normal practicals:

> I was interested in the activities because we were required to do [practical] things ourselves like making the speaker and looking at how things work and how we may use them. These things were different from the usual practical things we do, like running a trolley down a slope. (F15, Maldives)

Students in both samples made similar comments. About 30% of all students in the Maldives also considered the practicals to be related to their everyday life and hence to make better sense than other practicals. Although students in the New Zealand sample did frequent practicals many students (33%) claimed that the practicals during the intervention made more sense than their usual practicals.

6.6.3. Use of everyday applications to introduce the theory motivated students

Some students noted that making the speaker and looking at the telephone and the baby monitor made them more interested in finding out what was going on inside them (New Zealand: 22%; Maldives: 32%). The following comment made by a F2, a girl in the Maldives, illustrates this view:

> Making the speaker made me interested in finding out what was going on inside it. I felt confident about what I [already] know and I was able to ask questions. (F2, girl, Maldives)

Making the speaker enabled F2 to recollect what she already knew about electromagnetism, and helped her to formulate specific questions that she wanted to answer. Her sharpened focus not only made her interested in the physics but gave her confidence to ask questions about it.

Section A of the questionnaires provided a list of the main activities of the interventions and required students to rank each activity along a scale of interest ranging from "very interesting" to "not interesting". The highest mean ratings were given to making the speaker. Some students considered building the speaker to be the most interesting activity of the whole unit (Maldives: 22% of all students; New Zealand: 25% of all students).

6.6.4. The every-day nature of the contexts motivated students

About one third of the students interviewed identified the every-day nature of the applications used in the interventions to have motivated them to take an active interest in the lessons. The following comment illustrates this view:

> The sessions were relevant to me. I actually knew what was happening because we were talking about things I know about and things I see always. (F2, girl, Maldives)

Many students considered the sessions to be more informative than other physics sessions (Maldives, 23% of boys and 22% of girls; New Zealand, 27% of boys and 29% of girls). This was because the lessons were related to things they know rather than to "physics and science things" (M14, boy, New Zealand).

Although some students considered that they were learning physics while looking at everyday applications, a few found it difficult to believe that they could be learning "real physics" using this approach. This view was expressed by some high achievers (M15, Maldives, M4, New Zealand). These students appeared to share a belief that "real physics" can only be learnt using the classroom strategies they were used to. They considered the classroom activities to be "lacking in seriousness" (M15, Boy, Maldives).

6.6.5. Problems faced by some students

Some students identified aspects of the contextual teaching approach that they did not like. M15, a high achieving boy was unhappy about spending time looking at everyday applications and wanted to get to the "real physics". He said:

> I found the activities to be interesting, but could not get much into my mind. If you could stop wasting time and go to the real physics I think I would have benefited much more (M15, Maldives)

This view was also shared by F3, a girl in the Maldives who considered discussing everyday applications to be like "students expressing all sorts of ideas and joking around" and hence considered it to be a waste of time. She wanted the teacher to go on with the real "physics".

M7, a boy in New Zealand, found the sessions to be long-winded because the teacher was asking too many questions. He said that he "was getting tired of the teacher asking him what do you think to each and every question" he asked (M7, boy, New Zealand). M31, a boy in the Maldives, shared this view and once approached the researcher after class. He requested the researcher not to discuss so much in the class and to give him the proper physics notes so that he could study. He considered classroom discussion to be a waste of time because the GCE examinations were so close.

A major concern of the students in the Maldives was the GCE examinations. Many students noted that in all other subjects the teachers were rushing around to complete the syllabuses and in physics the teacher was not at all concerned about completing the syllabuses.

M8, a boy in New Zealand was not interested in the sessions. According to him he had completed the major part of his assessments for the Sixth Form Certificate and he was not interested in the physics activities any more. He once walked out of a session. When asked why he said that he never liked physics and made the following comment about why he was studying physics at sixth-form:

> Because they [his parents] think that it [physics] is practical that I take a science. But I am not a scientific minded person. I can do maths extremely well, but science, I don't really find complete. I don't think they answer things well enough. I can understand mathematical theories in physics. But when we get to the scientific

> side of things, I don't really understand. (M8, boy, New Zealand, 22/10)

It appears that the only students who expressed serious concerns about the teaching style were M15 and F5 from the Maldives, and M7 and M8 from New Zealand. The majority of the students appeared to have a positive view of the contextual strategy used during the classroom interventions. In the next section student learning as indicated by the pre- and post-tests is discussed.

6.7. STUDENT LEARNING DURING THE INTERVENTIONS

This section presents the data from the pre- and post-tests. The written answers of students were clarified through informal conversational interviews with individual students. Except in case of 3 boys (M4, M13, M25) in the Maldives students' written answers were the same as their oral answers. M4 and M25 suggested slight modifications to their answers in the pre-test and M13 claimed that he misread a question and changed about one quarter of his written answers to the post-test. These amendments were considered in marking the tests.

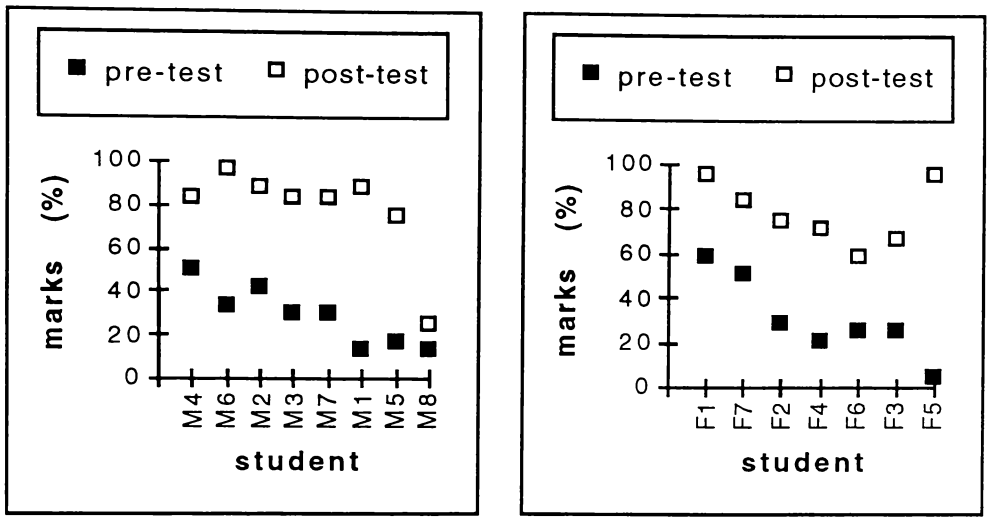
The test results of the New Zealand sample are shown in the following figures. Figure 6.2 compares the pre-test and post-test results of students in New Zealand. Figure 6.3 compares the post-test results of students in New Zealand to their average performance in other units[1]. In each figure students are arranged according to their classroom performance in former tests and assignments. The student with the highest average mark is to the extreme left of the figure.

Students in the New Zealand sample generally performed the same or better in the post-test compared to their average performance in the class. Except for M8 who was not interested in studying physics all the weaker students performed considerably better in the post-test. They achieved post-test marks comparable to those with higher average scores. Two girls (F3 and F5) with low average scores achieved post-test marks comparable to those with higher average scores. Students with higher average scores continued to perform well during the

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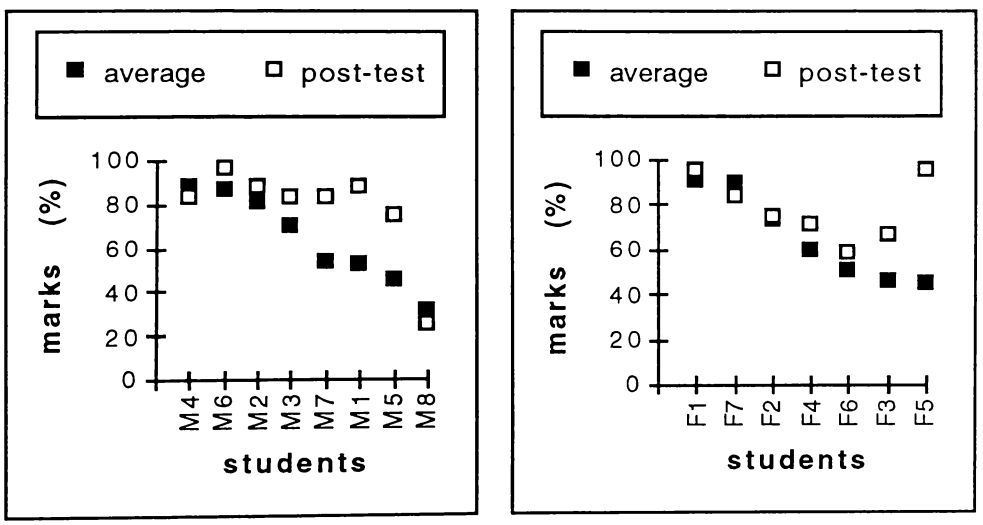
[1] The average was calculated from the scores of 4 class tests 2 assignments and 2 lab-reports in New Zealand.

intervention. A similar comparison for students in the Maldives is made in Figure 6.4 and Figure 6.5 and the same trend can be seen in them.



a) Boys b) Girls

Figure 6.2: Pre-test and post-test results of students in New Zealand



a) Boys b) Girls

Figure 6.3: Post-test results of students in New Zealand compared to their average performance.

Students in the Maldives sample too generally performed the same or better in the post-test compared to their average performance[1] in the class. The pre- and post-test results show the weaker students to have made considerable improvements in the performance. Except 3 girls and 2 boys (out of a sample of 46 students) all

[1] In the Maldives the aggregate total of all class tests and assignments prepared for the Grade 9 promotion test was used as the average.

students with lower average scores achieved marks comparable to the high-achieving students. The high-achieving students continued to perform well.

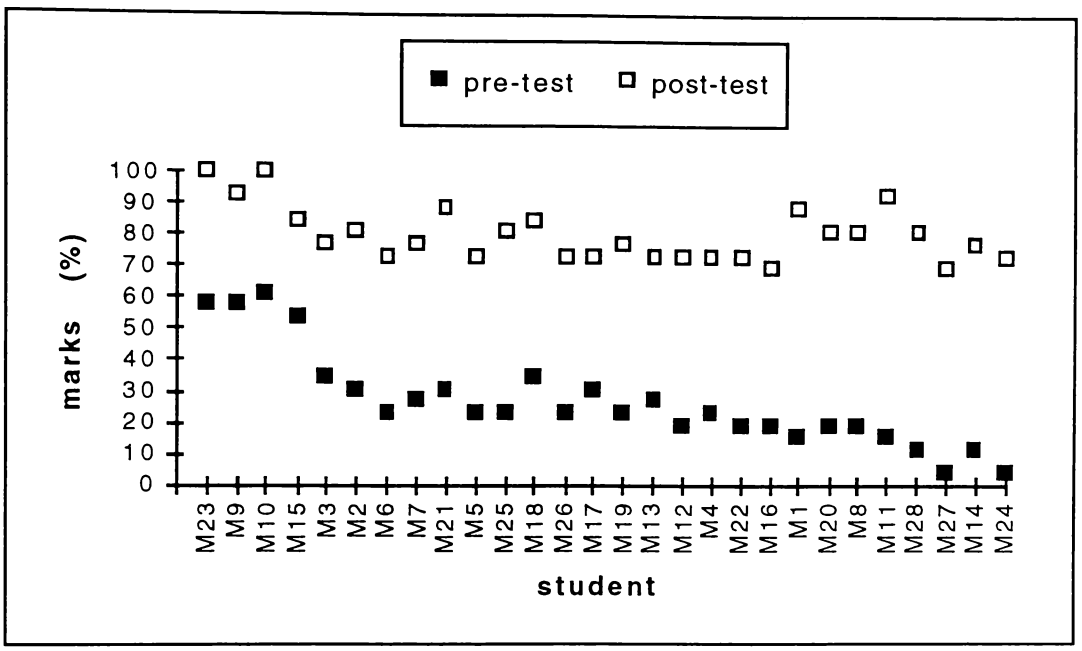


Figure 6.4a: Pre-test and post-test results of boys in the Maldives

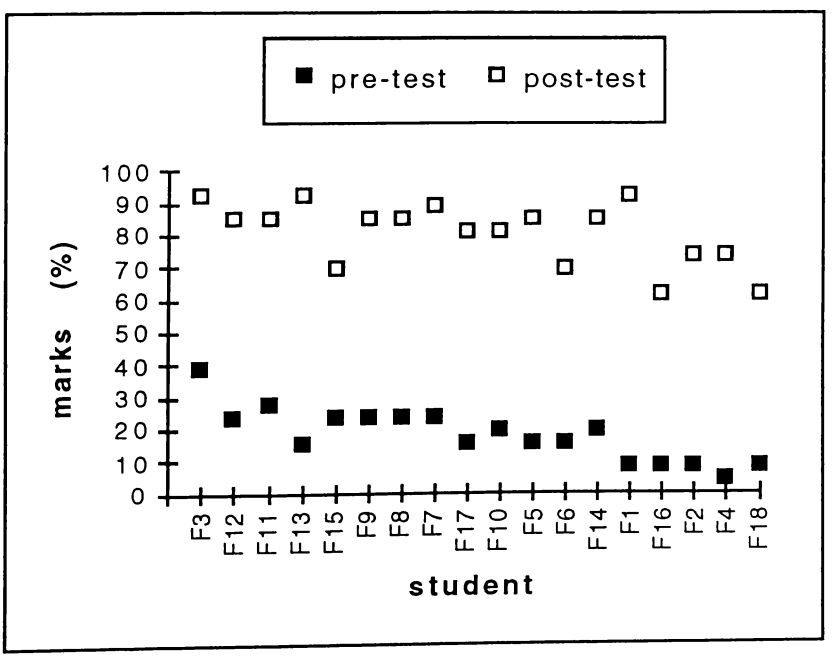


Figure 6.4b: Pre-test and post-test results of girls in the Maldives

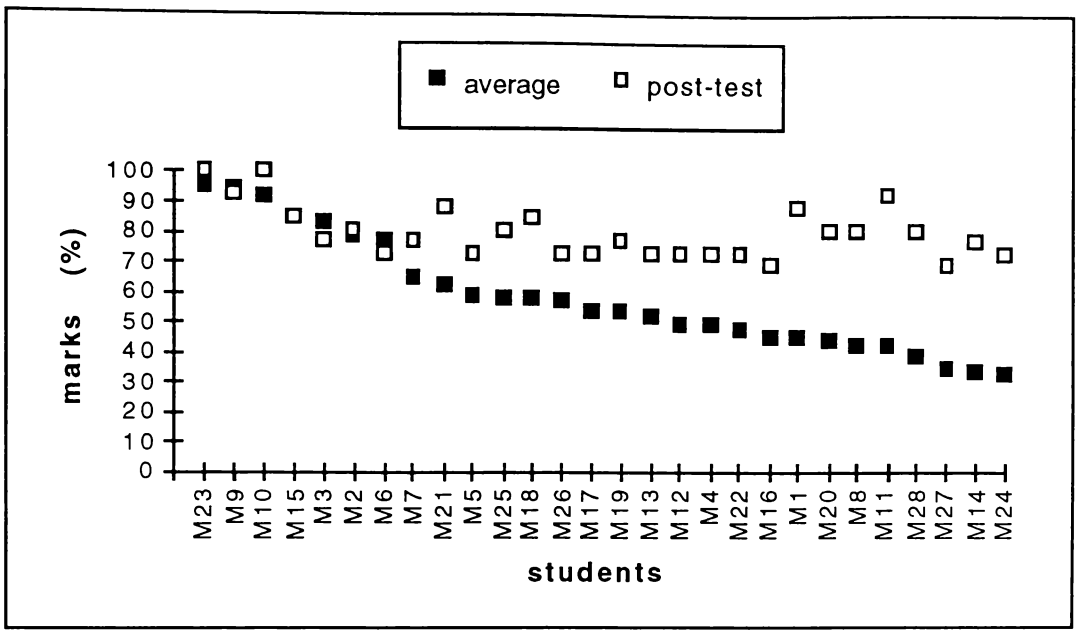


Figure 6.5a: Post-test results of boys in the Maldives compared to their average performance

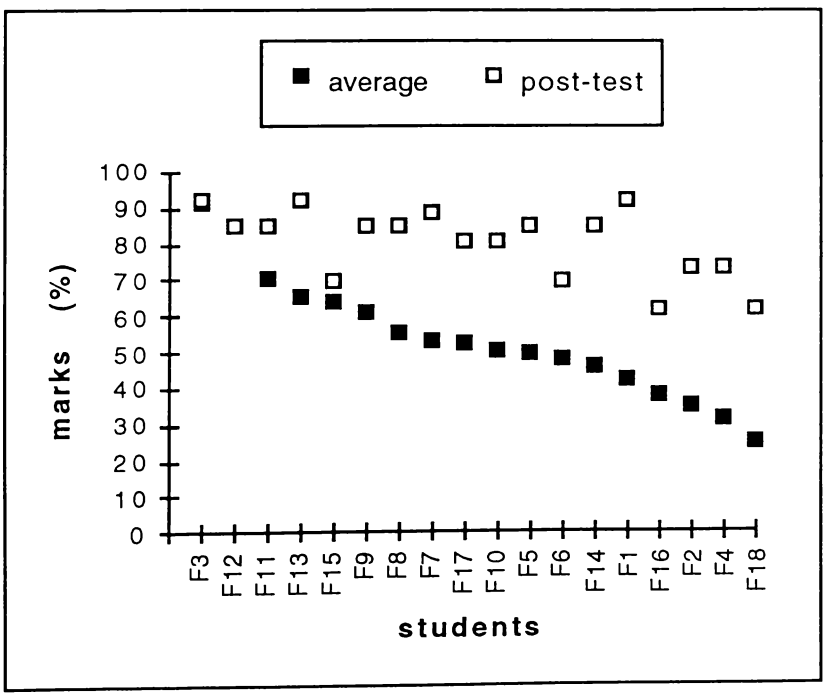


Figure 6.5b: Post-test results of girls in the Maldives compared to their average performance

The pre- and post-test results indicate enhanced cognitive outcomes for most students, particularly for the weaker students. The implications of the outcomes indicated by all the instruments used during this phase of the study are discussed next.

6.8. OUTCOMES OF PHASE THREE AND THEIR IMPLICATIONS

The data generated form this phase of the study has to be interpreted within the following constraints:

- The sample from the Maldives consisted of two single-sex classes, and the sample from New Zealand was from a single coeducational class.
- The teacher in New Zealand was unable to concentrate on the use of the contextual teaching strategy.

Certain student behaviours normally associated with learning were observed more frequently during the interventions than in other physics sessions. Students appeared to participate more in classroom activities during the interventions, and were observed to ask more in-depth physics questions during the interventions. Some weaker students appeared more confident about their learning, and more debate about physics-related issues were observed. These observations were made by the researcher in the Maldives, and the teacher and the researcher in New Zealand. Similar observations were made by students in their responses to the questionnaires and also during the informal conversational interviews.

Two features of student questioning deserve further comment:

- Student questions were often related to contexts which were not part of the teaching package, e.g. TV, VCR, computer. This provided a method of enriching the package by introducing further topics or microcontexts related to student interest.
- Exploring student questions inside the class, however, had to be managed considering the available time and the nature of the class. High ability students who were accustomed to the normal style of teaching did not like spending too much time on exploring student questions.

Students in the two samples considered the classroom activities and the teaching approach used by the teachers to be different from normal classroom practice. The students, particularly those in the Maldives, claimed to have participated more in the classroom activities during the interventions compared to other physics classes.

The weaker students in the two samples were noted by their teachers to responded positively to the contextual teaching strategy. The students were noted to gain confidence and to participate more in classroom activities. The students associated their increased motivation in the classroom activities with the contextual teaching strategies. There were no gender differences observed. It must be noted that gender differences will be difficult to observe in the Maldives sample where two single-sex classes were monitored.

Students who performed well in normal physics classes continued to enjoy the contextual approach to teaching and to perform well. A few high achievers in the Maldives were unsure about their learning during the contextual teaching approach and were concerned about their preparedness for the GCE examinations at the end of the year. The high achieving students in the two countries performed well in the post-tests and the weaker students made significant improvements in their performance in the post-test. One boy in New Zealand who was not interested in physics did not perform well in the post-test.

Students generally associated their increased motivation to participate in the contextual classroom activities to the following features of contextual teaching:

- the interactive nature of the activities;
- the hands-on nature of the activities;
- the use of everyday applications to introduce the theory; and
- the every-day nature of the contexts.

The lower levels of motivation in the New Zealand sample may be explained in terms of the teacher's administrative role making it difficult to find time for these features of contextual teaching in his classroom.

Within the constraints specified at the beginning of this section the outcomes discussed above indicate the following:

- Using the contextual approach for the teaching of senior secondary school electromagnetism in the two countries enhanced the cognitive outcomes of most weaker students and those who normally performed well in the class continued to do so.
- The majority of the students enjoyed the contextual approach to teaching and learning, and a marked increase in the motivation of weaker students was observed.
- Student questions may be used in contextual teaching to identify contexts that interest students. However, these questions need to be managed considering the available time and the nature of the class.

The next chapter reports the outcomes of Phase 4 which was designed to research in detail teachers' reactions to the new strategy of teaching, particularly their difficulties.

CHAPTER SEVEN

PHASE FOUR: REACTIONS OF TEACHERS TO CONTEXTUAL TEACHING

This chapter documents the research conducted during the fourth phase of the study. The chapter begins with an introduction, and details the sample of teachers and the data-collection procedures. The reactions of teachers to the contextual approach are then documented. Reasons for using the contextual approach, the strengths of the new approach as perceived by the teachers, and the difficulties they faced in using the approach are discussed. The chapter concludes by summarising the outcomes of this phase of the study.

7.1. INTRODUCTION TO PHASE FOUR

During the initial classroom interventions some difficulties faced by the teacher in the Maldives were noted. However the interventions were more focused on studying how the contextual classroom interventions influenced the cognitive and affective outcomes of students, and difficulties faced by teachers were not closely monitored. This phase of the study was designed to look more closely at teachers' reactions to contextual teaching and the difficulties associated with teacher change.

7.2. SAMPLE AND DATA COLLECTION IN PHASE FOUR

The research sample for this phase of the study comprised the following teachers:

- A senior physics teacher, A1, from Hamilton, New Zealand, teaching a Form 6 class of mixed ability boys and girls. He had observed the researcher teach

his class during the first phase of the study and was expected to have a working knowledge of the contextual teaching strategy.

- A senior physics teacher, X1, in Malé, Maldives, who was teaching a Grade 10 class of high ability boys. He was completely new to the teaching strategy.
- A senior physics teacher, Y1, in Malé, Maldives, who was teaching five Grade 10 class of mixed ability girls. He was completely new to the teaching strategy.

All the teachers used the teaching resource designed for Phase Three in their classes. A1's class was the research class in Phase Three. Phase Three and Phase Four of the study were conducted concurrently.

Data from the sample of teachers was collected through informal conversational interviews conducted continually during the use of the teaching resource. Some classroom sessions were observed by the researcher.

7.3. REASONS FOR USING THE CONTEXTUAL TEACHING APPROACH

The three teachers had different reasons for using the contextual teaching approach. A1 from New Zealand had seen the researcher teach the unit during the previous year and was convinced of the strengths of the new approach. When the researcher initially suggested the idea, X1 from a boys-only school in the Maldives was not prepared to accept the new strategy as an alternative to his normal method of teaching electromagnetism. He was a senior teacher who was successful and respected by his students, colleagues, and administrators. However, on further reflection he was convinced that the new approach may be as effective as his method of teaching and wanted to experiment. He said:

> When you suggested this method, starting from the telephones, speaker, microphone, etc. to build up the teaching of electromagnetism I was not prepared to buy that idea first. Then I invited you to a discussion with the rest of the physics teachers. Also, even before that I have many discussions with you. In all these discussions, gradually I came to realise that there is a point [in teaching physics through applications] ... So I saw that as something which has to be tried, which can be tried. After convincing myself of that only I accepted it... (X1/17/5)

X1 also had to convince himself that the approach was "acceptable in terms of modern educational psychology" before he tried it. He said:

> There are two approaches which can be classified as acceptable methods of teaching in terms of modern educational psychology. One needs to start from the raw environment—raw nature. The other is through applications. Raw nature means, in this particular context we are going to talk about, it is just a current wire, a magnet, or magnets and we build up our ideas. Then come to the point of the speaker. The speaker comes out as an end product, in one of the side lines....
>
> The other one [the contextual approach] you have brought us is through applications. So there is no doubt that method has to be tried and seen the success, whether it is succeeding or not. (X1/17/5)

Y1 from the girls-only school in the Maldives was concerned about the routine nature of his teaching and the lack of student-initiated interaction in his normal physics classes. He considered the contextual learning and teaching environment to be more student-centred than his normal physics classes and was eager to try the new strategy. He said:

> [In our previous method of teaching] we don't have to refer up or think about anything we just go. It is a pattern of teaching and for the children to take down notes to understand what we show them —demonstrations, mostly demonstrations— and there is a set pattern in our minds. There is no necessity for organising things in our minds. Here a new environment is created by the children. Their thoughts come to us. As a result we have to organise ourselves every moment. So it's dynamic. (Y1/4/4)

7.4. STRENGTHS OF CONTEXTUAL TEACHING

The strengths of contextual teaching, identified by the teachers, were as follows:

- Contextual teaching motivated students.
- Students appeared to be learning more when contextual teaching strategies were used.

These views are explored further in the following sections.

7.4.1. Students were more motivated

According to Y1 in the Maldives his class appeared to be more motivated and more inquisitive about the physics aspects during the trial unit when compared to previous classes who had studied electromagnetism with him. He observed his students to be more eager and more inquisitive about the classroom activities, and expected them to be learning more. He said:

> Compared to last year I always feel that the children are more alive. To come to the lab even. They are very keen to come and to inquire as to what's happening and to find out everything. If there is an apparatus set-up and all they'll want to know. Before I talk about it they will want to know everything about it. They come rushing into the lab. A lot of motivation is there.... The children are coming in a large way. They are bringing everything I want. I only have to tell them at the correct time. The interest is so much, sometimes, when I told them to bring telephones, I think I can now put up a shop of telephones. They are very keen. (Y1/18/4)

Y1 speculated that the increased eagerness and the inquisitiveness was due to the new style of teaching. He explained this view by comparing the motivation of the same group of students during the previous unit of work and during the unit on electromagnetism:

> Earlier I noticed that when they come to class I have to repeatedly go on telling them what we were doing. They did not come with an open mind... Now they are ... ready to accept what is being done here with an open mind. So there is definitely a difference.
>
> So I think half of my job is done because once that interest is in the majority, the rest who are not interested also joins them. (Y1/18/4)

A1 in New Zealand and X1 in the Maldives made similar observations about student motivation. According to X1 his students enjoyed the contextual approach more than the traditional approach. He said:

> They really enjoyed the classes. They liked it. Some of them brought walkie-talkies and speakers and they asked me to try their own speakers also to show the vibrations and so on and making speakers too. Although initially there was a sort of lack of inclination towards spending time on it, later they did enjoy the program. (X1/8/4)

X1 also noted that student motivation was never a problem in his classes. He was always able to reach out to almost all his students in his class and to make them interested in his physics lessons. He said:

> Well. [In] my normal teaching, I believe, almost all of them are involved. But there may be instances where one or two fellows are not interested in this or that. But finally they are incorporated in that venture. (X1/17/5)

7.4.2. Students appeared to be learning more

A1 and Y1 felt that the students exhibited behaviours they associated with learning more frequently during the contextual teaching process. X1 did not expect his students to be learning any more as a result of using the new teaching strategy.

Y1 observed his students to engage more with the physics aspects during contextual teaching. For example some students, after the session discussing how they thought the speaker to work, brought to class circular magnets removed from speakers. The students wanted to use iron-filings and plotting compasses to observe the field around the circular magnet because they had difficulties in visualising it. That was exactly what the teacher was planning for the session. He said:

> This is real physics. Now these children have gone home, thought about this and I didn't tell them. I wanted it to come from them. So they brought it today; the circular magnets. And they were all looking at the radial field formed by the circular magnet by sprinkling iron filings and of course by using the magnetic compass needle also. So that was very good. That was something I used to notice. In an earlier class that type of an approach was never there. (Y1/11/4)

Y1 stated that he had to be careful with his comments as students displayed a better understanding of the concepts and frequently challenged his explanations. He also noted that students asked more questions about everyday applications, and more detailed physics questions. Y1 described an incidence when some students wanted to know how the rules for detecting the direction of magnetic fields were derived. This was not required by the syllabus. However, when the students insisted he explained to them. To his surprise many understood the derivations and some of them were able to use the first principles instead of the rules. He noticed this behaviour in students of all abilities; not only in the brighter students. He said:

> You know when we came from the grip rule and to the Fleming's left-hand rule and the slap rule, they were a little reluctant. After the

> grip rule they have understood so well about the solenoid and the straight wire, they were a little reluctant to accept the left-hand rule at once. Thy said why do we have to study conventions. You tell us what is happening there. This is something that I didn't notice before. Earlier also there will be one or two smart students asking why is the wire going out, why is the loop going out, what is the reason, what are the forces acting here, tell us the forces that are acting here. That type of thing used to come from the brighter students. Now I see that they are not directly accepting what you say....
>
> [A]bout the left-hand rule, they said that this is a convention only that you are talking about; tell us why it is happening. That took me by surprise. I didn't accept that to come from them at once like this. So I was just thinking that [the question was only from] this particular child and the people behind who joined her in a group around one table in the lab. But the other tables joined in, tell us the reason. So that type of free thinking is coming which I feel very pleased with. So then I had to explain to them what it was and they were very happy after I explained about the nullifying effect at the one side and the adding effect on the other side. Then they said that's right. Now we do not want the left-hand rule. We are not interested.(Y1/12/5)

Similar observation was made by other teachers, and the reported incident was similar to one in the New Zealand class during the initial classroom interventions.

7.5. TEACHERS' REASONS FOR THE STRENGTHS OF CONTEXTUAL TEACHING

All teachers agreed that compared to more traditional approaches, the students, particularly the weaker students, appeared more motivated during contextual teaching. A1 and Y1 thought that the greater intrinsic motivation in their students produced enhanced learning outcomes, but X1 did not consider this to be true for his group of high achieving boys. Their reasons for the increased student motivation are now discussed under the following headings:

- Use of contexts made physics relevant.
- Engaging students with the technical aspects of contexts before teaching the physics aspects motivated them.
- Other reasons.

7.5.1. Use of contexts made physics relevant

A1 and Y1 speculated that students were showing more interest in the topic because the use of contexts from their everyday life enabled the students to see the relationship between the practicals and the theory. A1 said:

> I certainly think they are showing more interest in what's happening because we are discussing a device that is of relevance, specially having made one. I think they can see the relevance of the theory to the practicals they are doing. A more traditional approach would be, I guess, using the lab to demonstrate the facts and then showing this has applications in these devices like loudspeakers, motors, electrical meters and so on. I see the main difference in this is that we are starting with an interesting device, we have taught how this is expected to work ... then going to the theory of it and keep referring back to it and I think these students are showing more interest in the whole idea because of that. (A1/4/11)

Y1 shared the above view. He compared student interest in a unit of work that he completed before starting to teach the unit on electromagnetism:

> In the [unit on] oscilloscope and a.c. [alternating current] ... they were not participating ... there was hardly any reason for them to study... At least from the child's point of view they don't see a reason why they should do the oscilloscope. But the [unit on] electromagnetism that they are studying now they have a reason for studying. They feel that it is something that we have to know. It is nothing outside our area [everyday life], this is something that in our day to day life we are moving with this type of thing. I think the reason is inside them. So that is why I say they are very interested in them. (Y1/18/4)

X1 also noted that the contexts had a "real base in the minds" of the students in the Maldives and hence the method was "all right" (X1/8/4).

7.5.2. Engaging students with the technical aspects of contexts before teaching the physics aspects motivated them

According to X1 engaging students with the technical aspects of making the speaker stimulated the students and generated an interest in the physics of the speaker:

> And I believe that particular class where we prepared the speaker and then saw the movement of the coil on the magnet at a low frequency and so on have stimulated a lot of interest in the matter.

> In fact I found the coil movement in the magnet stimulated a lot. Because they saw that themselves. (X1/8/4)

The above view was shared by the other teachers. A1 noted that he always used applications in his teaching of physics, but only after teaching the relevant physics. According to him starting off with the application before teaching the physics was more effective in engaging students with the context:

> I think it is most interesting to the students if they can relate scientific concepts to some context, some equipment, life experiences of theirs. Now in the past I have done it that way around. I tended to teach the subject contents and then introduce the contexts later. 'And we have learnt about electromagnetism by the way did you realise this is why such and such happens in a loudspeaker?'. And this is the way I have been developing this unit and other units.
>
> Now we have tried the other way in that first you introduce the context and then ask 'would you like to know how it works, now let's find out what's inside it', and eventually get to the stage where you can get some scientific concepts out of what you are investigating. Now I think most students are more motivated and more interested in doing it this way. (A1/19/11)

Y1 speculated that engaging students with the various components inside the devices made students want to know what was going on inside them. This need to find out motivated students to learn the relevant physics.

7.5.3. Other reasons

All the teachers noted that the practical and hands-on nature of the activities, and the greater freedom given to the students during the activities may also be responsible for the increased student interest and engagement. According to them any teaching strategy that incorporates these elements would motivate students.

7.6. DIFFICULTIES IN USING THE CONTEXTUAL APPROACH

According to teacher X1 in the Maldives the new approach was like "cutting across the landscape of electromagnetism by a different path" (X1/15/4). As an

experienced teacher he already had a systematised strategy that worked relatively well for him, and the uncertainty associated with contextual teaching made its use initially unattractive for him

> It is a new approach so the path has to be cut. You come to a point and you realise that you haven't prepared the background for it and then you have to go back. In a normal approach, you've already systematised everything. (X1/24/4)

The problems faced by teachers were generally related to the structure of the teaching unit, and the management of student questions.

7.6.1. Problems related to the structure of the teaching unit

The teacher A1 in New Zealand had initial fears that a contextual learning environment may become "chaotic" and "unstructured" when students are allowed to choose contexts that interest them. However after observing the researcher teach his class during the initial classroom intervention he considered the teaching unit on electromagnetism to be "very structured" and "very manageable". According to him his initial fears were common to many of his colleagues:

> We talked about this in the physics meeting last night. The physics teachers were worrying about if you let the kids pick the context then you are going to have a tremendously wide open and chaotic situation with kids investigating cathode ray tubes and investigating amplifiers and there is going to be no structure and we were not convinced that there will be no real learning. (A1/3/11)

The structure and the organisation of the contextual teaching unit was different from the normal teaching units. While A1 and X1 structured their units of work along predetermined conceptual hierarchies, the contextual teaching unit was organised along contexts, applications, and themes. X1 from the Maldives considered the structure of the unit of work to be complicated and made the following comment:

> Well this is the first time, I believe, some of us are trying to approach the concepts of physics through applications. Of course, we are normally used to approach physics through activities. We start with experiments and then build our concepts based on the observations the students make. But this is a sort of novel approach where we try to approach a body of knowledge of physics through applications. For example, we take the telephone and focus our

> attention on the speaker and then from there lead our students to magnetic field, etc., that's quite a complicated task. (X1/8/4)

According to A1 the structure of the teaching unit appeared complicated because he was initially attempting to impose a framework based on a conceptual hierarchy on the contextual teaching unit. This made him switch back to his normal mode of teaching. However, when he started picturing the structural overview of the unit in terms of the contexts and themes, he found no more difficulties in using the contextual approach. According to him this resulted in a complete turnaround from the way he was working previously:

> In my previous approach, I tend to think in charts and structural overviews. So the structural overview in this [unit] would have started out with the word electromagnetism and then some diagram of a wire with a current going through it and a wire around a rod to turn it into a magnet and a wire near a magnet and then a magnet moving near a solenoid connected to a meter. And that's how I would start off with the senior kids and then I would get out of that the idea that these are some of the things that connect together and then build up the laws and then get to the applications.
>
> But now I think the diagram in my mind is the cut-away speaker and there would be lines to what's happening here, what's feeding into it, what's feeding out of it, how is it happening and get the concepts from the actual working device. Which is a complete turnaround from the way I was working. (A1/19/11)

By the end of the teaching unit X1 also indicated that his perceptions of the structure of the teaching unit had changed.

Y1 was used to structuring his teaching along themes and applications and did not find the use of the contextual approach complicated.

7.6.2. Problems in managing student questions

In his previous approach X1 was able to predict student questions and to structure his teaching so as to answer the questions as they were asked. Normally X1 organised his lessons along a sequence of physics concepts, and student questions were related to the concept that was being discussed. However, the lessons in the contextual learning unit were arranged along themes and contexts and student questions were related to the context that was being discussed. As a context may

bring together several areas of physics, student questions were not limited to a particular concept of physics at a given time. He said:

> And the students also ask questions now here and there. You feel that you have to always tell them to just wait for sometime. That problem is not there in the former teaching. You will be preparing everywhere and marching forward. So the student base is Okay. And any question the student is asking is purely inquiry-type and is in the right direction. But here you can not answer the question; you can not simply afford to spend the time in answering the question there. It's something which you are going to explain after sometime. Probably after a few periods. But that can easily be avoided if one goes through this once and establishes the pattern. (X1/24/4)

X1 found difficulties in managing student questions. He found that for effective contextual teaching he could no longer answer all questions immediately. Being used to predicting student questions and answering them as they were asked, he found it difficult to delay answering questions He said:

> Here I am not prepared to tell the child when he asks, why a coil is experiencing a force in the presence of a magnet. I am not going to answer him... Because I would like that to be left to that point where two moving charges attract or repel... So this is a sort of an embarrassing situation for me as a teacher... The fact remains that we are starting from the centre of the course, that is, magnet-current interaction. (X1/29/4)

Finally X1 adopted the strategy of grouping student questions into categories based on physics concepts. Although the questions were related to the context he delayed answering certain questions until such time that the concept was generally studied.

Students asking questions about different physics ideas at the same time was not considered a problem by A1 and Y1. They noted that these questions were generally asked during the focus phases and the challenge phases when introducing and discussing the contexts. They often reflected the questions back to the students to probe their prior understanding before teaching the relevant physics. During the latter parts of the challenge phase when the components of the applications (like the magnet in the speaker) were studied, student questions were focused to specific concepts (like magnetic fields, ferromagnetism, lines of force) as in normal classroom practice. Furthermore, these questions were used by the teachers to identify more contexts that students consider relevant.

7.6.3. Other problems

According to A1 and X1 they may never have attempted the new style of teaching if not for the presence of someone to help them throughout the intervention.

X1 considered a proper understanding of how to interrelate the contexts and the physics to be essential in using the contextual approach. He clarified his view as follows:

> It is not a very easy task for all teachers, in my opinion, unless somebody takes an effort to give a coaching on this matter. There is always a tendency for teachers to jump from the speaker straight to magnet-magnet interaction. They will not reap the benefit of the speaker...
>
> The whole idea of bringing in the speaker, in my opinion is, the speaker has some concrete reality in the minds of children here in Male'. Or the telephone or telecommunications. It may not be so in a distant island. I think in this approach we have assumed the present technological development is part of our nature... We accept telecommunications, radio, television, walkie-talkie all this as part of our environment; in a sense as an extension of this nature... So if the ideas that are going to be developed subsequently are not properly linked, properly started from the speaker, then the purpose is lost. (X1/8/4)

While X1 was particularly concerned about linking the concepts of physics and the contexts, A1 had more day-to-day problems. A1 did not have enough time to reflect on the new style of teaching because of other urgent demands on him by the school administration, and he was unable to fully utilise the contextual approach:

> I really need more time to prepare myself before each unit and before each lesson. I am not exactly happy with the amount of effort that I have put into handling your unit. I really should have put in more effort into preparing myself and being ready and handling the unit in a particular way. And again it is because it is this time of the year where there is so much work being done in the senior classes in terms of preparing them for the exams and assessing them and getting the marks sorted out and so on. I just did not have the energy or time to prepare in a more efficient way. So certainly part of the problems were in my making in the sense I did not have the time to prepare as well as I would have liked to have done. That has got nothing to do with the material you have provided. It just shows that it is impossible to pick up a new document, a unit and teach it efficiently without spending time preparing it obviously. Preparing equipment. (A1/19/11)

The difficulties A1 and X1 faced in using the contextual approach to teaching were generally related to getting used to the completely different way of structuring the teaching activities. Although A1 finally got used to the new structure, X1 had difficulties even by the end of the intervention. During the final interview X1 said:

> Personally I have another problem. That is, even if I am going to give a platform speech ... I don't like to take notes ... and I don't want to look at my notes in a lecture. That doesn't work well with me and I will never get anywhere. I have to *structure* that in my mind and go there and one after the other, it has to come to my mind. If it doesn't, there is something wrong.... It should be connected in such a way, even when the speech is going on then those ideas come one after the other on its own it gives a lot of inspiration and the speech becomes much better.
>
> Same thing with the classroom teaching for me. So if I take down the points that go in and deliver it to the class, I will not be able to give a successful class....
>
> So for that [contextual] approach, when you start from such centres [centre of the topic], massive work has to be done first, and then it has to be structured in your mind and that has to become mine, you know what I mean? It is a long process, probably my age also counts nowadays. Suppose I am a younger person, then I might have tried it better. (X1/17/5)

When asked whether he would use the contextual unit for teaching electromagnetism next year he said:

> I have not decided yet. I may choose this method, I may not choose. I reflect upon this often. So even after some time when we take up another topic like nuclear physics, still my mind would be working on this. So it is a process which takes place in my mind and finally it has to sort out. So when that does instinctively associate itself with me, that particular approach, then only I will take it as my natural method. Not otherwise. (X1/17/5)

Although teacher X1 had reservations about using the contextual approach teachers A1 and Y1 considered the contextual approach to have several strengths that made it more effective in teaching electromagnetism than their normal strategies. They felt that their students enjoyed the contextual approach more than the normal teaching approaches, and that they learnt more physics.

7.7. OUTCOMES OF PHASE FOUR AND THEIR IMPLICATIONS

All teachers considered the students to be enjoying the new style of teaching. A1, teaching a mixed ability mixed class, and Y1, teaching mixed ability girls-only classes, considered their students to be learning more in the contextual teaching than in their usual physics classes. They noted a marked increase in the motivation of the weaker students. X1, teaching a boys-only high-ability class, noted his students to be more motivated during his use of contextual teaching although he did not expect them to learn any more due to this increased motivation.

The teachers observed a marked increase in student interest in the technical aspects of the applications after engaging them with contexts prior to the teaching of the physics associated with them. This was also noted by all teachers after building the working model of the speaker.

The above observations are similar to the outcomes of the previous phases of the study and increase the consistency of the outcomes. However, the main aim of this phase of the study was to explore the difficulties faced by teachers when using the contextual approach to teaching.

The problems faced by teachers were generally related to the structure of the teaching unit and the management of student questions. The following observations may be made from an analysis of these difficulties

- Contextual teaching requires teachers to organise the lessons along themes.
- During contextual teaching student questions may not be limited to particular concepts of physics. Some questions may be related to contexts that integrate several concepts of physics.
- Student questions during contextual teaching are the main indicator of contexts that may interest students.
- A teacher who is used to organising lessons along conceptual hierarchies may find it difficult to understand the structure of contextual teaching activities structured by themes rather than by concepts.
- A teacher who is used to organising lessons along conceptual hierarchies may need to develop strategies for managing student questions that are not focused on a specific concept. The strategies may include delaying answers to some questions and leaving others for exploration as class projects.

The teacher change required for using the contextual approach to teaching may be complex. However the continuous reflection of the teachers with the researcher on the classroom activities appeared to be a successful strategy for facilitating this change.

The strategy used by the researcher was similar to that used by Bell (1993). She reported that when teachers shared anecdotes about their teaching activities with other teachers they went through a development process. However, she also observed the process of teacher change, required for engaging with students' ideas, to be complex as it required professional, personal, and social development on the part of the teacher.

The next chapter brings together the phases of research and outlines further research possibilities.

CHAPTER EIGHT

CONCLUSIONS

This chapter brings together the findings from the four phases of this study and examines how these findings inform the research questions. The chapter also outlines some implications of these findings for further research.

8.1. INTRODUCTION

The purpose of the research study was to explore the process of contextual teaching and its outcomes in physics classes at the secondary school. Recent research indicates that the use of contextual teaching strategies in science and physics classrooms enhances affective and cognitive outcomes. However these research studies were conducted in western countries, using teachers who were experienced in the use of contextual strategies. Although these studies indicated that teachers and students may face difficulties in using contextual teaching strategies, very little information about the nature of these difficulties was provided.

This study was designed to compare the process and outcomes of using contextual teaching strategies in a western country and a non-western country; New Zealand and the Maldives respectively. The study was also designed to clarify the difficulties teachers may face in using the strategies for the first time.

This research was conducted in four iterative phases. The first phase was designed to study the targeted student population in New Zealand and the Maldives. The aim was to explore student interests in technological contexts that they consider relevant. Student samples from Grade 10 and Grade 11 physics classes in the Maldives and the corresponding Form 5 science and Form 6 physics classes in New Zealand were chosen. An area of technology common to the two

countries—telecommunications— was used for the study and the following research questions were posed:

Research questions about relevant technological contexts:

1. What applications in telecommunications interest Grade 10 and Grade 11 physics students in the Maldives and the corresponding Form 5 science and Form 6 physics students in New Zealand?
2. What reasons do students suggest for their interest in these applications?
3. What cultural and gender differences are observed in the above?
4. How do the above interests and ideas inform the process of contextual teaching and learning in physics?

The findings from the first phase were used to compile contextual classroom interventions that were trialed in a Form 6 mixed-class in New Zealand and a Grade 11 mixed-class in the Maldives during the second phase of the study. The findings from the second phase were used to design the next two phases of the study that explored student and teacher reactions to the use of contextual teaching. The second, third and fourth phases were developed to explore the following research questions:

Research questions about the use of the contextual classroom interventions at senior secondary school physics classrooms in the Maldives and in New Zealand.

5. How do teachers and students respond to contextual learning and teaching strategies advocated by the interventions?
6. What difficulties do teachers and students face in using the contextual learning and teaching strategies?
7. What are the affective and cognitive outcomes of using the contextual learning and teaching strategies in mixed-ability classrooms?
8. What cultural and gender differences are observed in the process and outcomes of contextual teaching?

The sample for the third phase of the study comprised of Form 6 mixed-classes in New Zealand, a boys-only Grade 10 class and a girls-only Grade 10 class in the Maldives. The sample for the fourth phase of the study comprised of a teacher teaching a coeducational class in New Zealand, teachers teaching a boys-only Grade 10 class and a girls-only Grade 10 class in the Maldives.

The findings from the different phases of the study are discussed next.

8.2. THE RESEARCH FINDINGS

Research questions 1 to 4 were specific to Phase One of the study and the rest of the research questions were explored during the other phases. The following sections discuss how the findings from the individual phases of the study inform the research questions.

8.2.1. Questions 1, 2, 3 and 4: Student views about relevant technological contexts

Students were interested in applications in telecommunications, used for the interviews during the first phase, for a variety of reasons. These reasons often merged and inter-mingled. Some reasons were associated more with certain applications than others.

Reasons for student interest in applications used in telecommunications were similar in the two samples in spite of socio-political and economic differences between New Zealand and the Maldives. In both samples students were interested in technological applications that:

- were perceived to be useful to the students' needs;
- were perceived to be relevant to societal concerns;
- were considered new or modern; or
- the students were inquisitive about how they operate.

Similar reasons for student interest were noted by Jones (1988) who studied student interest in a wide range of technological applications in New Zealand. The compatibility of the outcomes indicate a consistency in student interest in technological applications at senior secondary school levels in New Zealand and enhances the reliability of the data collected.

No significant gender differences were noted in student interest. However as noted by Jones (1988) boys appeared to be more interested in technical contexts than girls in the two samples.

Although the reasons for student interest were similar in the two countries specific features that shape these interest—student's needs, concerns, and views— were different in the two countries. Because of this difference student interest in particular applications was different in the two countries.

The similarity in student interest in technological applications in the two samples indicated that similar contextual teaching strategies may be successfully used in physics classrooms in the two countries. Classroom interventions designed to test this possibility took note of the following:

- As a given technological context may not be relevant to all the students in a classroom, several inter-related contexts need to be used in contextual teaching and learning.
- When opportunities for learners to engage with the technical aspects of a context are provided early in the teaching and learning process, interest in the technical aspects may be developed in most students.
- Technological contexts relevant to the majority of the learners in senior secondary school physics may be chosen by considering the categories of student interest.

The curriculum area of electromagnetism was chosen for the next phases of the study. Classroom activities were designed based on the three-phase framework proposed by Cosgrove and Osborne (1985) and a combination of a macrocontext and microcontexts. During the initial interventions, conducted during Phase Two in the two countries, the activities were refined and compiled into a teaching resource. These and the interventions that followed in Phase Three and Phase Four explored the remaining research questions.

8.2.2. Questions 5, 6, 7 and 8: Student reactions to contextual teaching

The outcomes of Phase Two and Phase Three of the study indicate that the contextual approaches to teaching enhanced the affective and cognitive outcomes for the students who previously did not perform well in physics classes. The high achievers continued to perform well and they too were motivated and interested during contextual teaching. There were no significant gender differences. This

finding was supported by comments of teachers who used the contextual teaching strategy in their classrooms. The findings are similar to the findings from similar studies reported in the literature.

The reactions of teachers and students to the classroom interventions indicate the following features of contextual teaching to be responsible for the enhanced affective and cognitive outcomes:

- the interactive nature of the activities;
- the hands-on nature of the activities;
- the use of everyday applications to introduce the theory; and
- the every-day nature of the contexts.

These findings support the speculations made in designing the contextual teaching strategies.

8.2.3. Questions 5, 6, 7 and 8: Teacher reactions to contextual teaching

During the classroom interventions it was observed that different teachers reacted differently to the use of contextual teaching strategies. While some teachers found the use of the contextual teaching strategies to be complex, one teacher experienced minimal difficulties in using the new approach.

The difficulties faced by the teachers were mainly related to visualising the structure of the contextual teaching unit, and managing student questions during contextual teaching. The following observations appear to explain these difficulties:

- Contextual teaching requires teachers to organise the lessons along themes.
- During contextual teaching student questions may not be limited to particular concepts of physics. Some questions may be related to contexts that integrate several concepts of physics.
- Student questions during contextual teaching are the main indicator of contexts that may interest students.
- A teacher who is used to organising lessons along conceptual hierarchies may find it difficult to understand the structure of contextual teaching activities structured by themes rather than by concepts.

- A teacher who is used to organising lessons along conceptual hierarchies, may need to develop strategies for managing student questions that are not focused on a specific concept. The strategies may include delaying answers to some questions and leaving others for exploration as class projects.

8.2.4. Questions 3 and 8: Cultural differences

In spite of the socio-political and economic differences between the two countries student interest in technological contexts and the cognitive and affective outcomes of contextual teaching for students were similar in the two countries. This similarity needs further comment.

It was noted in Chapter 2 that many sub-cultures may interact within the physics classroom and shape the classroom culture. The sub-cultures include:

- *the culture of the society* (the culture of the learners) with its political struggles, minority groups and the resulting dynamics that operate, often unnoticed, to restructure the norms, values and beliefs of the society;
- *the culture of science* and its role in the progress of the society; and
- *the culture of science projected in the science curriculum* (the culture of school science) that is shaped by the norms, values and beliefs of the school system reflected by the politics of the system and the official and unofficial aims of science education.

The culture of science and the culture of school science were almost identical in the two countries. Any possible differences in the classroom cultures in the two countries would be largely due to differences between the cultures of the learners. The similar responses of students in the two countries may be because of similar aspects of the cultures of the learners being related to during the interventions. This may be because students in the two countries had similar experiences of the technological applications used during the interventions. This view is supported by the outcomes of Phase One.

Introducing contextual teaching, however, appeared to challenge aspects of the classroom cultures in the two countries. Teachers and students had to decide on how to react to the changes to the classroom culture imposed by the new style of teaching. For some students and teachers, accepting this change was difficult as

they saw no need for the change: the existing classroom culture served them well. This may explain why some high-achievers were unhappy about the new style of teaching and why the teacher in the Maldives, teaching a group of high-achievers, was not very enthusiastic about the new strategy. This may also explain some difficulties teachers faced in using the new approach, particularly their difficulties in visualising the structure of contextual teaching activities.

All teachers associated positive changes to the classroom culture with contextual teaching. The teacher who faced the least difficulties with contextual teaching wanted to change the classroom culture. Following the teachers who reacted positively to the new style of teaching for the next few years will give information about how embedded the teaching approach has become in their teaching practice.

The new style of teaching was well received by students, who previously did not perform well in the class, probably because they were alienated by the existing classroom culture and may have been wanting some change. The change from normal practice may have been partly responsible for the enhanced cognitive and affective outcomes for the students.

8.3. IMPLICATIONS FOR FURTHER RESEARCH

Recent research studies have successfully used contextual strategies in the teaching of science and non-science subjects in several western countries (see Chapter 2). This study indicates that similar contextual teaching strategies may also be used in non-western societies. However more studies in other non-western cultures would increase our understanding of this complex area, and similar studies to investigate the effectiveness of contextual teaching in other areas of the school curriculum also need to be conducted.

A further fruitful line of research stemming directly from this study would be:

- to investigate whether the teachers in this study continue to use the contextual approach when teaching electromagnetism; and
- to investigate whether the teachers develop similar teaching approaches for teaching other topic areas.

This study also indicates the importance of inservice support for adopting the contextual strategy for teaching. The approach used in this research was to provide classroom-based inservice help by the researcher. Other models of inservice support should also be investigated. The researcher had conducted some one-day inservice sessions for physics and science teachers in New Zealand and the results appear to be promising. Teachers expressed an interest in using the strategy and some have provided positive feedback about their use of the strategy. However the effectiveness of such a one-day interaction with teachers in bringing about the complex change required for some teachers to use the contextual teaching approach need to be studied further.

Teachers used strategies for managing student questions during contextual teaching that were different from their normal classroom practice. These strategies were not explored fully in this study. Research into these strategies will further clarify contextual teaching.

There appears to be little research on the process of learning during contextual teaching. This study concentrated on the learning outcomes and the process of teaching. The learning processes associated with contextual teaching also need to be studied.

Contextual teaching has many implications for curriculum research, particularly in the Maldives. The secondary school science curriculum in the Maldives is based on the London GCE examination prescriptions. This research has shown that the examination prescriptions may be met using contextual teaching strategies. However teaching schemes need to be developed for using the contextual approach in various curriculum areas and these schemes should be trialed in the classroom. In New Zealand the new curriculum changes recognise the importance of such research into curriculum development.

8.4. CONCLUSION

In conclusion it may be said that contextual teaching is a strategy that may be used by teachers to enhance the affective and cognitive outcomes of science and physics teaching at secondary school levels. This study has shown that similar contextual

teaching strategies may have similar success with students from different cultural backgrounds.

Some teachers may be able to use contextual teaching strategies without any difficulties. However some teachers, particularly those who are used to organising their lessons using conceptual hierarchies, may face initial difficulties in using the approach. Overcoming these difficulties may be complex and may need appropriate inservice support.

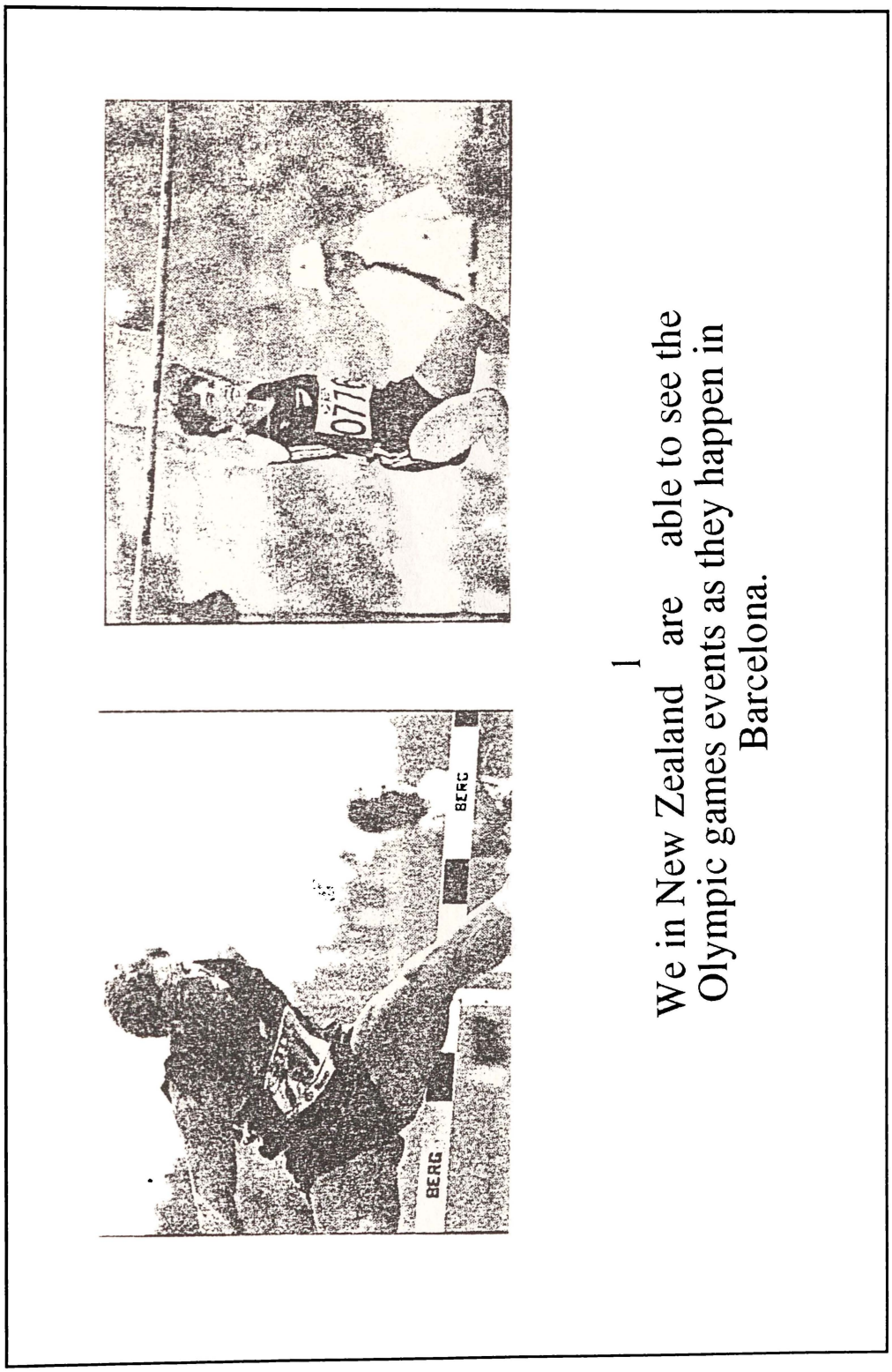
8.5. A FINAL COMMENT

Teachers use a variety of strategies for enhancing the learning outcomes of students. The procedures explored in this research, which we call contextual teaching should be viewed as a further strategy to be added to the teacher's 'bag of tools'.

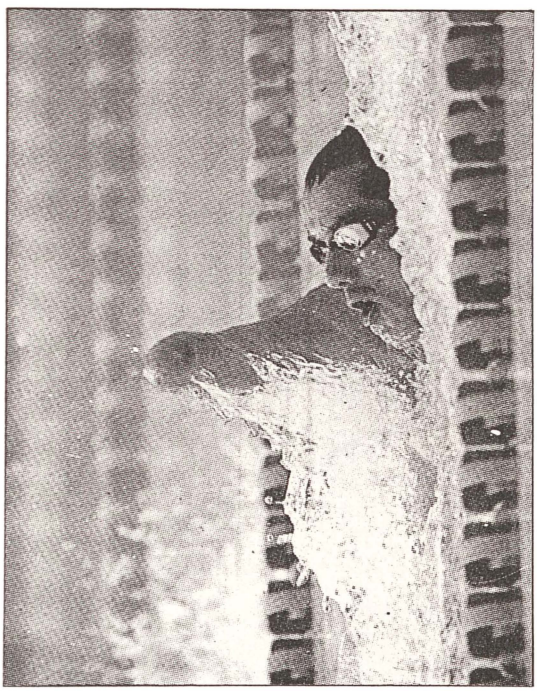
APPENDIX A1: Stimulus cards used in Phase One

[Pages 170 to 186]

1a) We in New Zealand are able to see the Olympic games events as they happen in Barcelona. [used only in New Zealand]

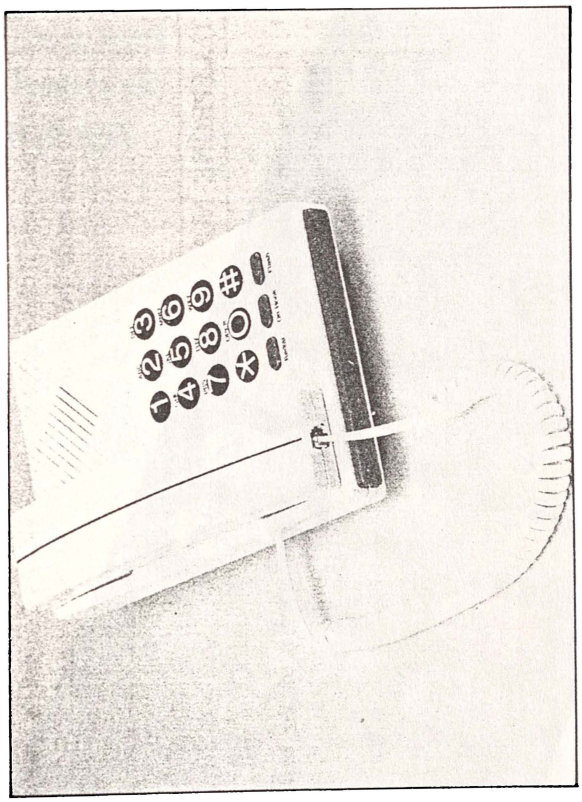


1b) We in the Maldives were able to see the Olympic games events as they happened in Barcelona. [used only in the Maldives]



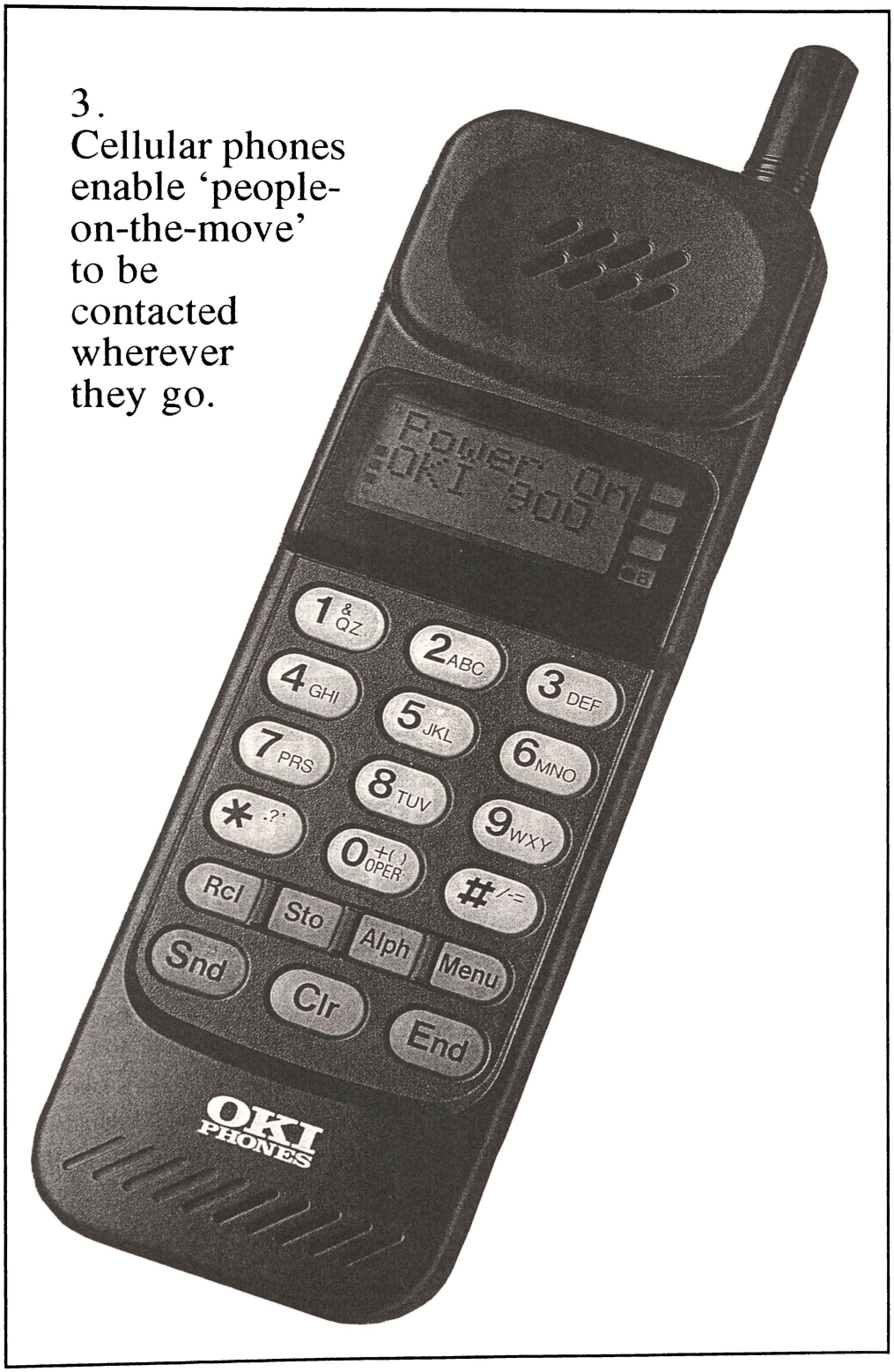
1. We in the Maldives were able to see the Olympic games events as they happened in Barcelona.

2) A telephone enables us to talk to people who are far away.

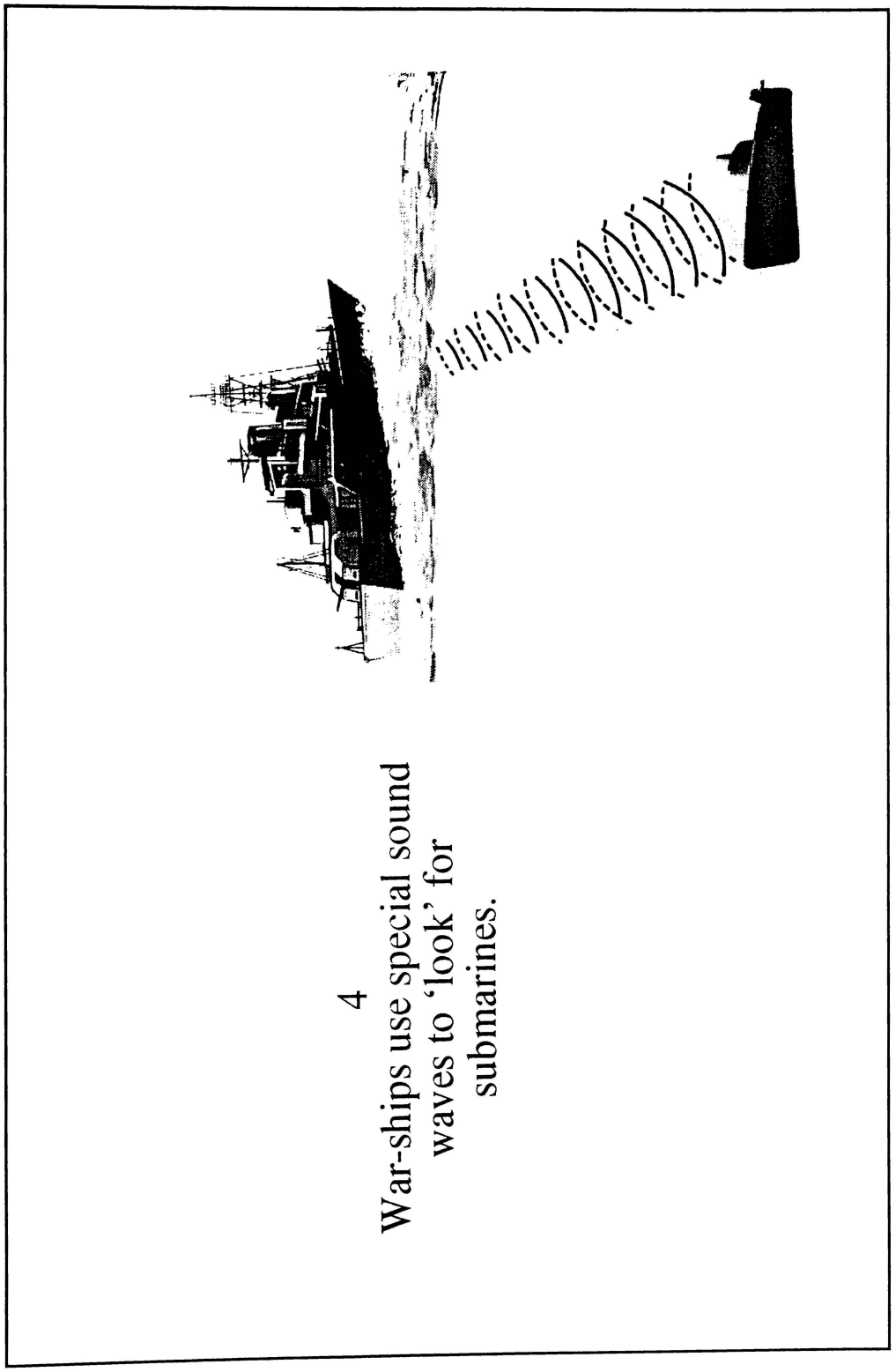


2. A telephone enables us to talk to people who are far away.

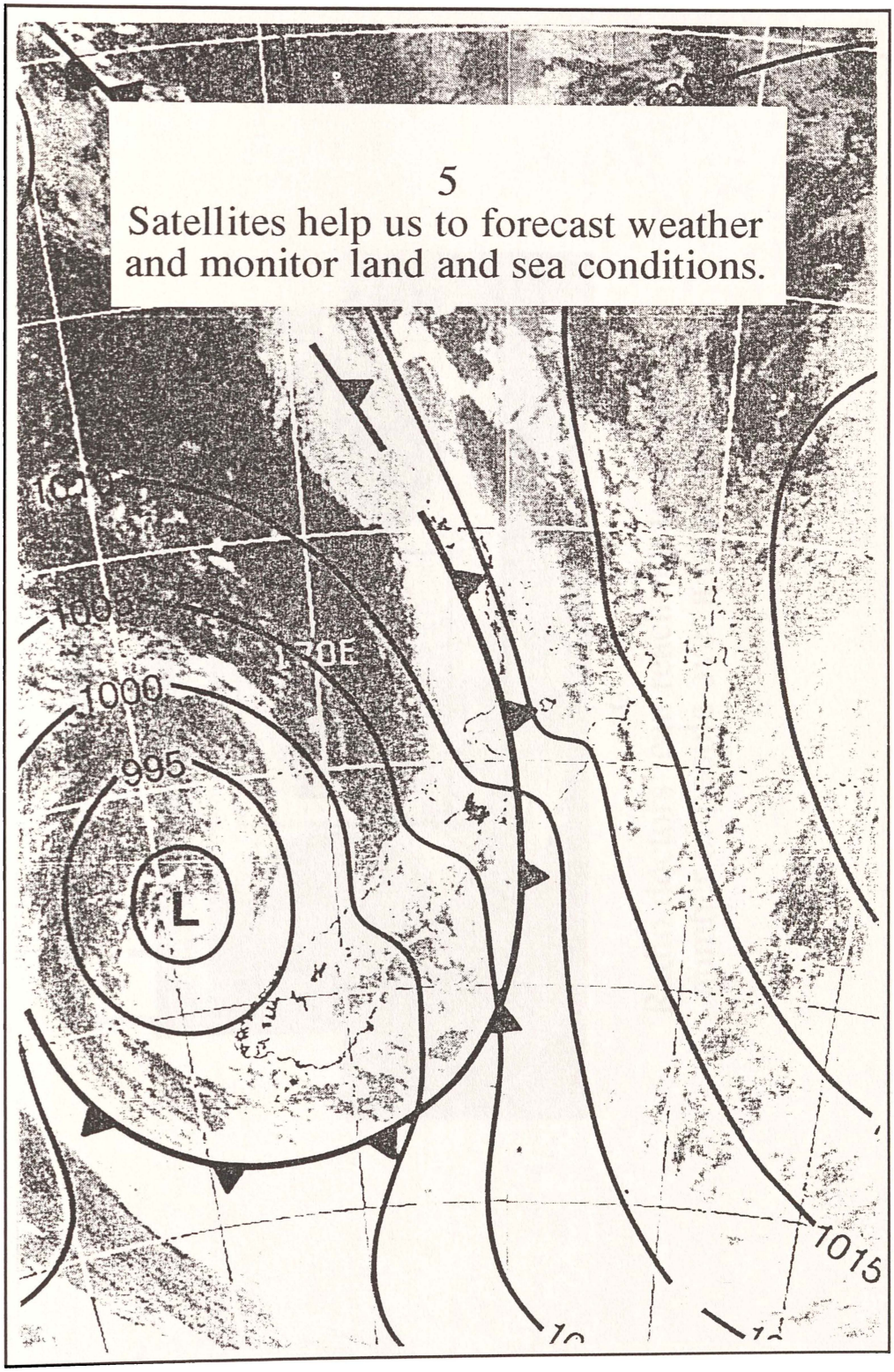
3) Cellular phones enable 'people-on-the-move' to be contacted wherever they go.



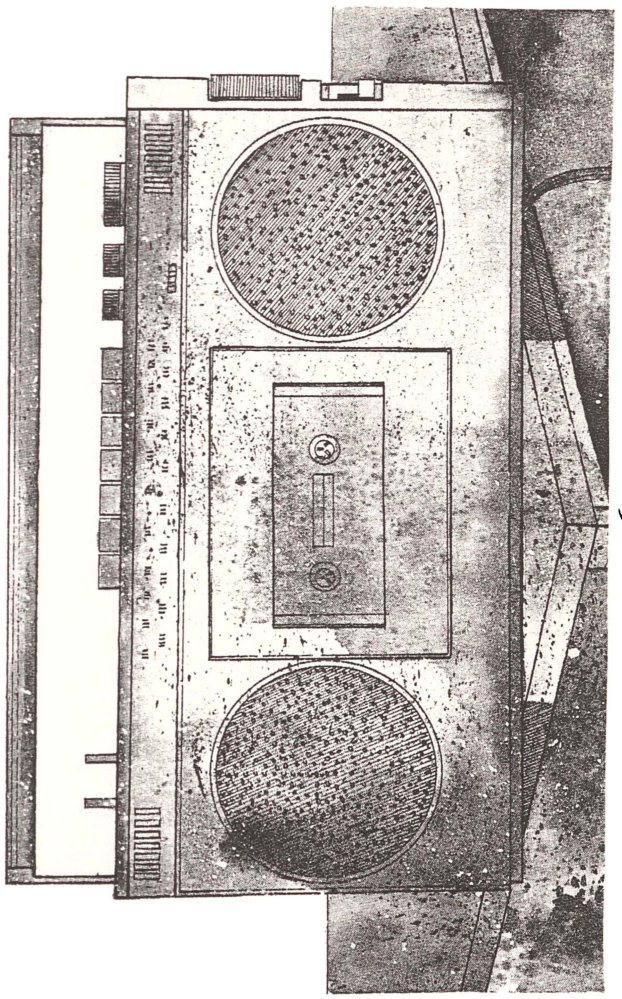
4) Warships use special sound waves to 'look' for submarines.



5) Satellites help us to forecast weather and monitor land and sea conditions.



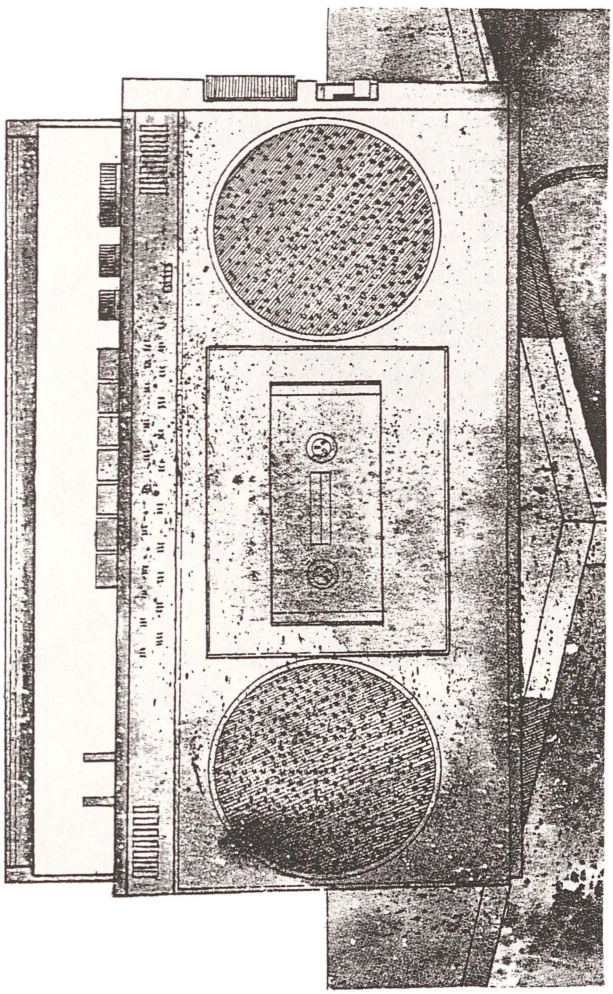
6a) A 'radio doctor' can reach out to a large number of people over a large area. [used only in New Zealand]



6

'Radio doctors' can reach out to a large number of people over a large area.

6b) A radio enables us to reach out to a large number of people over a large area. [used only in the Maldives]



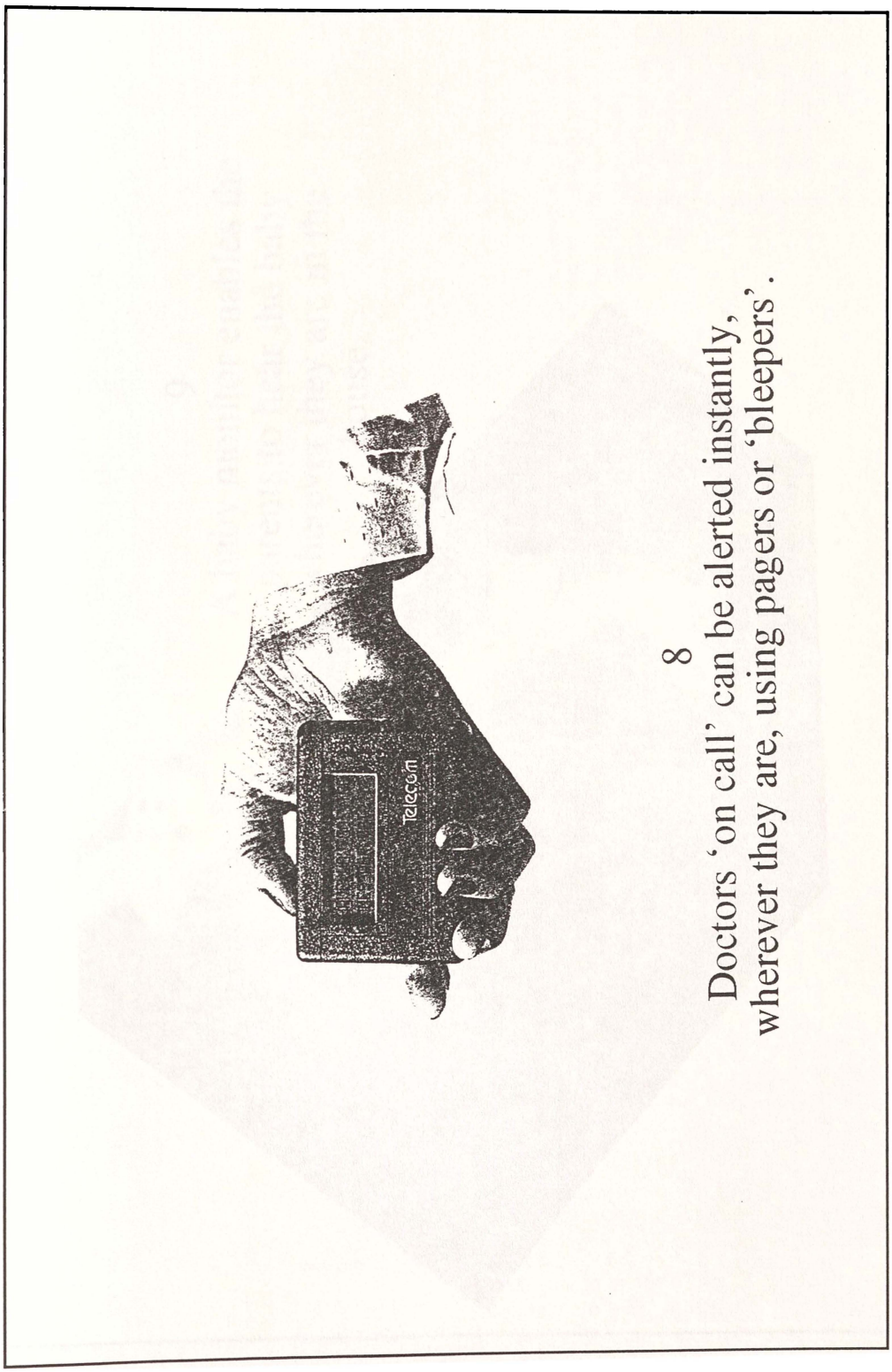
6

6. A radio can be used to reach out to a large number of people over a large area.

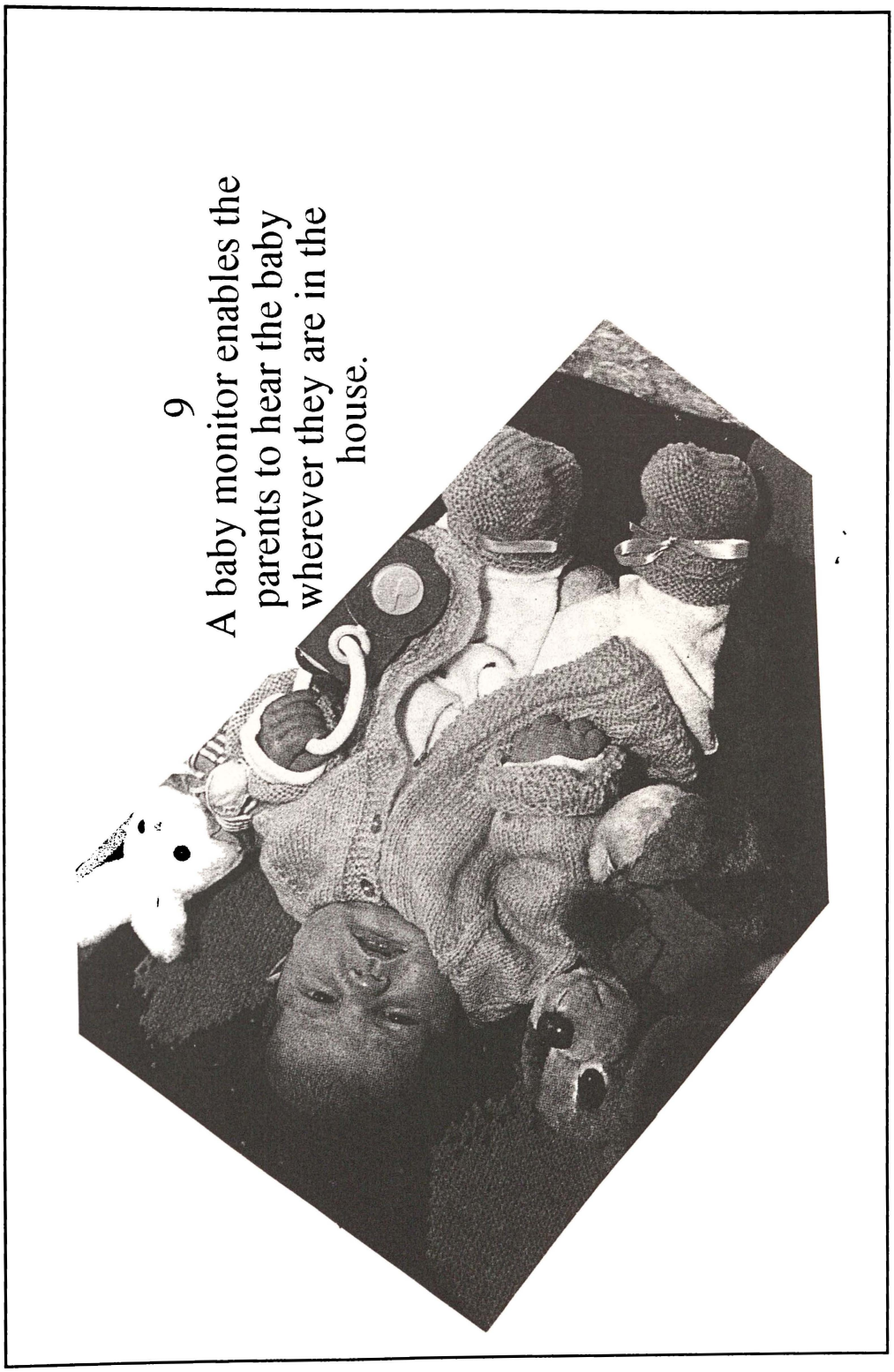
7) Radio transmitters are used to monitor migration of animals.



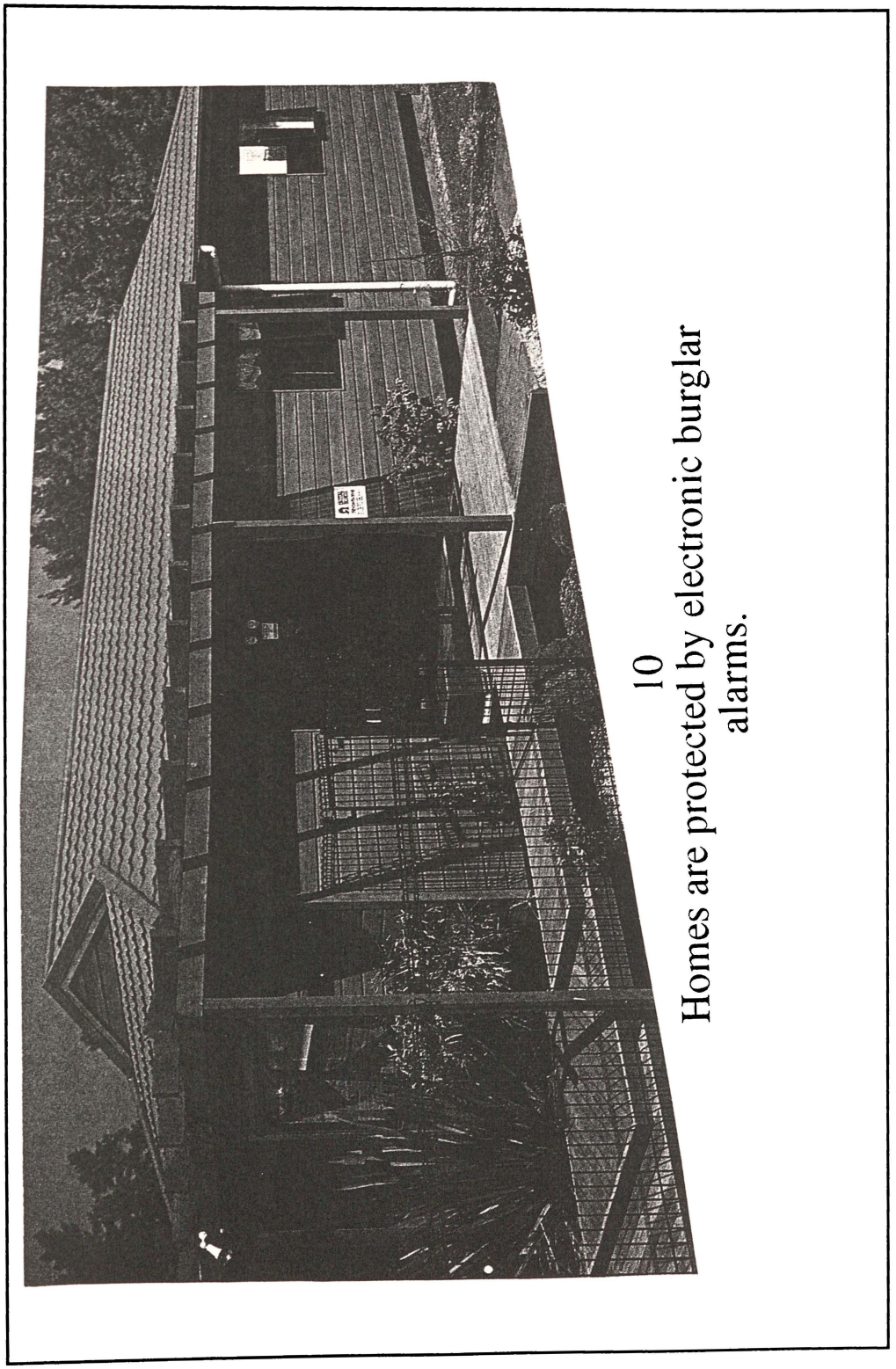
8) Doctors 'on call' can be alerted instantly, wherever they are, using pagers or 'bleepers'.



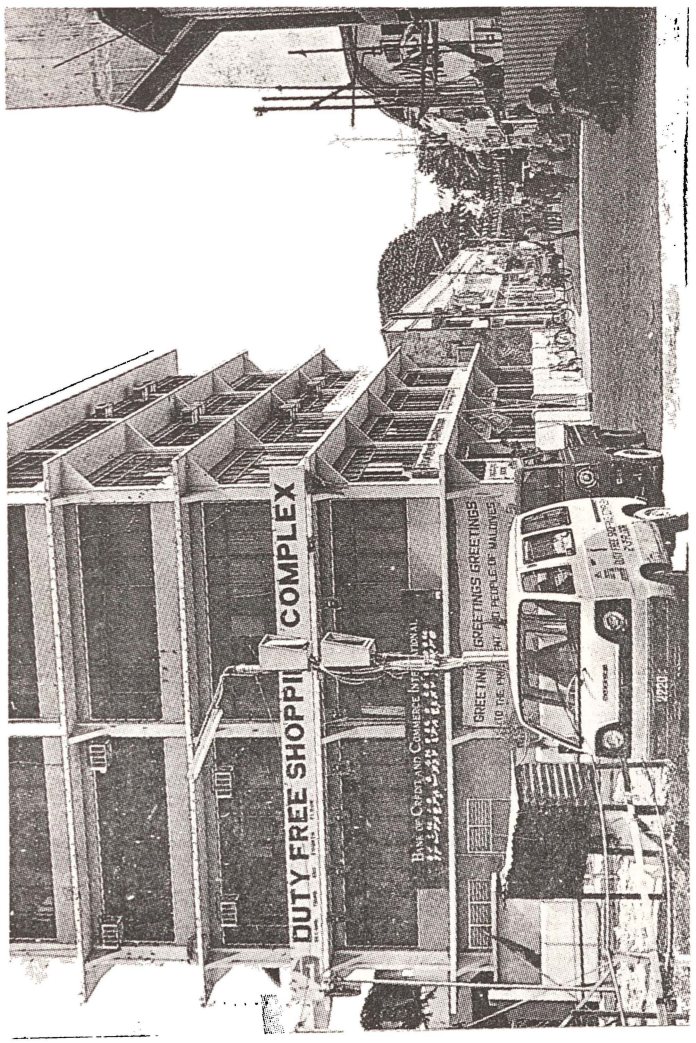
9) A baby monitor enables the parents to hear the baby wherever they are in the house.



10a) Homes are protected by electronic burglar alarms. [used only in New Zealand]

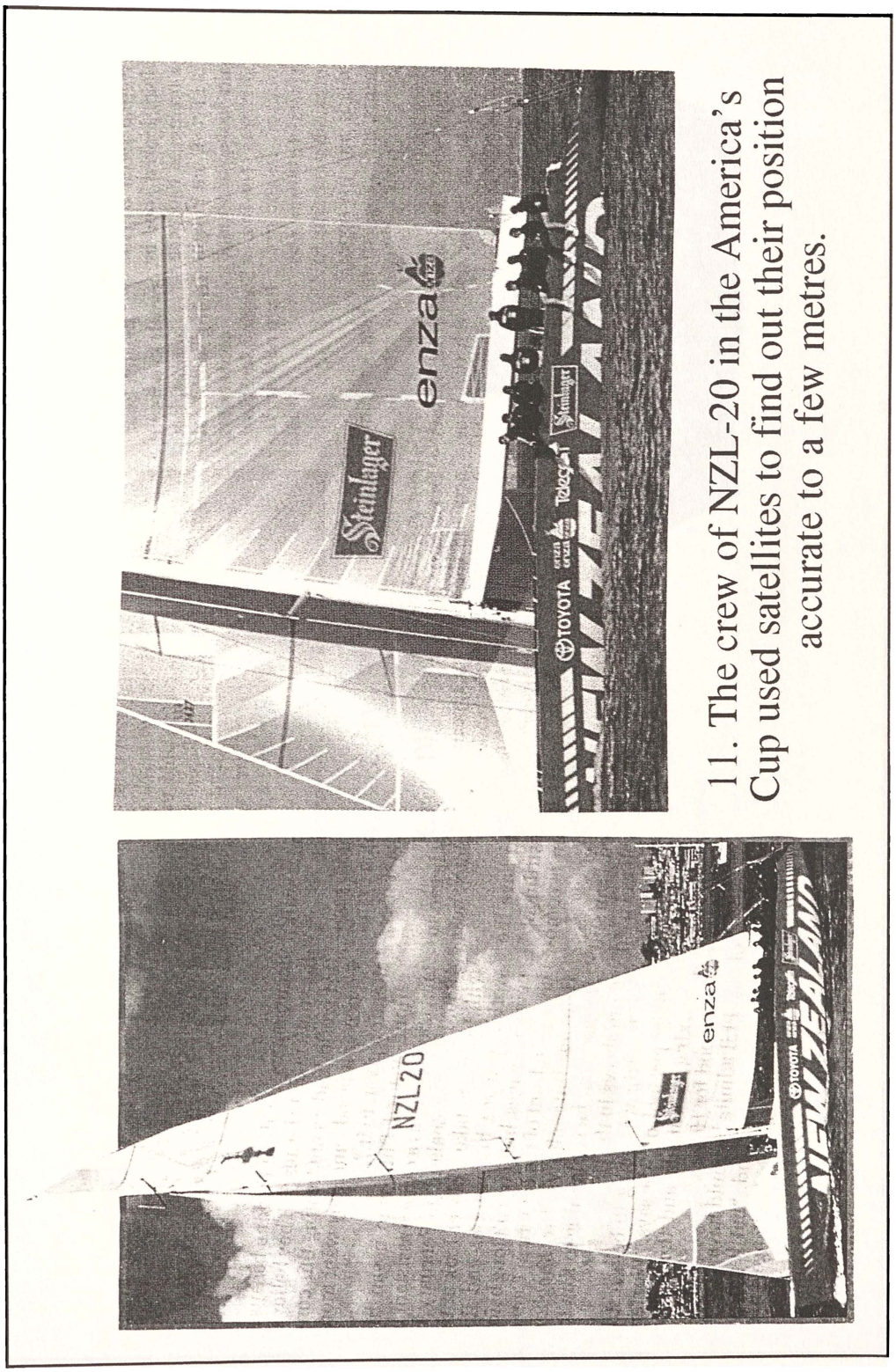


10b) Some shops and homes are protected by electronic burglar alarms. [used only in the Maldives]

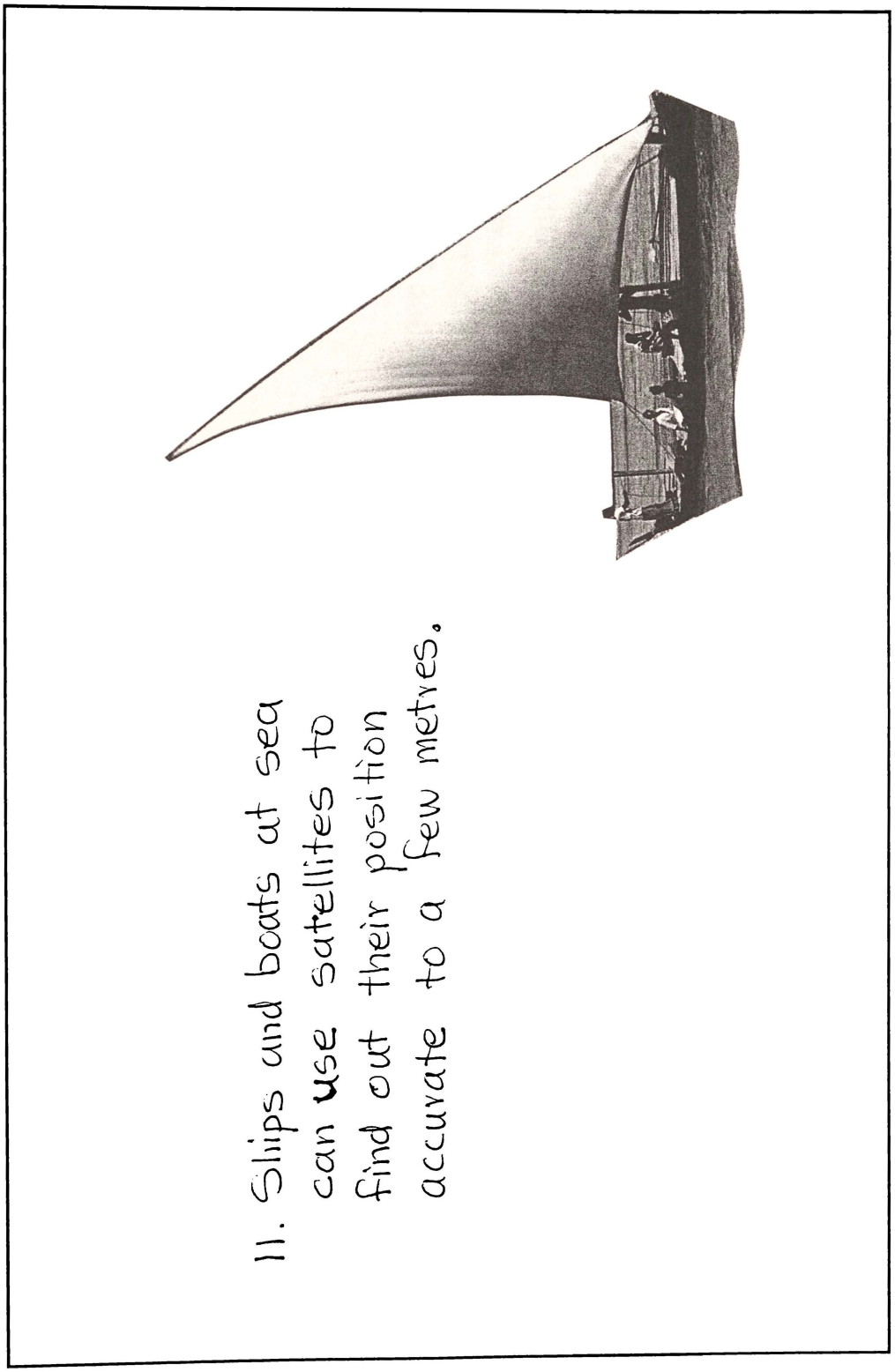


10. Some shops and homes are protected by electronic burglar alarms.

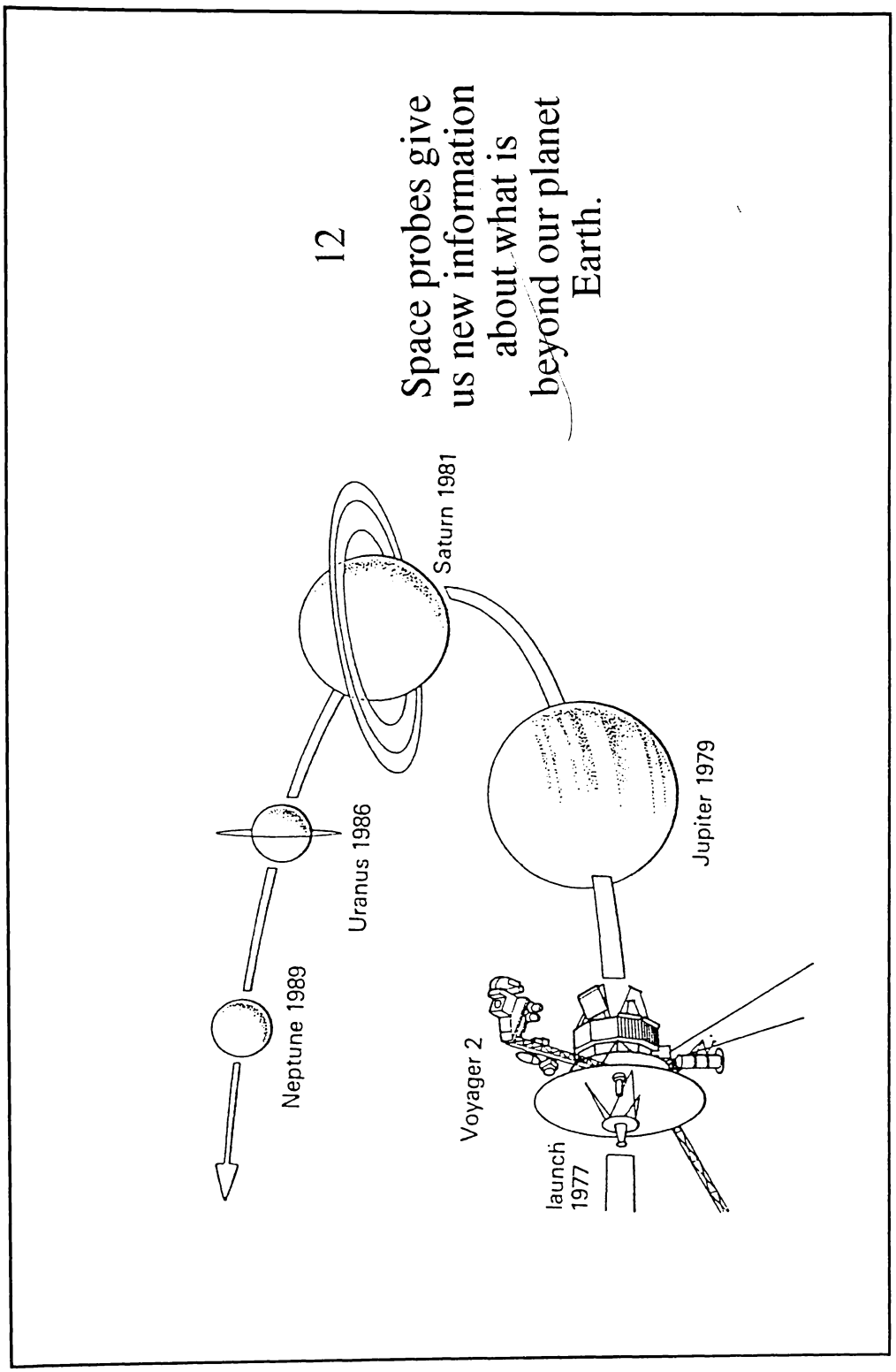
11a) The crew of NZL-20 in the America's Cup used satellites to find out their position accurate to a few metres. [used only in New Zealand]



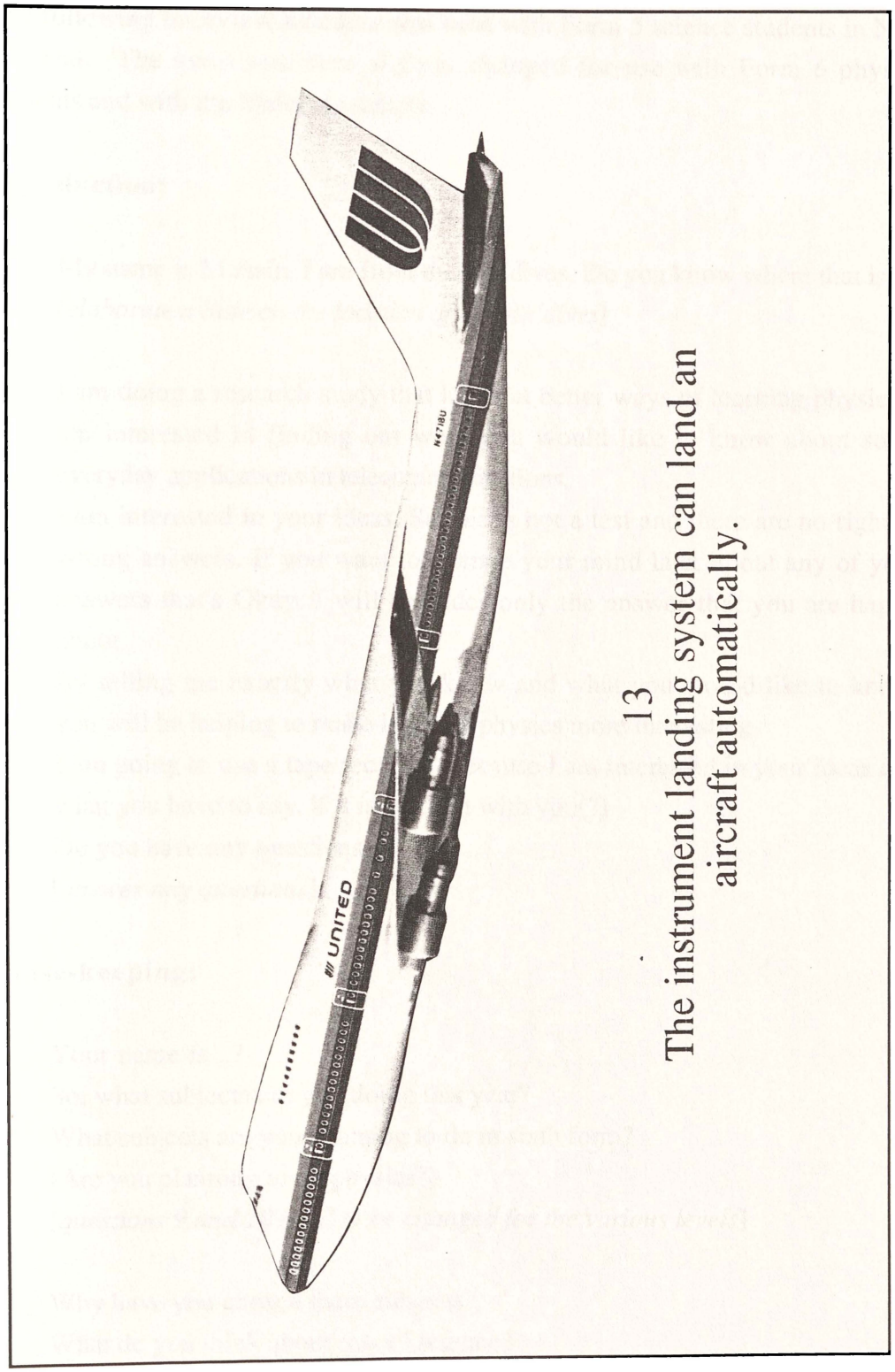
11b) Ships and boats at sea can use satellites to find out their position accurate to a few metres. [used only in the Maldives]



12) Space probes give us new information about what is beyond our planet Earth.



13) The Instrument Landing System can land an aircraft automatically.



APPENDIX A2: Interview schedule used in Phase One

The following interview schedule was used with Form 5 science students in New Zealand. The questions were slightly changed for use with Form 6 physics students and with the Maldives sample.

Introduction:

1 My name is Muhsin. I am from the Maldives. Do you know where that is?
[*elaborate a little on the location of the Maldives*]

2 I am doing a research study that looks at better ways of learning physics. I am interested in finding out what you would like to know about some everyday applications in telecommunications.

3 I am interested in your ideas. So this is not a test and there are no right or wrong answers. If you want to change your mind later about any of your answers that's Okay. I will consider only the answer that you are happy about.

4 By telling me exactly what you know and what you would like to know, you will be helping to make learning physics more interesting.

5 I am going to use a tape recorder, because I am interested in your ideas and what you have to say, if it is all right with you(?)

6 Do you have any questions?
[*answer any questions*]

House-keeping:

7 Your name is...?

8 So, what subjects are you doing this year?

9 What subjects are you planning to do in sixth form?

10 (Are you planning to do physics?)
[*questions 9 and 10 need to be changed for the various levels*]

11 Why have you chosen these subjects?

12 What do you think about school science?
- Is it interesting?
- Why do you say that?

Interview about applications:

13 I have a set of cards showing some examples of telecommunications.

14 I will talk with you a little about each one of them. Then you tell me how interested you would be in learning more about it and why. In the process we will fill this table.
[*show Data Sheet in Figure 4.1*]

15 If you do not understand something please tell me so and I will be happy to explain.
[*Show the set of stimulus cards, one by one and for each one of them read out the purpose and use of the application from the card and ask the following questions:*]

16 Would you be interested in learning more about it?
[*show table 4.6 and help tick the table*]

17 Can you tell me why you are (not / not very / very) interested in this?

18 Can you tell me how you feel this might work?
[*Try and establish the links made to science or physics.*]

[*Repeat this until all the cards have been used. Once all the cards have been exhausted, ask the following question:*]

19 Can you think of any thing else used for telecommunications, that you are interested to know more about?
[*If stated, add application to the data table and go through steps 16 to 19.*]

Ending:

20 Thank you very much....

APPENDIX A3: Student interest in applications used in telecommunications

Data collected from the data sheets used during the interviews with students in Phase 1 are presented in this appendix. The procedures used for the statistical analysis are also outlined.

The data

Table A3.1: The responses of students in New Zealand.

	Number of students*									
	Girls					Boys				
APPLICATION	[5]	[4]	[3]	[2]	[1]	[5]	[4]	[3]	[2]	[1]
Seeing Olympics live	6	4	5	1	0	3	8	4	0	1
Telephone	6	5	4	1	0	0	6	7	3	0
Cellular phones	3	8	4	1	0	3	9	4	0	0
Sonar in war-ships	0	3	5	1	7	2	3	5	1	5
Weather satellites	4	4	5	3	0	3	8	4	1	0
Radios	4	5	4	3	0	0	5	3	3	5
Monitoring animals	4	8	3	0	1	6	5	4	0	1
Pagers and 'bleepers'	2	8	4	2	0	3	8	4	1	0
Baby monitor	5	5	5	1	0	1	3	5	2	5
Burglar alarms	3	6	5	1	1	4	6	4	0	2
Satellites in navigation	1	4	6	3	2	5	4	6	0	1
Space probes	8	4	1	1	2	8	7	1	0	0
Inst. landing system	6	4	6	0	0	4	10	2	0	0

* [5] very interested; [4] interested; [3] slightly interested; [2] not sure; [1] not interested

Table A3.2: The responses of students in the Maldives.

	Number of students*									
	Girls					Boys				
APPLICATION	[5]	[4]	[3]	[2]	[1]	[5]	[4]	[3]	[2]	[1]
Seeing Olympics live	7	4	1	3	1	4	9	3	0	0
Telephone	6	6	3	1	0	10	5	1	0	0
Cellular phones	6	5	4	0	1	10	3	3	0	0
Sonar in war-ships	2	6	3	2	3	3	7	4	0	2
Weather satellites	9	4	2	1	0	8	6	1	1	0
Radios	9	3	2	0	2	6	5	3	1	1
Monitoring animals	4	6	2	1	3	6	2	4	1	3
Pagers and 'bleepers'	6	7	2	0	1	7	7	2	0	0
Baby monitor	9	3	2	2	0	6	4	3	1	2
Burglar alarms	6	6	2	0	2	9	7	0	0	0
Satellites in navigation	6	5	2	3	0	8	6	2	0	0
Space probes	12	1	2	1	0	8	5	3	0	0
Inst. landing system	6	7	3	0	0	9	4	2	1	0

* [5] very interested; [4] interested; [3] slightly interested; [2] not sure; [1] not interested

Data analysis using Student's *t-test*

Using the Student's *t-test* for independent samples, the test statistic t was calculated for each application, for each comparison. The following equation was used (Weiss and Hassett 1991, p 501):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(s_1^2/n_1\right) + \left(s_2^2/n_2\right)}}$$

$\bar{x}_1$ = mean interest of the first group under consideration for the application.
$\bar{x}_2$ = mean interest of the second group under consideration for the application.
s_1 = sample standard deviation of the scores given by the first group.
s_2 = sample standard deviation of the scores given by the second group.

The critical values $\pm t_{\alpha/2}$ for the two-tailed test were determined by the degrees of freedom, df, calculated as follows (Weiss and Hassett 1991, procedure 10.5, p 501):

$$\mathrm{df} = \frac{\left[\left(s_1^2/n_1\right) + \left(s_2^2/n_2\right)\right]^2}{\frac{\left(s_1^2/n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2/n_2\right)^2}{n_2 - 1}}$$

The critical values were determined from standard tables.

The mean interest $\bar{x}$ for each application was calculated using the following equation.

$$\bar{x} = \frac{\sum xf}{n}$$

f = number of students who gave the application a rating of x.
n = total number of students under consideration who gave a rating to the application.

The sample standard deviation s was calculated for each application using the following equation:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2 f}{n - 1}}$$

$\bar{x}$ = mean interest of the group under consideration for the application.
f = number of students who gave the application a rating of x. [The five-point scale used in the data sheet was assigned ratings from 1 to 5. The rating of 1 was assigned to the 'not-interested' end of the scale and 5 was assigned to the 'very-interested' end.]
n = total number of students under consideration who gave a rating to the application.

The use of a *t-test.* is warranted in this instance because the samples were independent and randomly selected (Gay 1981). Furthermore the number of students in each group used in the comparisons was greater than 30 and hence the sample in each comparison may be considered large (Weiss and Hassett 1991). As the test was about the differences in the mean ratings of students the two-tailed test was chosen.

The comparisons

Table A3.3: Responses of all students in the New Zealand sample compared to the responses of all students in the Maldives sample.

	New Zeal.		Maldives		Statistic		
APPLICATION	Mean	SD	Mean	SD	t	df	Notes
Seeing Olympics live	3.84	1.18	3.94	1.83	0.24	53	
Telephone	3.59	0.28	4.31	1.93	2.09	32	
Cellular phones	3.88	0.78	4.19	2.08	0.79	39	
Sonar in war-ships	2.50	1.83	3.34	1.52	2.01	60	
Weather satellites	3.69	0.93	4.31	2.17	1.50	42	None of the
Radios	3.06	1.01	3.97	2.42	1.96	42	differences are
Monitoring animals	3.91	1.49	3.44	1.64	1.20	61	significant
Pagers and 'bleepers'	3.72	1.17	4.19	1.59	1.34	57	at 0.05 level
Baby monitor	3.22	0.91	3.94	2.47	1.54	39	
Burglar alarms	3.59	1.32	4.22	1.98	1.49	54	
Satellites in navigation	3.34	0.78	4.13	1.96	2.09	41	
Space probes	4.19	2.31	4.41	2.44	0.37	62	
Inst. landing system	4.06	0.66	4.25	1.84	0.54	39	

Table A3.4: Responses of girls compared to the responses of boys in the New Zealand sample.

APPLICATION	Girls		Boys		Statistic		Notes
	Mean	SD	Mean	SD	t	df	
Seeing Olympics live	3.94	0.96	3.75	0.91	0.57	30	
Telephone	4.00	1.10	3.19	0.79	2.41	27	
Cellular phones	3.81	0.72	3.94	0.16	0.67	16	
Sonar in war-ships	2.25	1.34	2.75	1.10	1.15	29	
Weather satellites	3.56	0.35	3.81	0.72	1.24	22	
Radios	3.63	0.67	2.50	0.00	6.71	15	significant (0.025)
Monitoring animals	3.88	1.01	3.94	1.21	0.16	29	
Pagers and 'bleepers'	3.63	0.93	3.81	0.72	0.64	28	
Baby monitor	3.88	0.71	2.56	1.00	4.29	27	significant (0.025)
Burglar alarms	3.56	0.84	3.63	1.00	0.19	29	
Satellites in navigation	2.94	0.58	3.75	0.61	3.86	30	significant (0.025)
Space probes	3.94	1.90	4.44	0.94	0.94	22	
Inst. landing system	4.00	0.00	4.13	0.45	1.12	15	

Table A3.5: Responses of girls compared to the responses of boys in the Maldives sample.

APPLICATION	Girls		Boys		Statistic		Notes
	Mean	SD	Mean	SD	t	df	
Seeing Olympics live	3.81	1.66	4.06	0.16	0.60	15	
Telephone	4.06	1.15	4.56	1.37	1.12	29	
Cellular phones	3.94	1.21	4.44	1.62	0.99	28	
Sonar in war-ships	3.13	0.97	3.56	1.00	1.25	30	
Weather satellites	4.31	1.70	4.31	1.39	0.00	29	None of the
Radios	4.06	1.98	3.88	1.44	0.31	27	differences are
Monitoring animals	3.44	1.16	3.44	1.37	0.00	29	significant
Pagers and 'bleepers'	4.06	1.25	4.31	0.94	0.64	28	at 0.05 level
Baby monitor	4.19	1.84	3.69	1.50	0.84	29	
Burglar alarms	3.88	1.41	4.56	0.72	1.73	22	
Satellites in navigation	3.88	1.24	4.38	1.18	1.16	30	
Space probes	4.50	2.05	4.31	1.27	0.31	25	
Inst. landing system	4.19	0.79	4.31	1.70	0.27	21	

APPENDIX B1: The curriculum requirements in electromagnetism for the Form 6 class in New Zealand and the Grade 11 class in the Maldives.

Curriculum requirements in electromagnetism for the Form 6 class in New Zealand

According to the curriculum requirements of the sixth-form electromagnetism course in the school[1] in New Zealand by the end of the unit the students should be able to:

- describe/analyse
  - magnetic field due to current in a wire.
  - electromagnets/solenoids.
  - force on a current carrying wire in a magnetic field.
  - electromagnetic induction.
- observe/measure
  - effect of current in wires, coils and solenoids on magnetic compasses.
  - direction of motion of wire placed close to a horseshoe magnet.
  - voltage/current induced by relative motion of magnetic fields and wires including effect of direction and rate of change on magnitude/direction of voltage.
- draw fields due to one wire, two parallel wires, coil and solenoid.
- use the equation F=BIL to find force on a wire, or magnetic field strength.
- predict direction of induced voltage/current when a magnet is moved near a solenoid.

Curriculum requirements in electromagnetism for the Grade 11 class in the Maldives

The sections 5.5 to 5.7 of the GCE A'Level physics prescriptions used to teach grade 11 electromagnetism in the Maldives are shown below ((ULEAC 1992, p 589-590):

5.5 *Magnetic fields*

Permanent magnets.	Use of field lines to describe the space around magnets. Explanation of permanent magnets using the idea of domains.

[1] The specifications were derived from school records but are presented in a different format.

Magnetic flux density: the tesla.	Magnitude of B defined by $F=BIL$. Direction of B given by the left-hand rule. Vector nature of B; concept of neutral point.
Quantitative study of the force on a current-carrying conductor in a magnetic field, and on a charged particle moving through a magnetic field.	Derivation of BQV from BIl expected.
Magnetic effect of a steady current.	Patterns near ring, short solenoid and straight wire to be known (directions included). Use of a pre-calibrated Hall probe to explore a steady magnetic field.
Magnetic flux density within a long solenoid and near a long straight wire. Force between parallel current-carrying conductors; the definition of the ampere and μ_O.	Relations $B=\mu_O nI$ and $B=\mu_O I/2\pi r$ to be known and investigated experimentally, but derivations are *not* required.

5.6 *Electromagnetic induction*

Magnetic flux, flux linkage and the phenomenon of electromagnetic induction.	Experimental demonstration that cutting magnetic flux induces a p.d. across a conductor and that change of flux linked induces an e.m.f. in a circuit.
Faraday's and Lenz's laws of electromagnetic induction.	$E=Blv$ for a moving conductor should be known but its derivation will not be examined. $E=N(\Delta\varphi/\Delta t)$ numerically should be known, and understood to confirm the law of conservation of energy. Use of a search coil and oscilloscope to study oscillating magnetic fields.
Meaning of r.m.s. and peak values and their relationship for sinusoidal currents and p.ds.	Understanding of $I=I_O \sin 2\pi ft$. Knowledge of, without proof, $I_{rms} = I_O/\sqrt{2}$, $V_{rms} = V_O/\sqrt{2}$.
Energy and power.	Resistive circuits only; mean power $=1/2(I_O V_O)$.

5.7 *Applications of the principles associated with field phenomenon*

an understanding of the principles of section 5 is expected in familiar and unfamiliar situations....

APPENDIX B2: Work sheet for concept-mapping exercise

What do we know about electromagnetism?

We have talked about electromagnetism in a variety of topics and this exercise will help us review and find out what we already know about the topic. This is not a test.

We are going to draw a 'map' showing the relationships between some physics concepts in electromagnetism. Such a map is called a 'concept map'. An example of a concept map is shown below in Fig. 1.

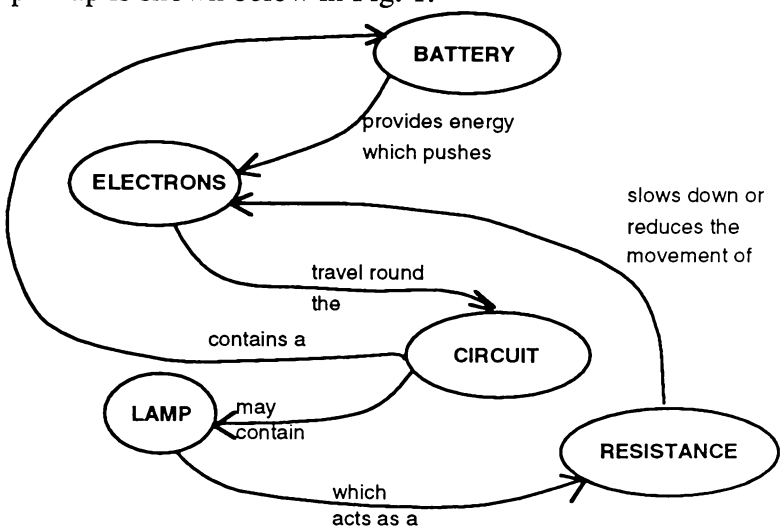


Fig. 1: Concept map showing some relationships in electricity.
Note how the links between the concepts are written down.

Use the list below and any other words you want, to draw a concept map showing how you would link these words. We call these words concepts. The list is only a guide and the concepts are not arranged in any order of importance.

You may find it useful to cut out the words and arrange them as you wish to draw the diagram. If you join any two concepts by an arrow, make sure that you write down the relationship between them. Your concept map may turn out to be bigger than the example shown above.

Use the next sheet for drawing your map. Additional sheets are available.

CURRENT

FORCE

MAGNET

MAGNETIC FIELD

SOLENOID

WIRE

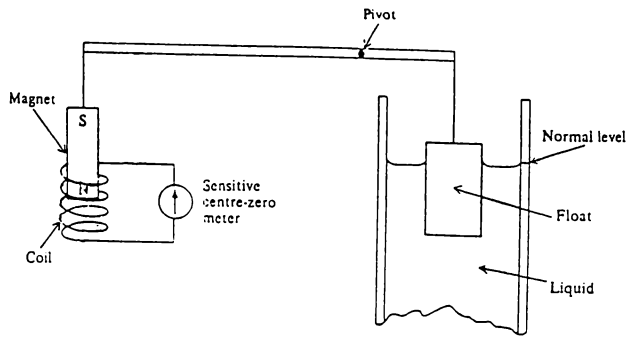
APPENDIX B3: Pre-test used in the Maldives during Phase 2

Pre-test on Electromagnetism

Name:_____ **Class:** _____ **Date:** _____

Please answer the following questions in the spaces provided.

Question One



(a) In the petroleum industry the device illustrated above is used to show changes in liquid levels. If the liquid level rises above the normal level at a steady rate, the meter indicates an electric current. Explain why there is a current as the magnet moves down into the coil.

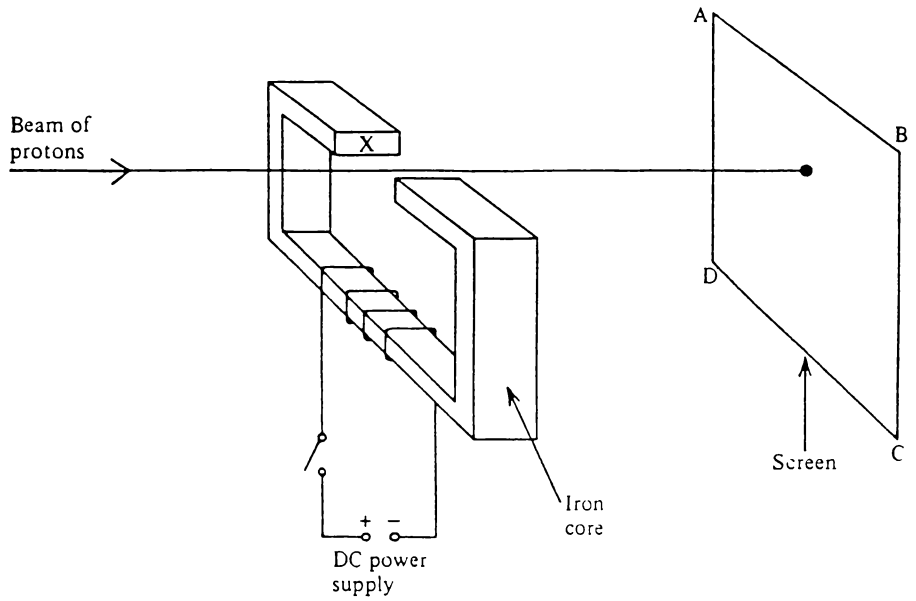
(b) On the diagram above show the direction of this current.

(c) If the liquid level then falls suddenly back to normal, how will the size and direction of this current compare to that in (b)

(d) State two ways in which the size of the current could be increased by modifying **only the right side of the apparatus.**

Question Two

A beam of protons is projected between the poles of an electromagnet and produces a bright spot on a special screen. The apparatus is enclosed in a vacuum and arranged as shown in the diagram



(a) When the current is switched on

(i) what magnetic pole is produced at the pole marked X on the diagram,

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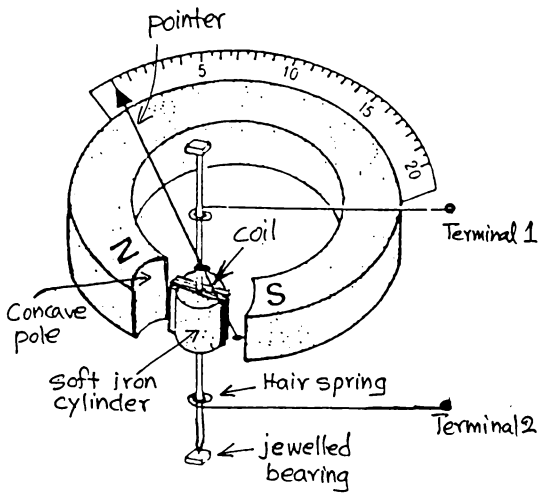
(ii) in which direction will the spot on the screen be deflected?

(b) Give **two** ways in which the size of the spot deflection on the screen could be increased.

(c) What **two** changes might be observed if a beam of electrons were used for the experiment instead of a beam of protons?

Question Three

This question is about a moving coil galvanometer. In such a meter, a coil is pivoted on jewelled bearings between the poles of a permanent magnet. Current enters and leaves the coil by hair springs above and below it. The soft iron cylinder at the centre of the coil is fixed as shown in the diagram.



Explain

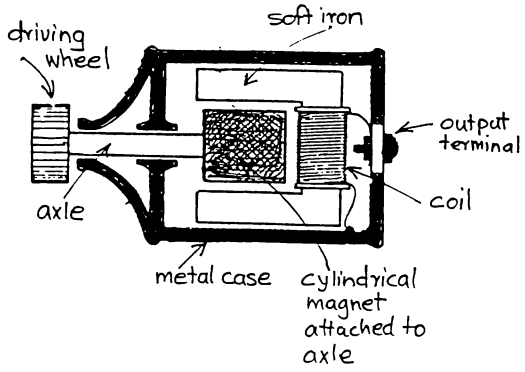
(a) why the pointer deflects when a current passes through the coil and

(b) how the pointer is able to show the current that flows through the meter.

Question Four

This question is about a bicycle dynamo which produces an alternating potential difference when the driving wheel is turned by the motion of the tyre. This pd is used to light the bicycle lamp.

In such a dynamo, the cylindrical rotor is a permanent magnet with the poles across its diameter. The e.m.f is induced in the coil which is at rest.



Explain how the e.m.f. is induced across the ends of the coil.

APPENDIX B4: Data describing student learning in Phase 2

The following data were used:

- performance of the student samples in class tests, assignments, and practicals before the interventions (average);
- performance of the student sample from New Zealand in a unit test given to the whole of the Form 6 (unit test);
- performance of the student sample from the Maldives in a unit test given to the whole of the Grade 11 (unit test); and
- performance of the student sample from the Maldives in the pre- and post-tests (pre-test and post-test).

Table B4.1: The Maldives sample

boy	average	unit test	pre-test	post-test
m1	77	70	63	73
m2	75	73	57	68
m3	60	78	40	63
m4	51	60	23	53
m5	45	70	17	63
girl	average	unit test	pre-test	post-test
f1	78	80	70	66.7
f2	76	77	40	60
f3	62	78	33.33	63.3
f4	53	71	26.67	66.7
f5	42	68	20	50

Table B4.2: The New Zealand sample

[Note: Pre- and post-tests were not used in New Zealand.]

Boy	average	unit test	Girl	average	unit test
F	96	93	E	78	93
O	84	60	I	69	87
K	82	87	N	64	50
D	79	93	A	43	73
M	78	80	G	37	60
H	64	67			
L	61	53			
J	59	73			
C	59	80			
B	56	67			

APPENDIX B5: The questionnaire used in Phase 2

Unit on Electromagnetism **Name** _____

Evaluation Sheet **Date** _____

This evaluation sheet seeks your personal opinion and your individual comments about the unit on electromagnetism that you have completed. Your comments will be used to improve the unit for future use.

1 What is the most interesting thing you did that you can recall from the unit? Why was it interesting?

2 What is the least interesting thing you did that you can recall? Why was it not interesting?

3 Is this unit any different from the other units you have covered in physics? Why is it different?

4 Compared to other units how do you feel about the unit in general? The following table is designed to get you thinking. Please tick (√) a position along the following scales to indicate what you think.

	Very ←			Not sure			→ Very	
Boring	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Interesting
Difficult	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Easy
Unenjoyable	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Enjoyable
Uninformative	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Informative
Irrelevant to me	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Relevant to me
Complicated	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Straightforward
Inadequate practicals	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Adequate practicals
Inadequate theory	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Adequate theory
Inadequate examples	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Adequate examples
Vague explanations	:____:	:____:	:____:	:____:	:____:	:____:	:____:	Clear explanations

Please write down any other observations that you want to include.

5 Please write down any other comments you would like to make about the unit .

Thank you very much for your help.

APPENDIX B6: Data from the semantic differential probes in the questionnaire used in Phase 2

The data generated from student responses to the semantic differential probes are presented in this appendix. The procedures used for the statistical analysis are also outlined.

The data

The probes required students to compare the unit on electromagnetism to other units that they have covered during the academic year. These responses were rated on a -3 to 0 to +3 scale. The number of responses for each category along the scale is given in the following tables.

Table B6.1a: The ratings given by boys in the Maldives

Maldives-Boys	Very [-3]	[-2]	[-1]	Not sure [0]	[1]	Very [2]	[3]	
Boring		2		1	2	4	1	Interesting
Difficult		1		2	2	5		Easy
Unenjoyable					2	6	2	Enjoyable
Uninformative				2		2	6	Informative
Irrelevant to me			2			4	4	Relevant to me
Complicated		2		1	1	2	2	Straightforward
Inadequate practicals			2	2		5	1	Adequate practicals
Inadequate theory		3		1		6		Adequate theory
Inadequate examples	1	2	1	4		2		Adequate examples
Vague explanations	2	1	1	1	2	2	1	Clear explanations

Table B6.1b: The ratings given by girls in the Maldives

Maldives-Girls	Very [-3]	[-2]	[-1]	Not sure [0]	[1]	Very [2]	[3]	
Boring			1			2	2	Interesting
Difficult				2	1	1	1	Easy
Unenjoyable						2	3	Enjoyable
Uninformative						2	3	Informative
Irrelevant to me				1	2	1		Relevant to me
Complicated			1		1	1	2	Straightforward
Inadequate practicals				2			3	Adequate practicals
Inadequate theory		1		1		1	2	Adequate theory
Inadequate examples					2	1	2	Adequate examples
Vague explanations	1		1			1	2	Clear explanations

Table B6.2a: The ratings given by boys in New Zealand

New Zealand-boys	Very [-3]	[-2]	[-1]	Not sure [0]	[1]	[2]	Very [3]	
Boring				2		4	4	Interesting
Difficult				1	3	5	1	Easy
Unenjoyable				2	2	3	3	Enjoyable
Uninformative					3	1	6	Informative
Irrelevant to me			1	2	4	3		Relevant to me
Complicated				2	1	2	5	Straightforward
Inadequate practicals				1	2	1	6	Adequate practicals
Inadequate theory			2	2	1	2	3	Adequate theory
Inadequate examples				1	2	2	5	Adequate examples
Vague explanations				1	1	1	7	Clear explanations

Table B6.2b: The ratings given by girls in New Zealand

New Zealand-girls	Very [-3]	[-2]	[-1]	Not sure [0]	[1]	[2]	Very [3]	
Boring						4	1	Interesting
Difficult			2	1	1	1		Easy
Unenjoyable					1	3	1	Enjoyable
Uninformative							5	Informative
Irrelevant to me				2	1		2	Relevant to me
Complicated					3		2	Straightforward
Inadequate practicals						1	4	Adequate practicals
Inadequate theory				1		1	3	Adequate theory
Inadequate examples					1	1	3	Adequate examples
Vague explanations							5	Clear explanations

Data analysis

The mean rating for each pair of words and phrases that describe the activity was calculated for each sample, and for boys and girls in each sample. These mean ratings were used to compare the student opinions. The nonparametric median test was used (Siegal and Castellan 1988) to determine the significance of the differences between the opinions.

As the median test can not be used on the ranked data provided above, the scores given by individual students were used. For each comparison the median of the scores given by the two groups was determined and the values of A, B, C, and D in the following 2X2 contingency table was determined.

No. of score:	Group I	Group II	Combined
exceeding the combined median	A	B	A+B
that do not exceed the combined median	C	D	C+D
Total	m	n	N=m+n

Groups I and II were the different groups that were compared. For the first comparison (Table B6.3) Group 1 was all the students in the Maldives sample and Group II, all students in the New Zealand sample. Because of the small values of A, B, C, and D, Fisher exact test was then used for processing the two-by-two contingency table. The probability, p, of observing the distribution indicated by the table was calculated by the recursive use of the following equation. (see Siegal and Castellan 1988)

$$p = \frac{(A+B)!(C+D)!(A+C)!(B+D)!}{N!A!B!C!D!}$$

The comparisons

The following additional abbreviations are used in the tables.

p(extr) = the sum of all probabilities associated with more extreme combinations of A, B, C and D.

p (total) = [the minimum value of p quoted under the column 'p>='] + [p(extr)]

n/s = the probability is too large for the difference to be significant.

Table B6.3: Responses of all students in the New Zealand sample compared to the responses of all students in the Maldives sample.

All students	MALD	NZ	m	n	A	B	C	D	p>=	p(extr)	p (total)
Boring (Interesting)	1.20	2.07	15	15	3	5	12	10	0.233		n/s
Difficult (Easy)	1.07	1.13	15	15	7	7	8	8	0.285		n/s
Unenjoyable (Enjoyable)	2.20	1.80	15	15	5	4	10	11	0.287		n/s
Uninformative (Informative)	2.33	2.53	15	15	0	0	15	15	1		n/s
Irrelevant (Relevant) to me	1.57	1.07	14	15	?	5	5	10	0.07?		n/s
Complicated (Straight-forward)	1.15	1.93	13	15	7	7	6	8	0.275		n/s
Inadequate (Adequate) practicals	1.33	2.40	15	15	4	10	11	5	0.028	0.005	0.033
Inadequate (Adequate) theory	0.80	1.53	15	15	2	6	13	9	0.09		n/s
Inadequate (Adequate) examples	0.40	2.20	15	15	2	8	13	7	0.022	0.003	0.025
Vague (Clear) explanations	0.27	2.60	15	15	3	12	12	3	0.001	0.000	0.001

Table B6.4: Responses of girls compared to the responses of boys in the New Zealand sample.

New Zealand	GIRLS	BOYS	m	n	A	B	C	D	p>=	p(extr)	p (total)
Boring (Interesting)	2.20	2.00	5	10	1	4	4	6	0.35		n/s
Difficult (Easy)	0.20	1.60	5	10	1	6	4	4	0.163		n/s
Unenjoyable (Enjoyable)	2.00	1.70	5	10	1	3	4	7	0.44		n/s
Uninformative (Informative)	3.00	2.30	5	10	0	0	5	10	1		n/s
Irrelevant (Relevant) to me	1.40	0.90	5	10	2	3	3	7	0.4		n/s
Complicated (Straight-forward)	1.80	2.00	5	10	2	5	3	5	0.392		n/s
Inadequate (Adequate) practicals	2.80	2.20	5	10	0	0	5	10	1		n/s
Inadequate (Adequate) theory	2.20	1.20	5	10	3	3	2	7	0.24		n/s
Inadequate (Adequate) examples	2.40	2.10	5	10	0	0	5	10	1		n/s
Vague (Clear) explanations	3.00	2.40	5	10	0	0	5	10	1		n/s

Table B6.5: Responses of girls compared to the responses of boys in the Maldives sample.

Maldives	GIRLS	BOYS	m	n	A	B	C	D	p>=	p(extr)	p (total)
Boring (Interesting)	1.80	0.90	5	10	2	1	3	9	0.22		n/s
Difficult (Easy)	1.20	1.00	5	10	2	5	3	5	0.392		n/s
Unenjoyable (Enjoyable)	2.60	2.00	5	10	3	2	2	8	0.15		n/s
Uninformative (Informative)	2.60	2.20	5	10	0	0	5	10	1		n/s
Irrelevant (Relevant) to me	1.00	1.80	4	10	0	4	4	6	0.21		n/s
Complicated (Straight-forward)	1.60	0.88	5	8	2	2	3	6	0.392		n/s
Inadequate (Adequate) practicals	1.80	1.10	5	10	3	1	2	9	0.073		n/s
Inadequate (Adequate) theory	1.20	0.60	5	10	2	0	3	10	0.095		n/s
Inadequate (Adequate) examples	2.00	-0.40	5	10	5	2	0	8	0.007	0.000	0.007
Vague (Clear) explanations	0.80	0.00	5	10	3	3	2	7	0.24		n/s

APPENDIX C1: The teaching resource used in the Maldives during Phase 3 and Phase 4.

[pages 209 to 238]

Introduction

In this document I have attempted to share with my fellow physics teachers, a contextual approach to the teaching of Grade-10 electromagnetism that my students find meaningful, motivating and interesting. It is by no means a comprehensive scheme of work; it is only an attempt to illustrate how *I* use some everyday applications for the learning and teaching of the topic 'electromagnetism'.

I have structured this document into three sections:

The Unit of Work, where I have outlined the suggested scheme of work and provided some activities that I have tried out in the classroom. These are only suggestions that may have to be modified in order to reflect the user's style of teaching.

Additional Notes, where I have provided some bits of information that I find useful to focus my thinking on the context. Although elements of theory that I find useful, are outlined, the additional notes *do not* provide all that is required at this level.

Exercises, some that have used in the classroom and some that I have compiled for this document. I have presented the exercises in two categories;

- **exercises for the suggested activities in the sub-unit** within the context of the application that is being discussed, and
- **more applications for the sub-unit;** where the physics concepts and ideas illustrated in the sub-unit are considered within the context of other applications.

I hope that my colleagues will find this useful and interesting. I would appreciate your comments any time.

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GCE O/L Requirement For Electromagnetism (as in their syllabuses)

The magnetic effect of a steady current. Magnetic field lines; magnetic flux patterns for a straight wire, a circular coil and a solenoid.

Electromagnets and strong permanent magnets. (A knowledge of experimental techniques to investigate the earth's magnetism is *not* expected.)

The force on a current-carrying conductor, and on a moving charged particle, in a magnetic field. Principle of measurement of direct current.

Electromagnetic induction: experiments to illustrate that cutting magnetic flux induces an e.m.f. in a circuit.
The structure and use of a transformer.

Candidates will be expected to

8.1. recall that magnets repel and attract other magnets and attract magnetic substances,
8.2. know how to identify the poles of a magnetic dipole by suspending it in the earth's magnetic field,
8.3. recall the properties of magnetically hard and soft materials,
8.4. be familiar with the use of low voltage/high current supply units for experimental work in electromagnetism,
8.5. know that an electric current in a conductor produces a magnetic field round it,
8.6. understand the terms magnetic field line or magnetic line of force and magnetic flux pattern,
8.7. sketch and recognise magnetic flux patterns for a straight wire, a flat circular coil and a solenoid, each carrying a current, and for a strong permanent dipole magnet,
8.8. understand that magnetism is induced in some materials when they are placed in a magnetic field,
8.9. describe the construction of electromagnets,
8.10. know how to use permanent magnets to produce a desired magnetic flux pattern, e.g. a uniform magnetic flux pattern over a small region
8.11. sketch and recognise the magnetic flux pattern for a straight wire carrying a current perpendicular to a uniform magnetic field,
8.12. appreciate that there is a force on a current-carrying conductor placed in a magnetic field so long as the conductor is not parallel to the field,
8.13. appreciate that there is a force on a charged particle when it moves in a magnetic field so long as its motion is not parallel to the field,
8.14. recall that the force on a current-carrying conductor in a magnetic field increases with the strength of the field and with the current,
8.15. be familiar with the principle of the moving coil galvanometer,
8.16. understand that the relative motion of a conductor and a magnetic field can cause an e.m.f to be induced in a circuit,
8.17. describe experiments to demonstrate that induced currents increase when the rate of cutting of magnetic field lines increases,
8.18. understand that a changing magnetic flux through a circuit causes an e.m.f. to be induced in the circuit,
8.19. appreciate electromagnetic induction as an energy transfer process,
8.20. relate the turns ratio of an ideal transformer to the ratio of the input and the output voltages,
8.21. make use of an understanding of the physical principles involved in a study of electromagnetism to situations or to devices which may or may not be familiar.

Contents

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GCE O/L requirements i

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The unit of work

This unit is designed to present physical concepts of electromagnetism using telecommunications as a 'macro-context'. The suggested activities are linked by the theme *'investigating the technology for transferring sound'* and the physical concepts are viewed in several other relevant contexts.

The approaches to teaching and learning physics suggested in this module are based on the following premise:

- students bring to the classroom, their personal experiences, ideas, concepts and attitudes about the physical world;
- irrespective of their backgrounds, aspects of telecommunications interest students;
- the appropriate use of personal experiences and ideas of students— specially in areas that interest them— enhances student motivation and learning.

The unit is thus structured into three sub-units of work:

Sub-units	Suggested Activities (with approx. duration)
1. **Telecom-munications:** Getting the message across	1.1 What do we know about telecommunications? (1 period) • Class discussion about student's understandings of telecommunications equipment and services. 1.2 Let's look at some applications. (1 period) • Investigating student's ideas about how some applications transfer sound
2. **The speaker:** Converting signals into sound	2.1 Making a speaker. (2 periods + HW) 2.2 How do scientists talk about speakers? (8 periods + HW) • Permanent magnets; • Magnetic fields due to currents; • Force on a current-carrying conductor in a magnetic field. **NOTE:** Exercises may include looking at some other relevant applications. For example: • the d.c. motor • the moving-coil galvanometer
3. **The Microphone:** Converting sound into signals	3.1 How does a microphone work? (1 period) 3.2 Physics of the microphone. (8 periods + HW) **NOTE:** Exercises may include looking at some other relevant applications. For example: • the transformer • the bicycle dynamo • the speedometer • the recording/play-back head

Sub-Unit 1: Telecommunications: Getting the message across

This sub-unit aims to:

- explore students' interests and ideas about some everyday aspects of telecommunications,
- focus on the need for some technical jargon (the concepts of electromagnetism) in order to talk about how telecommunications equipment operate,
- provide opportunities for team work and for using investigative skills, and
- develop an awareness about the impact of some physics-based technology on their lives.

Suggested Activity 1.1: What do we know about telecommunications?

The teacher may initiate a discussion about telecommunications equipment that students see or use in their daily life. The information in additional notes 1.1.1 may help. The discussion may focus on:

- some telecommunications equipment that we use or hear about in our daily life,
- why we use them,
- what we would like to find out more about these or other equipment, and
- how we think some of these equipment work.

The discussion may also be used to illustrate the nature of science and technology. See additional notes 1.1.2.

Suggested Activity 1.2: Let's look at some applications.

An old, opened-up telephone and/or some other telecommunication equipment like a baby monitor, or a walkie-talkie may be used during the discussion. Students' ideas about how these equipment transfer sound from one place to another may also be found out (see additional notes 1.2.1).

The use of the microphone and the speaker in converting sound into electric signals and back into sound respectively, need to be stressed here as this constitutes the unifying theme for the whole unit.

Sub-Unit 2: The speaker: Converting signals to sound

This sub-unit aims to:

- get a feel for students' existing knowledge and understandings about some concepts of electromagnetism,
- provide opportunities for the teacher to introduce new concepts of electromagnetism, and
- provide opportunities for students to develop some skills and attitudes required by the syllabus.

In sub-unit 1 students would have discussed the roles of the microphone and the speaker in the transfer of sound. The microphone converts sound into electric signals while the speaker converts electric signals into sound. This sub-unit will focus on the role of the speaker.

Activity 2.1 may be used as a focusing activity where students will make a working speaker. The rest of the activities may be used to study some physics concepts and principles that are embedded in the process of converting electric signals back into sound by the speaker. These concepts and principles include;

- magnetic fields, field lines and flux,
- magnetic flux patterns for a straight wire, a circular coil and a solenoid.
- induced magnetism,
- magnetic materials,
- magnetic effect of current in a conductor, and
- force on a current-carrying conductor in a magnetic field

The exercises suggest some relevant contexts that may be used to extend the understanding of these concepts and principles. These include:

- the d.c. motor
- the moving-coil galvanometer

Note: Understanding the principle of d.c. motors and meters as well as the force on a moving charged particle, in a magnetic field is a GCE O/L requirement.

Suggested Activity 2.1: Making a speaker.

Examining old speakers, preferably some cut out to expose the coil and the magnets, may be a good introduction to this activity. The students may then be challenged to make their own working speakers using bar-magnets, coil-wire and paper (see additional notes 2.1.1) and to suggest how they think the speaker works.

Students' ideas about the magnetic field, current in the coil, and the resultant force due to their interactions may be explored by focusing on;

- the various parts of the speaker including the permanent magnet, and the coil,
- why the coil moves in and out of the magnet.

Students may be encouraged to try out various ways of improving the operation of their model or even to build a second if they think it may work better. They may also be required to share with the rest of the class the changes they made to improve their design.

The classroom discussion about the working of the speaker may be used to establish the need for a clearly understood set of technical terms; the terminology of scientists; the concepts of electromagnetism.

Suggested Activities 2.2
How do scientists talk about speakers?

These activities are based on investigating the various parts of the speaker in detail. The two interacting parts of the speaker are:
- the permanent magnet, and
- the coil of wire attached to a (paper) cone.

The activities may be structured as follows:

Activity	
2.2.1: Parts of the speaker: • the magnet and • the coil	• Finding out students ideas and suggestions about the shape of the magnet inside the speaker may be used to start the activity. • The discussion about the particular shape (see additional notes 2.2.2) of the speaker-magnet is a useful context for introducing the concepts of magnetic fields, field lines (see additional notes 2.2.1), induced magnetism and the use of magnetically soft materials to guide field lines, (see additional notes 2.2.3, and 2.2.4). • A model of the speaker, made by one of the groups may be used to introduce the concept of the magnetic effect of current in a coil and hence the magnetic effect of a current in a conductor. This may be used as an entry-point to discussing magnetic fields due to currents in solenoids, coils and wires. Plotting field lines, using plotting compasses may be a useful practical activity here. • Exercises (see exercises 2.2.1).
2.2.2: Why does the speaker vibrate?	• Exploring students' ideas about why the speaker vibrates when electric signals pass through the coil may be used to start the activity (see additional notes 2.2.6). Students may be asked to propose ways of verifying their suggestions and demonstrations based on their suggestions may be carried out using the model speakers they prepared before. This is a useful context for introducing the concept of force on a current carrying conductor in a magnetic field (see additional notes 2.2.7 and 2.2.8). • Exercises (see exercises 2.2.2).

Sub-Unit 3: The microphone: Converting signals into sound

This sub-unit aims to:

- find out students' ideas about electromagnetic induction,
- provide the opportunity for the teacher to introduce the new concepts of electromagnetic induction.
- provide opportunities for students to develop some of the skills and attitudes required by the syllabus.

Suggested Activity 3.1: How does a microphone work?

In introducing the activity, a brief review of the role of the microphone and the speaker in the transfer of sound may be useful to establish the context. The discussion about how the microphone works may be used to find out students ideas about electromagnetic induction, by focusing on

- the various parts of the microphone, including the permanent magnet, and the coil (see additional notes 3.1.1),
- how a current is produced when the cone vibrates.

A dynamic microphone is essentially a moving coil speaker in reverse. To illustrate this point, a small speaker may be connected to the microphone input of the amplifier that is connected to a speaker. Any feed-back may be reduced by cupping the speaker in the hand.

Two speakers connected directly to each other using long wires may be used to transfer the tapping sound on one of the speakers to the other.

Suggested Activity 3.2: Physics of the microphone.

A demonstration using a sensitive galvanometer (like a light beam galvanometer) may be used to 'show' the induced current in the speaker coil when it moves in the magnetic field.

Faraday's Law and Lenz's law may be introduced at this point. These laws may also be extended to a single wire by using a wire connected between the terminals of the galvanometer and a powerful 'U' magnet.

Some exercises including other relevant applications may be used to extend the understanding of these concepts and principles. Exercises 3.1 include the following applications:

- the transformer
- the bicycle dynamo
- the speedometer
- the recording/play-back head in tape recoeders

Note: Understanding the structure and use of a transformer is a GCE O/L requirement.

Additional Notes

Additional notes for suggested activity 1.1. What do we know about telecommunications?

1.1.1. Telecommunications

Telecommunications is the term used for transferring information over a distance. 'Tele' means 'far off' in Greek.

The story of telecommunications started in the mid 19th century when the telegraph was invented. Shortly after that the telephone was invented. This was followed by a revolution in telecommunication technology - the radio, TV, facsimile (fax) machines, satellite transmissions, etc.

In the book 'Telecommunications: A technology for change' Eryl Davies writes:

> Telecommunications technology has changed the world beyond recognition since 1800. Cheap, convenient transport, diverse energy supply and weapons technology have all had their effect. But the impact of these would have been insignificant without the technology which enables us to send and receive, at the flick of a switch or the turn of a dial, that lifeblood of modern society - information.

Some applications of telecommunications are used to pass information over long distances. The telephone enables us to talk to family or friends overseas or in other towns. Other applications like the baby monitor are used within the house. A baby monitor enables the sounds made by the baby to be heard through a speaker unit that can be carried around in the house.

1.1.2. Science, technology and telecommunications

Some writers consider science to be a universal discipline through which people investigate the living, material, physical and technological components of their environment. Technology is often considered to be the creative and purposeful use of human knowledge, skills, and physical resources to solve practical problems.

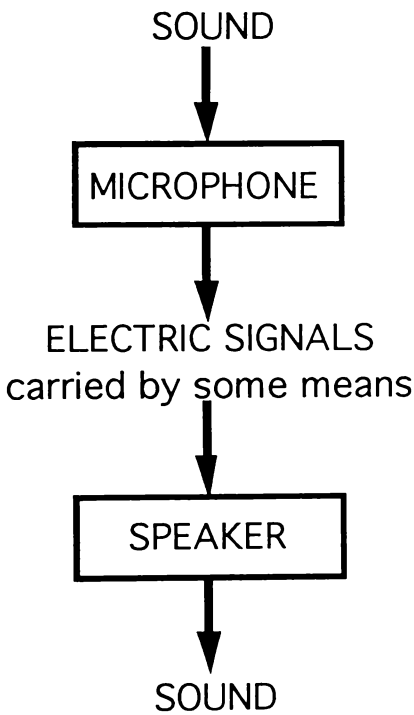
Thus the technological attribute of telecommunications spans the socio-cultural, organisational, and technical aspects of objects, systems and environments designed for facilitating day-to-day communication. Science in telecommunications takes the form of applied science that may be accessed through the technical aspects of telecommunications.

Additional notes for suggested activity 1.2.
Let's look at some applications.

1.2.1. Telephones and baby monitors

Both the telephone and the baby monitor are used to transfer sound. In this transfer, the sound waves may be transformed into a variety of forms before they reach the destination. In a telephone conversation for example, the sound waves that carry speech, are converted into electric signals that travel along wires and may also involve a stage where these electric signals are converted into electromagnetic waves. If the message is to pass through optical cables, the signals need to be converted into light.

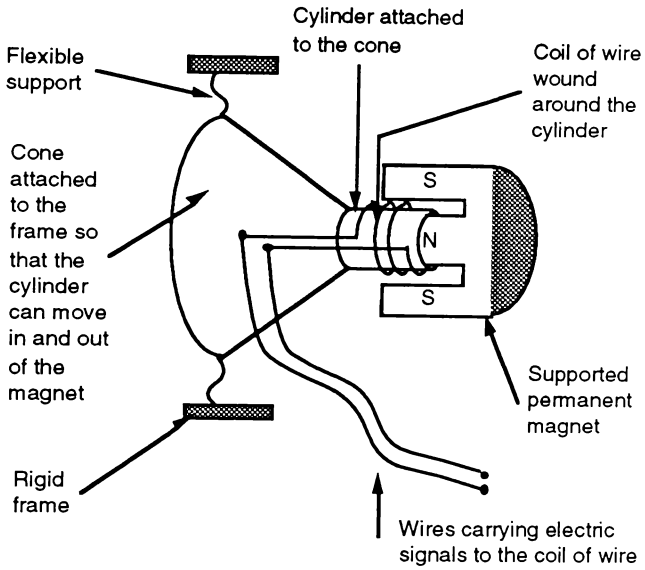
This may be represented by the following block diagram. The same figure may also be used to represent the working of the baby monitor, except that the electric signals may be carried by waves rather than by wires.



Additional notes for suggested activity 2.1.1. Making a speaker.

2.1.1 Building a speaker

A speaker converts electric signals into sound waves. There are different types of speakers. The basic design of a **moving coil speaker** is shown below. It consists of a cone with a small cylinder attached to it. A coil of wire is wound around the cylinder. The edge of the cone is supported by flexible supports that allow the cylinder (with its coil) to move in and out of a magnetic field.



A working model of the speaker may be built, using he following material:

- sheets of A4 size cards (about 2 sheets per group), for the cone and the cylinder;
- Sellotape and glue;
- a pair of scissors;
- bar magnets (about 3 each group);
- about 8 metres of thin insulated (enamelled) wire per group;

In designing and building the speaker, students should be encouraged to produce their own designs, which may be quite different from the diagram.

A signal generator with an 8-ohm or 4-ohm speaker output may be used to test the speakers produced by students. Virtually any design will work, if about 6 metres of wire is wound around a cylinder of about 2.5 cm diameter. The magnet need not be of a particular shape. One bar magnet positioned inside the cylinder will produce audible sound.

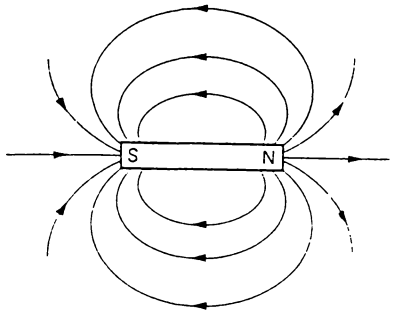
Alternatively, a variable low voltage supply (0-6 Vac will do) can be used to produce a 50Hz sound off the speakers made by the students. In using a low voltage supply, a lamp or a rheostat need to be used in series to avoid overloading the power supply.

Additional notes for suggested activity 2.2. How do scientists talk about speakers?

2.2.1: Field lines and magnetic fields

Magnetic field lines are imaginary, and do not exist in reality. They are used to represent the strength and the direction of a magnetic field, and hence are used according to some commonly agreed rules. Some of these rules are stated below.

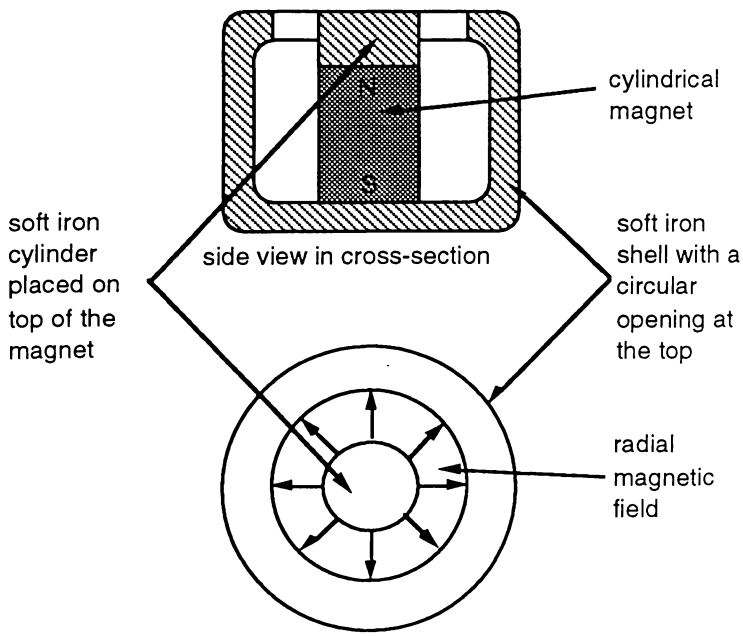
- The direction of a field line represents the magnetic force on a "free" north pole. Field lines are often called lines of force.



- The spacing of the lines represent the strength of magnetic field; ie., the closer the lines are at a point, the stronger is the magnetic field strength at that point.
- A magnetic field line represents the *resultant* magnetic force near the line. Therefore, field lines must be drawn so that they do not cross each other. Crossing field lines would mean that there are two resultant magnetic forces at the point where the lines cross.

2.2.2: The magnet in a speaker

The magnet in a speaker is designed to give a **radial magnetic field**. A radial magnetic field has its magnetic field lines radiating out evenly in all directions.



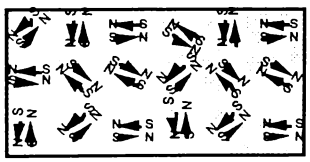
top view showing the radial magnetic field

The above figures show how a radial magnetic field is produced using a cylindrical magnet and a ring made of soft iron. Soft iron is a soft ferromagnetic material that is used to 'guide' the field lines (see additional notes 2.2.3 and 2.2.4).

2.2.3: Ferromagnetic materials

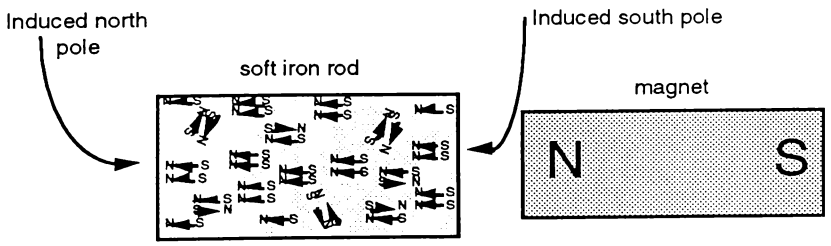
Materials like iron and steel, that can be magnetised are known as ferromagnetic materials.

One *theory* suggests that, ferromagnetic materials have small groups of atoms called 'magnetic domains' that behave like very tiny magnets. The domains of an un-magnetised ferromagnetic material are arranged so that the magnetic fields of the neighbouring domains cancel out. This is why a piece of iron does not normally act as a magnet. The diagram below represents this arrangement of domains in an un-magnetised piece of iron. Each arrow represents a domain.



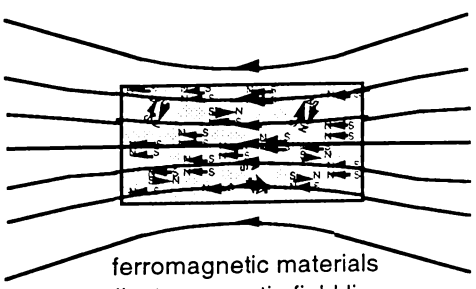
Magnetic domains [N◄S] are arranged so that the magnetic fields of neighboring domains cancel out

When a piece of iron is placed near a magnet, most of the magnetic domains align themselves to the magnetic field, inducing magnetic poles at the ends of the piece of iron. (The following figure is **NOT TO SCALE.**)



Most of the magnetic domains [N◄S] rearrange and magnetic poles appear at the ends of the rod.

This rearrangement of the domains inside the ferromagnetic material increases the strength of the magnetic field induced in the material. This increase in the strength of the magnetic field will re-shape the magnetic field too. The reshaping of the magnetic field may be visualised as the "collection" of field lines by the ferromagnetic material.



ferromagnetic materials collects magnetic field lines

Heating a ferromagnetic material almost to its melting point and cooling it in a strong magnetic field, makes it a permanent magnet. This is because the magnetic domains can be easily aligned in the direction of an applied magnetic field, when the inter-molecular forces are made relatively 'weaker' by heating.

Similarly, heating a bar magnet until it is red hot will make it loose its magnetism. This is because the magnetic domains can easily loose their orientation when the inter-molecular forces are made relatively 'weaker' by heating.

2.2.4: Magnetically 'soft' and 'hard' materials

Some ferromagnetic material, like steel or Alcomax (an alloy of iron, nickel and aluminium), will retain magnetism even after being taken out of a magnetic field. If the magnetic field is strong enough, these material may become permanent magnets. Soft iron almost instantly looses its magnetism once the magnetic field is removed.

Ferromagnetic material can thus be classified into two broad groups—soft and hard— according to their magnetisation. Soft magnetic materials like soft iron, can be easily magnetised and demagnetised. Hard magnetic materials like hard steel, need strong magnetising fields and retain their magnetisation.

2.2.5: Magnetism explained in terms of moving electrons

Any moving electron has a magnetic field associated with it. In the atomic structure, the electron is in constant motion. Normally electrons are paired together so that the individual magnetic fields of the pair are opposed to each other and hence, cancel out. In ferromagnetic materials, there are unpaired electrons in the energy levels of the atom that give the whole atom a magnetic field. A group of such atoms form a magnetic domain.

This explanation may also be used to describe the magnetic field associated with a current in a wire. The free electrons that carry the current in a wire may be are not paired so as to cancel their magnetic fields.

2.2.6: The working of the speaker: two models

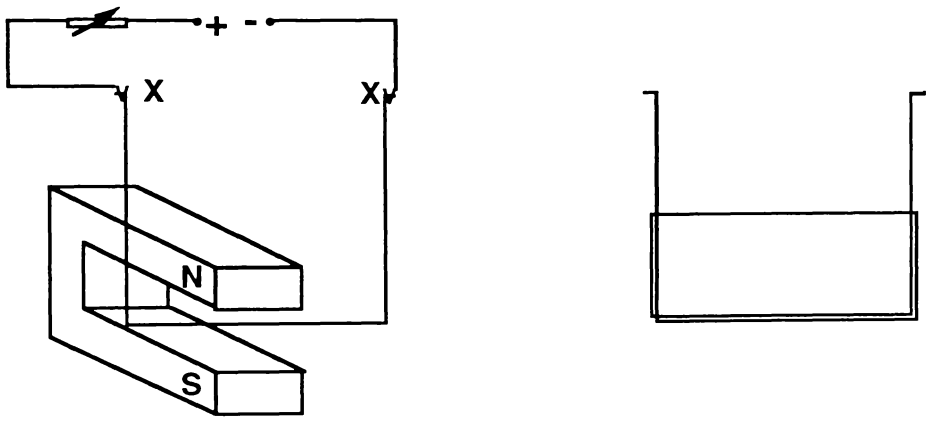
One possible explanation is to view the speaker coil as an electromagnet. Signals from the amplifier or the signal generator provide an alternating current that flows through the coil to make it an electromagnet. As the strength of the signal as well as the direction of the current that it produces in the coil, varies, the strength and the polarity of the electromagnet varies causing it to vibrate inside the magnetic field.

2.2.7: Force on a current-carrying conductor in a magnetic field

The following demonstration may be used to further explore the force on a current-carrying conductor in a magnetic field. (See the figure on next page.)

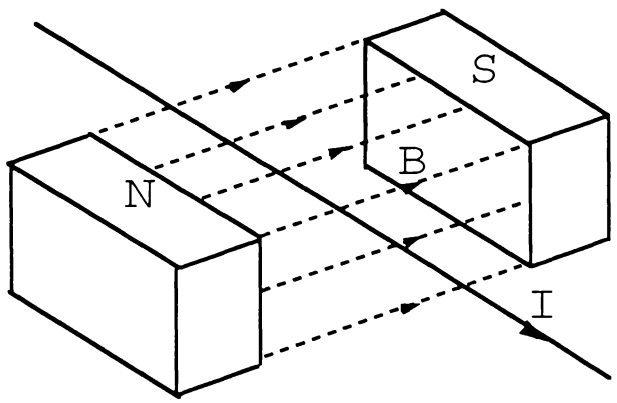
A loop of thin wire is suspended at XX so that it can swing freely between the poles of a U-shapes magnet. The current in the loop may be gradually increased so that it tilts in or out of the magnetic field, depending on the direction of the current. The loop would normally stay tilted as long as the current flows. If a large current is suddenly switched on, the wire loop may oscillate in and out of the magnetic field.

The demonstration may also be used to illustrate the right-hand slap rule (or Fleming's left-hand rule. See additional notes 2.2.8.), as well as to arrive at the formula F=BIL by demonstrating the general relationships between force, the strength of the magnetic field, the current and the length of the conductor inside the magnetic field.



2.2.8: The right-hand slap rule

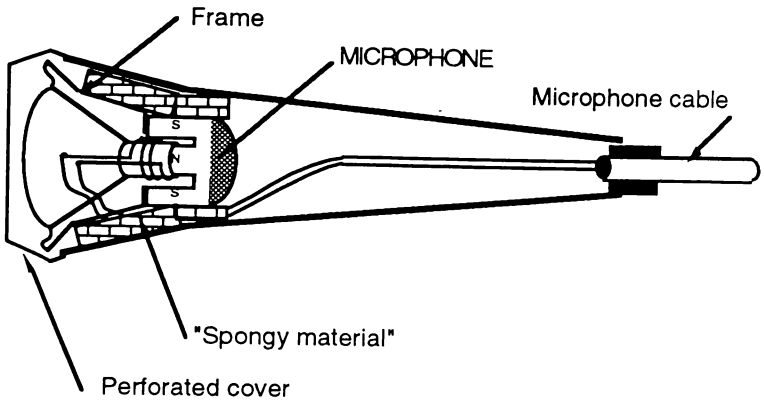
This is an alternative to Fleming's left-hand rule that is used to predict the force on a wire carrying a current in a magnetic field.



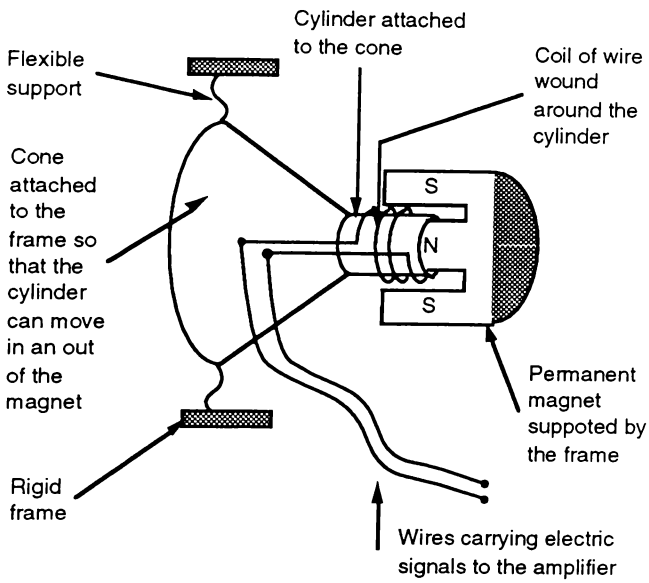
F, force on the wire, in units of newtons.
B, strength of the magnetic field, in units of tesla, T.
I, current in the wire, in units of amperes.
L, the length of the wire perpendicular to the magnetic field, **inside** the magnetic field, measured in units of metres.

Additional notes for suggested activity 3.1: How does a microphone work?

3.1.1: A dynamic microphone



a hand-held dynamic microphone



Details of a dynamic microphone

A microphone converts sound waves into electric signals. One common type is the dynamic microphone. It is called dynamic, because it has a moving coil.

In a dynamic (or moving coil) microphone the sound waves vibrate the cone and the coil of wire attached to it moves in and out of a magnetic field. This movement of the coil in the magnetic field is essential to converting the vibrations of the sound waves into electric currents.

Exercises

Exercises for suggested activity 2.2.1: Parts of the speaker

1. Figures A and B show how permanent magnets may be used in speakers to produce magnetic field lines that are perpendicular to the speaker coils. Figure A uses a cylindrical magnet with its poles at the two ends. Figure B uses a magnet shaped like a ring.
   a) Copy the cross-section of the figures A and B into your note book and show how you think the magnetic field lines travel through the soft-iron.
   b) Can aluminium be used instead of soft-iron in the magnet arrangements? Explain your answer.

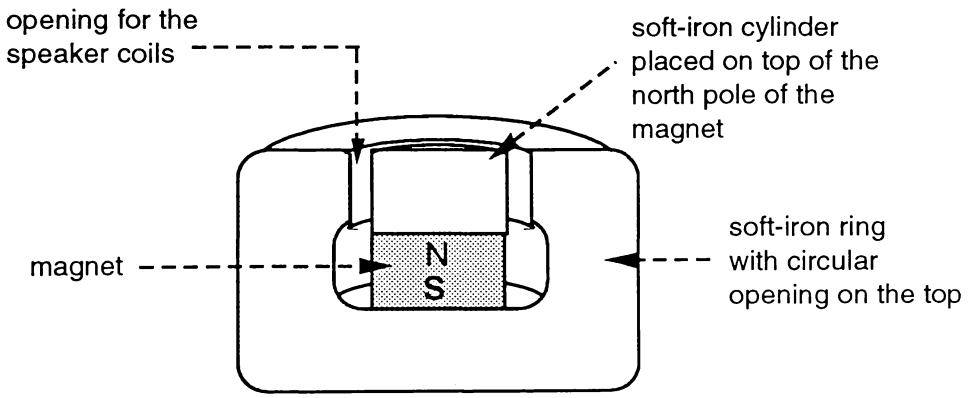


Figure A

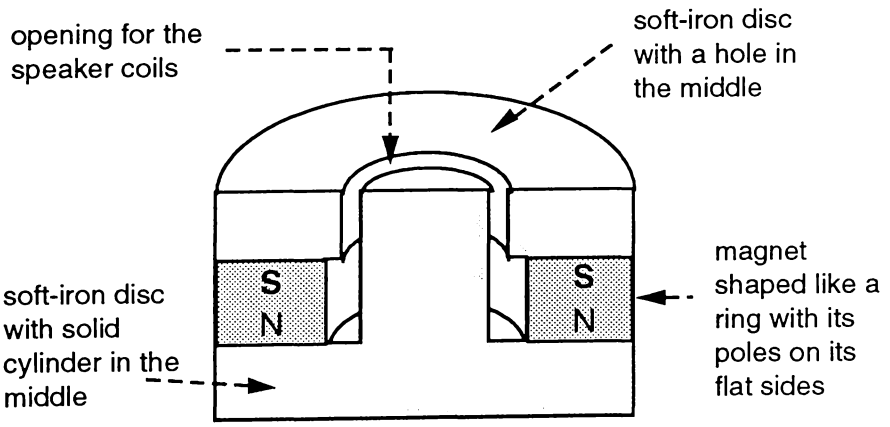


Figure B

2. In designing a magnet-arrangement for a model speaker, a student made the following observations.
   a) Two magnets attracted each other when placed as follows. Copy the following figure into your note book and draw the magnetic field between and around the magnets.



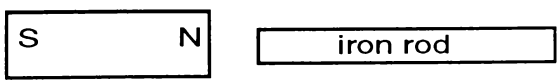
b) The two magnets repelled when placed as follows. Copy the following figure into your note book and draw the magnetic field between and around the magnets.



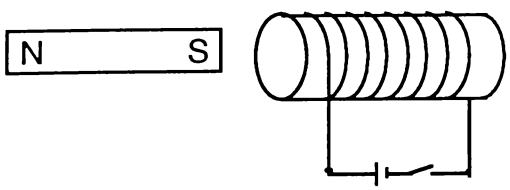
c) When a small plotting compass is placed at point a, between the two similar magnets shown below, the compass needle did not seem to be influenced by the magnets. This point is called a **neutral point**. Copy the figure into your note book and draw the magnetic field between the magnets and around them. Suggest a possible reason for this observation.



d) An iron rod attracted the magnet when brought closed to the magnet. Copy the following figure into your note book and draw the magnetic field between and around the magnet and the iron rod. Draw the field lines as they would travel inside the magnet and the iron rod. Mark the poles induced across the ends of the iron rod.



3. To test a speaker coil, a student connects it to a battery and a switch as shown below. When the switch is closed the coil moves.

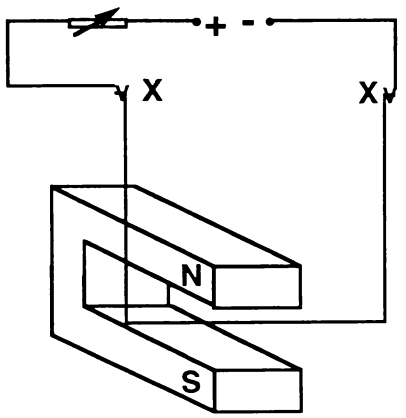


a) Copy the above figure into your note books and mark the direction of current in the coil.
b) Does the coil move towards the magnet or away from the magnet? Explain your answer.
c) Suggest two changes that can increase the force that cause this movement.

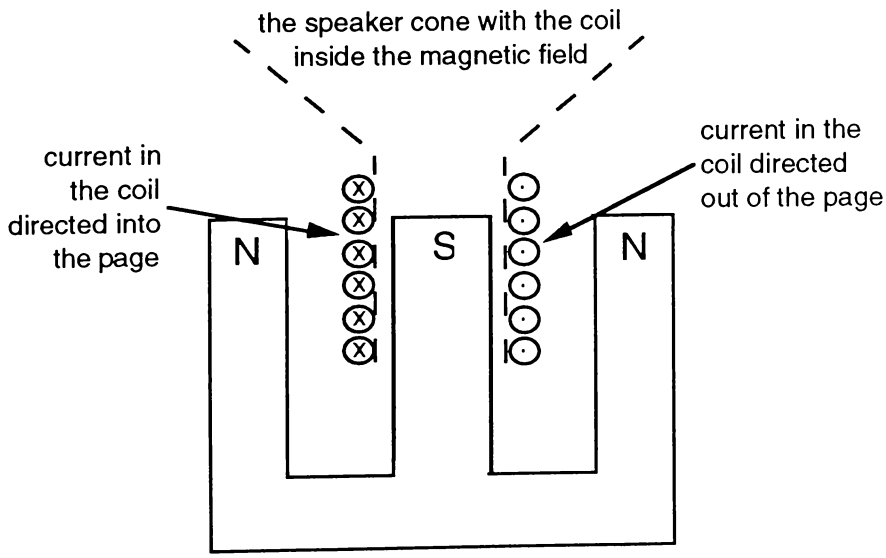
Exercises for suggested activity 2.2.2: Why does the speaker vibrate?

1. A student decides to investigate the force that makes a speaker vibrate and conducts the following experiment. The student suspends a wire loop between the poles of a horse-shoe magnet as shown in the diagram.

   a) What is the direction of the force on the loop when it is connected to a power supply as shown in the diagram?
   b) Suggest two ways of increasing this force on the loop.
   c) Suggest two ways of reversing this force.



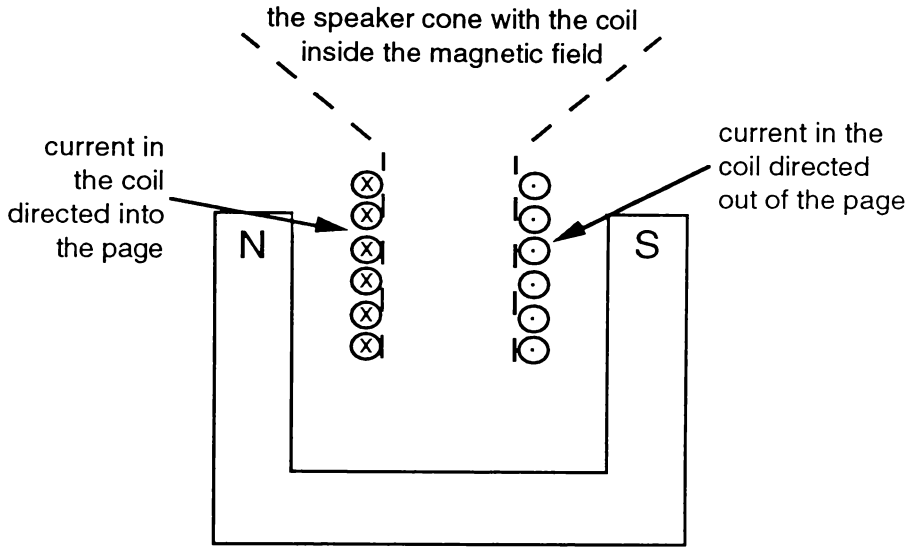
2. In a given moment the current in a speaker coil flows as shown below. Note that crosses on one side of the coil indicate that the current is going into the paper, and the dots on the other side indicate that the current is coming out of the paper in the coil.



   a) Copy the figure and draw the field between the poles of the magnet.
   b) What is the direction of the force on the right-hand side of the coil?
   c) What is the direction of the force on the left-hand side of the coil?

d) What do you think is the result of the forces in b and c on the coil?
e) The electric signal that 'drives' the speaker is a form of an alternating current. Explain in terms of the forces on the coil why the speaker cone vibrates when such a signal flows in the coil.

3. A student placed a speaker coil between the poles of a U-shaped magnet and passed a direct current through it.



a) Copy the figure and draw the field between the poles of the magnet.
b) What is the direction of the force on the right-hand side of the coil?
c) What is the direction of the force on the left-hand side of the coil?
d) What do you think is the result of the forces in b and c on the coil?
e) Would you use a U-shaped magnet in designing a speaker? Explain your answer.

4. Commercial speakers manufactured now are relatively smaller than those in the 1960's and 1970's. However, the smaller speakers produce similar or better quality sound. What do you think is the reason for this?

More applications for sub-unit 2:

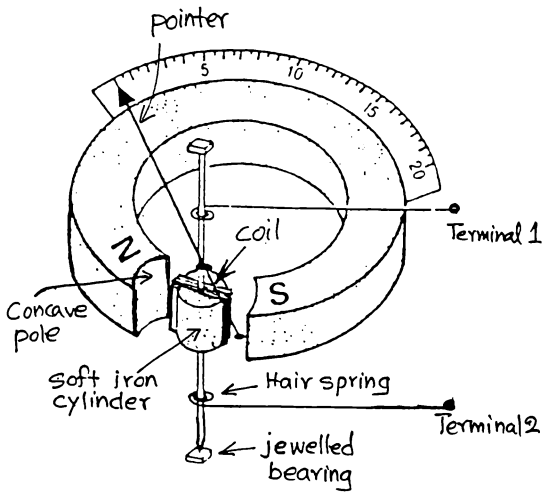
1. The galvanometer

Moving coil galvanometers are used in a variety of applications to measure small currents. The sound level indicators in some hi-fi systems are galvanometers that measure small currents in the amplifier output. The ammeter used in the lab consists of a moving coil galvanometer connected in parallel to a very low value resistor called a shunt. Voltmeters are galvanometers connected in series with a very high resistance.

(Suggested further reading: Section 7.7: Electric meters, *Explaining Physics* by S Pople.)

A moving coil galvanometer has the following basic components.

- A magnetic field,
- A soft iron cylinder fixed in the middle of the magnetic field.
- A coil that is supported so that it does not touch the soft iron cylinder, but is able to slide over it.
- A pointer that is attached to the coil and turns with it.
- Hair springs.



1. Explain the purposes of the following:
   a) the radial magnetic field,
   b) the fixed soft iron cylinder, and
   c) the hair springs

2. What is the path of the current through the meter?

3. Explain why the pointer deflects when a current passes through the terminals.

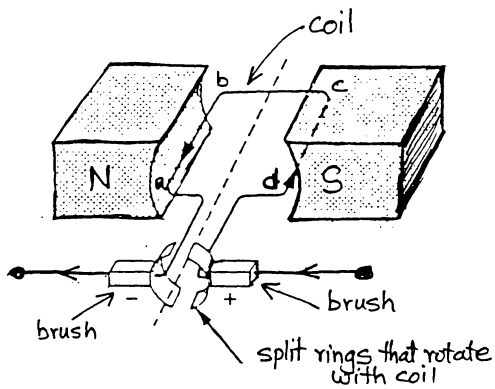
2. The dc motor.

Motors have become a very important part of our daily lives. Motors are used to drive the pumps that supply water to our homes. Our cassette player, CD player, VCR, toys, and several other equipment we use in our daily lives have motors incorporated into them. In this exercise, we will look at motors that work on direct current, or dc motors.

(Suggested further reading: Section 7.6: Electric motors, *Explaining Physics* by S Pople.)

A dc motor has the following basic components.

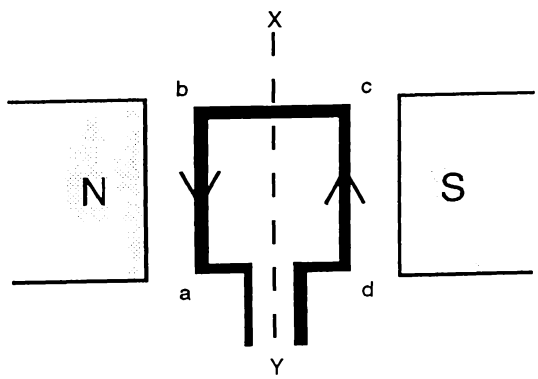
- A magnetic field,
- A coil that is supported so that it can rotate.
- A copper ring, split into two halves. Each half is connected to one end of the coil.
- two brushes that are fixed so that they slip over the split ring of copper.



1. Explain the purposes of the following:
   a) the curved poles of the magnets,
   b) the split rings, and
   c) the brushes.

2. What is the path of the current through the motor?

3. The figure below shows a top view of the coil abcd, between the magnetic poles. The coil which is free to rotate about the axis XY, carries a current as indicated by the arrows. Which sides ab, bc, cd, and da do not experience a force? Give a reason for your answer.

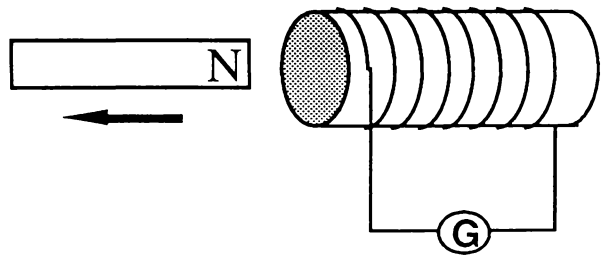


3. Explain why the coil rotates.

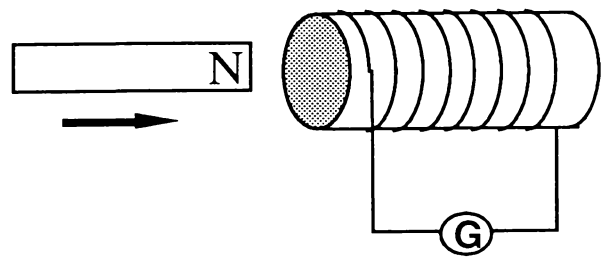
Exercises for suggested activity 3.2:
The physics of the microphone

1. A student makes a coil similar to that in a microphone and tests it by using a magnet and a very sensitive ammeter called a galvanometer (G).

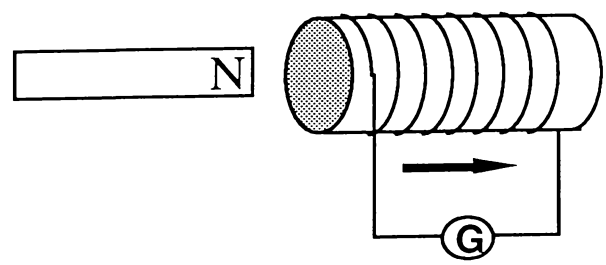
   a) Use the laws of electromagnetic induction to explain why a current is observed in the galvanometer when the magnet is moved away from the coil. Copy the figure onto your note book and mark the poles that appear on the coil due to this current. Also show the direction of this current.



   b) When the magnet is moved towards the coil, the galvanometer deflects in the opposite direction. Explain.



   c) The student tries moving the coil instead of the magnet and observes a current in the coil. Explain.



2. In trying to understand more about how a dynamic microphone converts the motion of its coil into electric signals, a student moves a length of wire inside a magnetic field as shown below and observes the induced current using a very sensitive galvanometer.

   Copy the figures into your note book and indicate the direction of induced current in the wires. The arrow in each figure indicates the direction of motion of the wire.

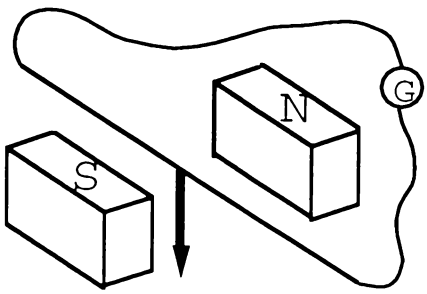


Figure A

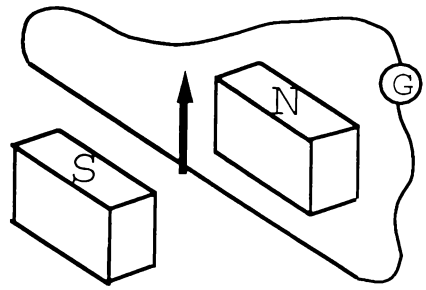


Figure B

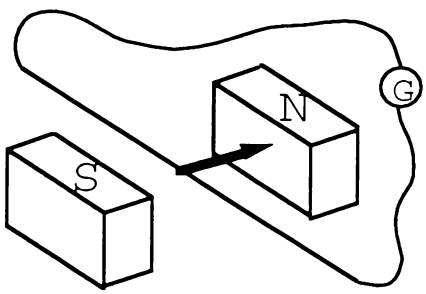


Figure C

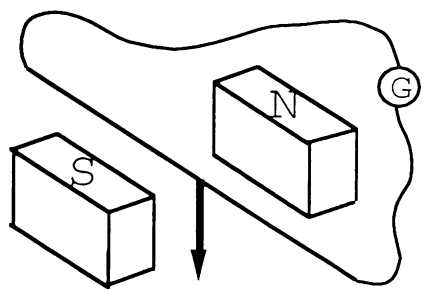


Figure D

3. When the wire in Figure B is pulled **vertically upwards** at a speed of 1m/s a positive reading of +0.0002 mA is registered on the ammeter.

   a) If the wire is pulled **vertically down**, at the same speed, the reading of the ammeter will most probably be:

A	+0.0002 mA,	B	-0.0002 mA,
C	0 mA	D	+0.0004 mA
E	-0.0004 mA		

   b) If the wire is pulled **horizontally** at a speed of 2 m/s the reading of the ammeter will most probably be:

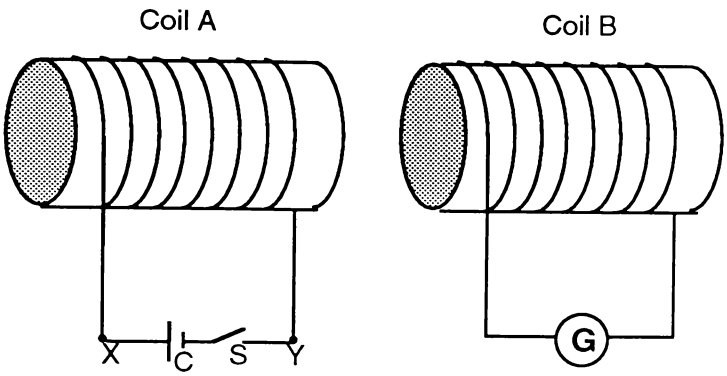
A	+0.0002 mA,	B	-0.0002 mA,
C	0 mA	D	+0.0004 mA
E	-0.0004 mA		

4. Dynamic microphones used to be very large and not very sensitive. What changes may have enabled designers to make smaller and more sensitive microphones?

More applications for sub-unit 3:

1. Transformers

Instead of using a bar magnet to induce electricity in a coil (coil B), a student decides to use an electromagnet. She places another coil (coil A) with its ends (X and Y) connected to a battery cell (C) and a switch (S) as shown below.

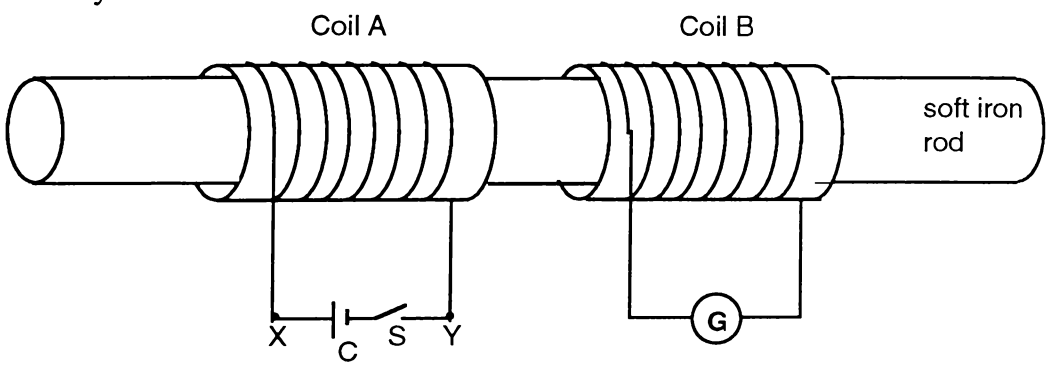


1. Copy the figure and indicate on your diagram, the magnetic poles that appear on coil A when switch S is closed.

2. With S closed and coil A is pulled away from coil B, the pointer on the centre-zero galvanometer deflects to the left and gradually goes back to zero. Explain this observation.

3. With S closed, if coil B is moved away from coil A which way will the galvanometer pointer deflect?

4. It was found that slipping a soft iron rod through the coils increases the deflection of the galvanometer pointer, when any of the coils are moved. Why do you think so?



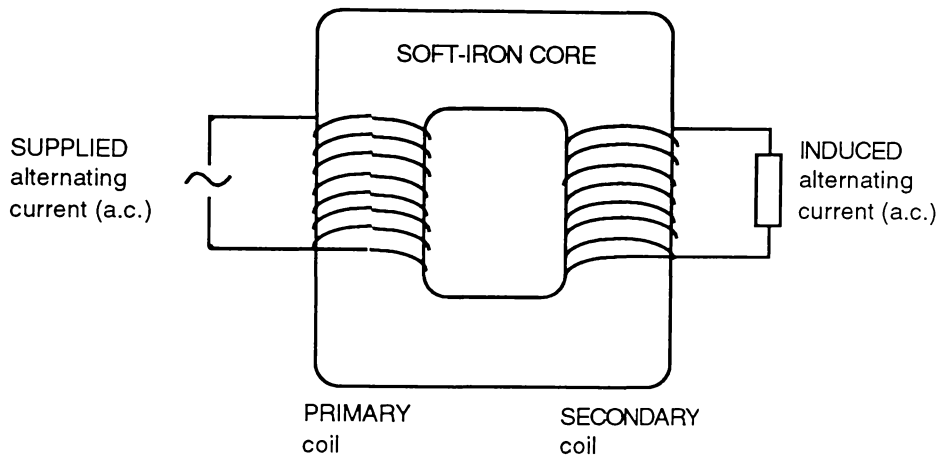
5. In the above arrangement, the student also observes the following. Suggest possible explanations for these observations.

   a) When switch S is closed the galvanometer pointer flicks to on side and comes back to zero.
   b) When S is kept closed, the pointer remains at zero.
   c) When switch S is opened, the galvanometer pointer flicks to the opposite side and comes back to zero.
   d) When S is kept open, the pointer remains at zero.

e) When the battery cell (C) and a switch (S) is removed and a 6V ac source is connected across XY, the galvanometer pointer vibrates very fast.

The process observed by the student is called **mutual induction**. Mutual induction is the process in which a *change* in the current through one coil brings about an induced e.m.f. in the other. Many applications, including the transformer, make use of mutual induction.

The basic design of a transformer is shown below.



The effect of supplying alternating current to the **primary coil** is the same as repeatedly switching on and off the current in coil A, in the experiment conducted by the student. The alternating current forms a continuously changing magnetic field in the soft-iron core and a current of the same frequency is induced in the **secondary coil**.

6. Why is the soft-iron core shaped like a ring?

7. The induced voltage in the secondary coil depends on the number of turns in the secondary coil, the number of turns in the primary coil and the supply voltage. By referring to your text-book or any other O/L physics book find out how these are related.

   (Suggested further reading: Section 7.10: Mutual Induction and Transformers, *Explaining Physics* by S Pople. Section 70: Transformers, *Physics for Today and Tomorrow* by T Duncan)

8. Also by referring to your text-book or any other O/L physics book find out the following:
   a) step-down transformer
   b) step-up transformer

9. Ideally we would like our transformers to be 100% efficient. We would call such a transformer an **ideal transformer**. In an ideal transformer, there will be no energy wasted and all the energy supplied to the primary coil will be transferred to the secondary coil:

   i.e., power in = power out
   Vp x Ip = Vs xIs

where, Vp = primary voltage
Ip = primary current
Vs = secondary voltage
Is = secondary current

a) A transformer reduces a supply voltage of 220V to 20V. If the transformer is 100% efficient, and the current in the primary coil is 1A, what is the current in the secondary coil?

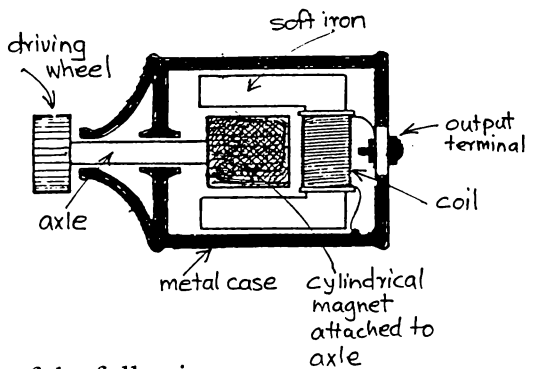
b) A transformer has 800 turns on the primary coil and 20 turns on the secondary coil. If the primary e.m.f. is 240V and the current in the secondary circuit is 4A, and assuming there is no loss of energy, calculate the secondary e.m.f. and the primary current.

10. The resistance of windings, eddy currents and leakage of field lines are some factors that lead to energy loss in transformers. By referring to your text-book or any other O/L physics book find out the measures taken in order to reduce these factors in a practical transformer.

2. The bicycle dynamo.

A bicycle dynamo is a simple form of an alternating current generator. Alternating current generators are used in power-stations to provide electricity to our homes. These generators can be water driven as in hydro-electric systems or driven by steam or diesel engines. The movement of the bicycle wheels drives the bicycle dynamo.

A bicycle dynamo has the following parts.
- A cylindrical magnet attached to an axil. The magnet has its poles across its diameter (ie., on the sides of the cylindrical magnet),
- A U-shaped soft iron core.
- A coil that is wound around the soft iron core.
- A driving wheel that is turned by the bicycle tyre. The driving wheel turns the axil and the magnet.

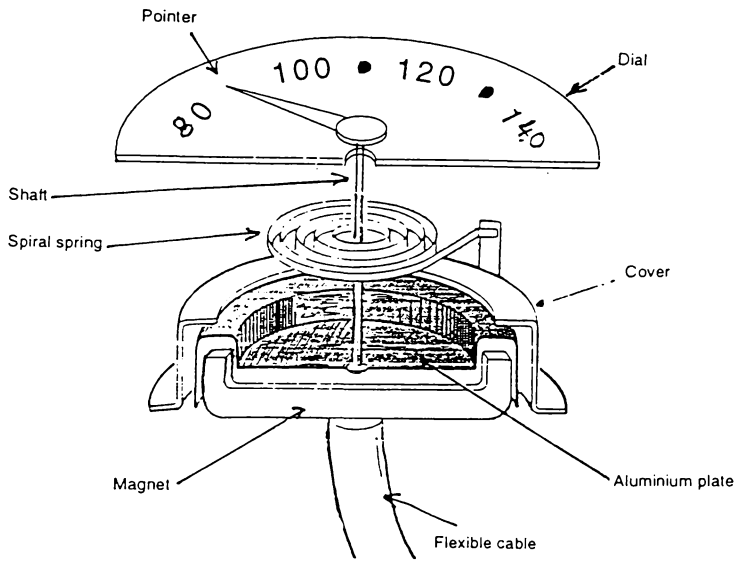


1. Explain the purposes of the following:
   a) the magnet having its poles across its diameter,
   b) the soft iron core,

2. Explain how an alternating current may be produced by the dynamo.

3. The speedometer

A speedometer is used in a vehicle to indicate the speed at which it is travelling. There are several forms of speedometers. The most common design of the speedometer consists of a permanent magnet and an aluminium plate arranged as shown in the figure below. The aluminium plate is supported by a spiral spring so that it can turn, moving the pointer attached to it across the scale on the dial. The magnet is connected to the transmission (the mechanism that turns the wheels of the vehicle) via a flexible cable. This causes the magnet to rotate with the wheels.



Although the magnet and the plate do not touch each other, the rotating magnet exerts a force on the aluminium plate. When the magnet rotates, the aluminium plate turns in the same direction until the force that is making the plate turn is balanced by the force applied by the unwinding spiral spring. When the magnet stops rotating, the spring turns the plate back to the original position, moving the pointer back to zero.

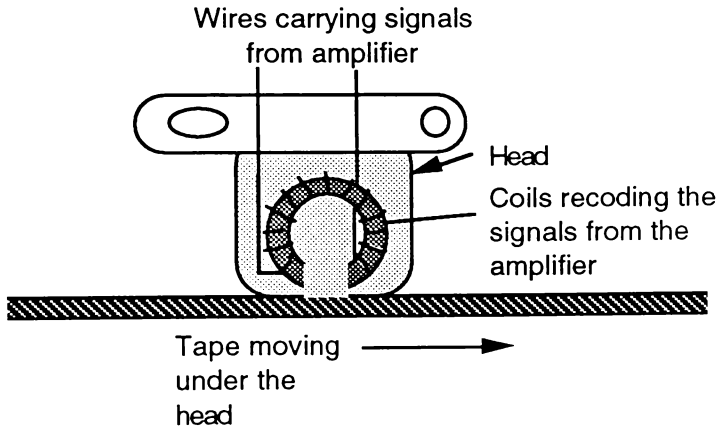
1. Explain how the rotating magnet makes the aluminium plate turn?

2. Why is the plate made of aluminium and not of iron?

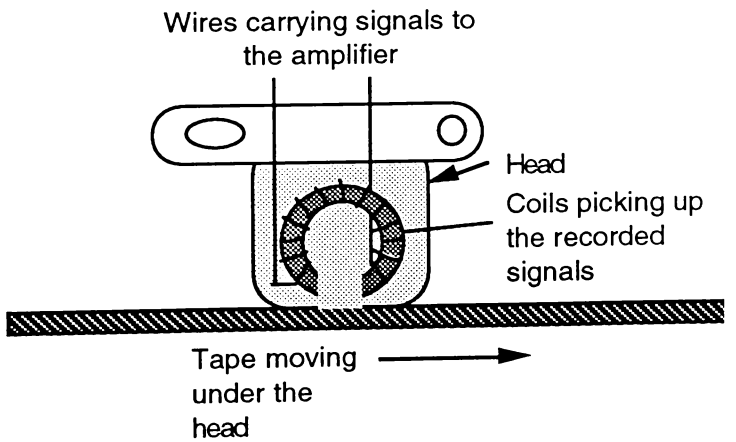
3. If the speed of the car increases, the speed of the magnet also increases. This increases the force on the plate and the pointer turns more. Why does the increase in the rotational speed of the magnet produce a greater turning force on the aluminium plate?

4. The cassette-tape recorder.

A tape recorder may be used to record signals from a microphone or any other source on tape and to play it back later. In the process of recording the signals are made stronger by the amplification circuits inside, and transferred to tiny coils inside the record/playback 'head' that is in contact with the tape. As the tape moves by the head, the signals are recorded on the tape. All cassette-tapes are coated by a layer of ferromagnetic material.



1 In terms of the magnetic domains suggest how the signal may be recorded on the tape.



2. In the playback mode, the recorded tape moves past the 'head' that picks up the signals from the tape and sends them to the amplifier circuits to make the signal stronger. Suggest how the 'head' may pick up the signals.

APPENDIX C2: Introductory comments about the curriculum in the resource used in New Zealand during Phase 3 and Phase 4.

Physics in the New Zealand Curriculum

The module is consistant with the aims of Physics in the New Zealand Curriculum and meets its achievement objectives for physics at sixth form level

Scientific Knowledge, Skills and Attitudes Targeted in the Module

The scientific concepts, and principles that will be introduced in this module include:

- the use of ferromagnetic material to change magnetic field patterns;
- the magnetic effect of a current;
- magnetic fields around current-carrying wires and solenoids;
- the force on a current-carrying conductor in a magnetic field;
- laws of electromagnetic induction.

The scientific models that will be introduced in this module include:

- the use of field lines to describe magnetic fields;
- the use of a simplified theory of magnetic domains to introduce ferromagnetism.

In this module, students will be given the opportunity to use and to develop their investigative skills and attitudes needed for:

- exploring how some everyday equipment work;
- problem solving;
- communicating their ideas;
- group work;
- debate.

APPENDIX C3: Pre-test used in the Maldives during Phase 3

Pre-Test on Electromagnetism.

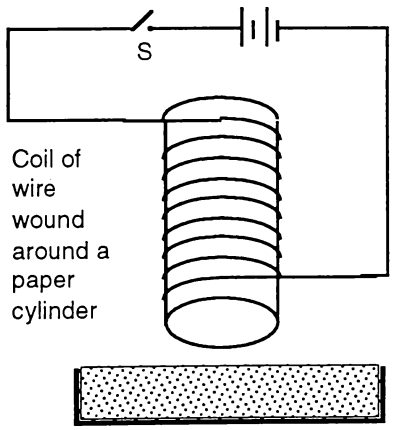
This test is to find out what you already know about electromagnetism. Your answers will **NOT** be used to give you a grade and will **NOT** contribute towards any formal assessment.

Use the blank sheets provided for your answers. Remember to write your name and class on each sheet of paper. **Please do not write on this question paper. Please remember to return the question paper with your answers.**

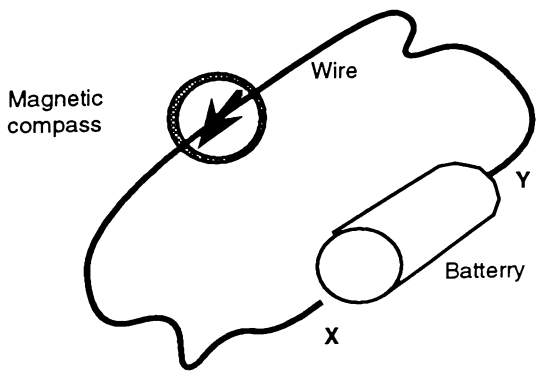
Question one

In the arrangement shown, a coil of insulated wire is supported above a tray containing iron filings. The coil is connected to a battery through a switch S. When the switch is closed, a few iron filings are picked up by the coil.

a) Explain why the iron filings are picked up by the coil.
b) With the switch S kept closed, a soft iron rod is inserted into the coil. What would you expect to observe?
c) Suggest some devices where such a coil may be used.



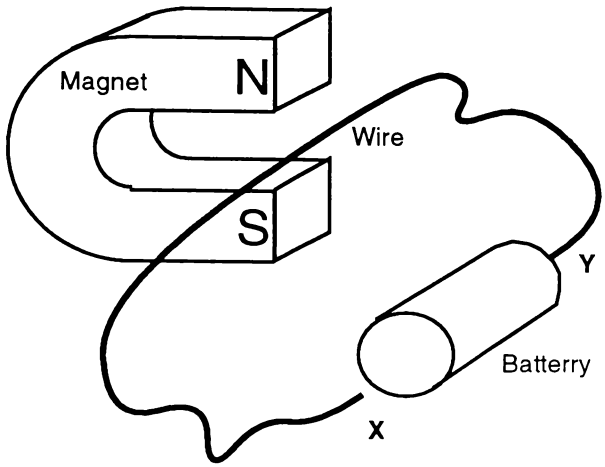
Question two



A wire is placed on a magnetic compass as shown in the figure. The end Y of the wire is connected to one of the terminals of a 1.5V battery.

a) Explain why the magnetic needle of the compass deflects slightly to the right when the end X of the wire is connected to the other terminal of the battery.
b) Suggest how this deflection of the magnetic needle may be increased.

Question three



The same wire used in question two is placed on one of the poles of a U-shaped magnet as shown above. The end Y of the wire is connected to one of the terminals of a 1.5V battery.

a) Explain why the wire jumps away from the magnet when end X of the wire is connected to the other terminal of the battery.

b) Some devices make use of this effect. Name such a device. For what purpose would you use the device?

APPENDIX C4: Pre-test used in New Zealand during Phase 3

Pre-Test on Electromagnetism.

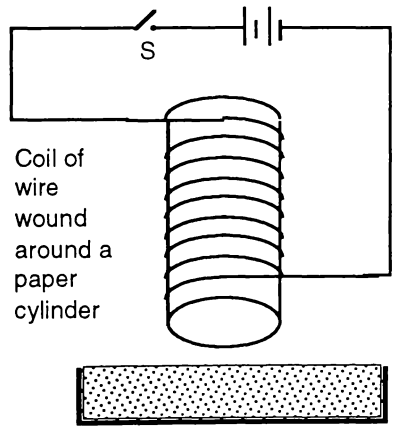
This test is to find out what you already know about electromagnetism. Your answers will **NOT** be used to give you a grade and will **NOT** contribute towards any formal assessment.

Use the blank sheets provided for your answers. Remember to write your name and class on each sheet of paper. **Please do not write on this question paper. Please remember to return the question paper with your answers.**

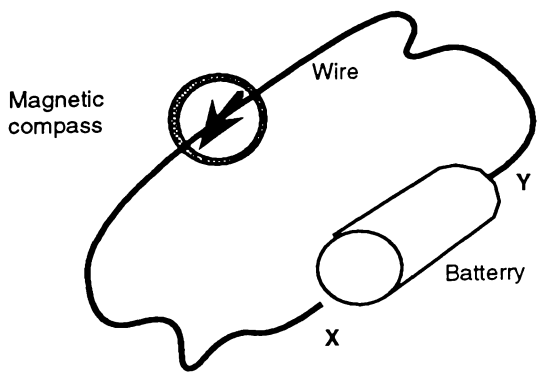
Question one

In the arrangement shown, a coil of insulated wire is supported above a tray containing iron filings. The coil is connected to a battery through a switch S. When the switch is closed, a few iron filings are picked up by the coil.

a) Explain why the iron filings are picked up by the coil.
b) With the switch S kept closed, a soft iron rod is inserted into the coil. What would you expect to observe?
c) Suggest some devices where such a coil may be used.



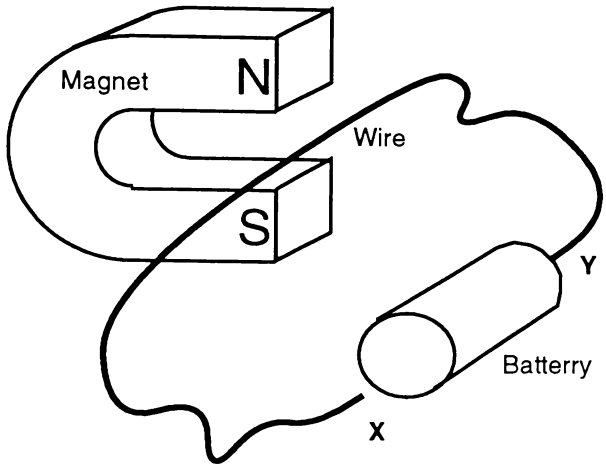
Question two



A wire is placed on a magnetic compass as shown in the figure. The end Y of the wire is connected to one of the terminals of a 1.5V battery.

a) Explain why the magnetic needle of the compass deflects slightly to the right when the end X of the wire is connected to the other terminal of the battery.
b) Suggest how this deflection of the magnetic needle may be increased.

Question three



The same wire used in question two is placed on one of the poles of a U-shaped magnet as shown above. The end Y of the wire is connected to one of the terminals of a 1.5V battery.

a) Explain why the wire jumps away from the magnet when end X of the wire is connected to the other terminal of the battery.

b) Some devices make use of this effect. Name such a device. For what purpose would you use the device?

Question four

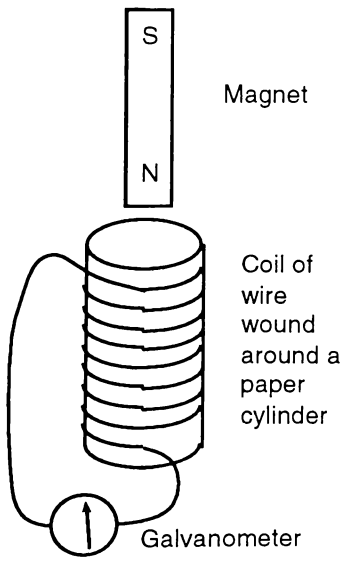
A coil of wire is wound around a paper cylinder and is connected to a sensitive galvanometer as shown in the figure.

When a magnet is allowed to fall through the paper cylinder a deflection in the galvanometer pointer is observed.

a) Explain why the galvanometer pointer deflects.

b) Suggest two ways of increasing this deflection in the galvanometer pointer.

c) Some devices make use of this effect. Name such a device. For what purpose would you use the device?



APPENDIX C5: Questionnaire used in the Maldives during Phase 3

Evaluation Sheet: Unit on Electromagnetism

Name _____ **Date** _____

This evaluation sheet seeks your personal opinion and your individual comments about the unit on electromagnetism that you have completed. Your comments will be used to improve the unit for future use. These sheets will not be viewed by your teachers or by your school authorities. Thank you very much for your help.

SECTION A: Your comments about the classroom activities

This section requires you to comment on the various activities conducted in the unit on electromagnetism.

The main classroom activities are listed below. Place tick along the scale beside each activity to indicate how you feel about the activity.

	Main activities	Your interest							
1	Talking about telecommunications	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
2	Finding out how a telephone and a baby monitor work	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
3	Making a speaker	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
4	Looking at the physics of the speaker	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
5	Looking at electromagnetism in other applications	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting

- State your reasons for being very interested (or interested) in some of the above activities. [Use the back of this sheet if necessary.]

SECTION B: Your comments, comparing this unit to other physics units

This section requires you to compare the unit on electromagnetism to other units that you have covered in physics. Please tick a position along the scale after each question to indicate your answer to each of the following questions.

	Questions	Your comment		
1	Are the classroom activities in this unit any different from those in your normal physics classes?	Very different	1 2 3 4 5 6 7	Just the same
2	Compared to other units in physics, did you observe any differences in the way this unit was taught?	Very different	1 2 3 4 5 6 7	Just the same
3	How would you compare your classroom participation during this unit to that in other units?	Participat-ed **more**	1 2 3 4 5 6 7	Participat-ed **less**
4	Compared to other units in physics, did you feel that you were learning more or less physics in this unit?	Learning **more**	1 2 3 4 5 6 7	Learning **less**
5	Compared to other units, how informative did you find this unit?	**More** informative	1 2 3 4 5 6 7	**Less** informative
6	How relevant was this unit to you, compared to other units in physics?	**More** relevant	1 2 3 4 5 6 7	**Less** relevant
7	Compared to other units in physics, how interesting did you find this unit?	**More** interesting	1 2 3 4 5 6 7	**Less** interesting
8	Compared to other units in physics, how enjoyable did you find this unit?	**More** enjoyable	1 2 3 4 5 6 7	**Less** enjoyable
9	Compared to other units in physics, how difficult did you find this unit?	**More** difficult	1 2 3 4 5 6 7	**Less** difficult

- What are some other differences that you may have observed between this unit and other units in physics? [Use the back of this sheet if necessary.]

SECTION C: Other comments

Please write down any other comments you would like to make about the unit. Feel free to comment on **any** aspect(s) of the unit (the teaching, the practicals, the help you received during the unit, the tests, etc.).

SECTION D: Your suggestions

What would you recommend changing in this unit, in order to make it better?

[NOTE: In the actual questionnaire more writing space was provided.]

APPENDIX C6: Questionnaire used in New Zealand during Phase 3

Evaluation Sheet: Unit on Electromagnetism

Name _____ **Date** _____

This evaluation sheet seeks your personal opinion and your individual comments about the unit on electromagnetism that you have completed. Your comments will be used to improve the unit for future use. These sheets will not be viewed by your teachers or by your school authorities. Thank you very much for your help.

SECTION A: Your comments about the classroom activities

This section requires you to comment on the various activities conducted in the unit on electromagnetism.

The main classroom activities are listed below. Place tick along the scale beside each activity to indicate how you feel about the activity.

	Main activities	Your interest							
1	Talking about telecommunications	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
2	Finding out how a telephone and a baby monitor work	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
3	Making a speaker	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
4	Looking at the physics of the speaker	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
5	Looking at the physics of the microphone	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting
6	Looking at electromagnetism in other applications	Very interesting	1 :	2 :	3 :	4 :	5 :	6 :	7 :	Not interesting

- State your reasons for being very interested (or interested) in some of the above activities. [Use the back of this sheet if necessary.]

SECTION B: Your comments, comparing this unit to other physics units

This section requires you to compare the unit on electromagnetism to other units that you have covered in physics. Please tick a position along the scale after each question to indicate your answer to each of the following questions.

	Questions	Your comment		
1	Are the classroom activities in this unit any different from those in your normal physics classes?	Very different	1 : 2 : 3 : 4 : 5 : 6 : 7	Just the same
2	Compared to other units in physics, did you observe any differences in the way this unit was taught?	Very different	1 : 2 : 3 : 4 : 5 : 6 : 7	Just the same
3	How would you compare your classroom participation during this unit to that in other units?	Participat-ed **more**	1 : 2 : 3 : 4 : 5 : 6 : 7	Participat-ed **less**
4	Compared to other units in physics, did you feel that you were learning more or less physics in this unit?	Learning **more**	1 : 2 : 3 : 4 : 5 : 6 : 7	Learning **less**
5	Compared to other units, how informative did you find this unit?	**More** informative	1 : 2 : 3 : 4 : 5 : 6 : 7	**Less** informative
6	How relevant was this unit to you, compared to other units in physics?	**More** relevant	1 : 2 : 3 : 4 : 5 : 6 : 7	**Less** relevant
7	Compared to other units in physics, how interesting did you find this unit?	**More** interesting	1 : 2 : 3 : 4 : 5 : 6 : 7	**Less** interesting
8	Compared to other units in physics, how enjoyable did you find this unit?	**More** enjoyable	1 : 2 : 3 : 4 : 5 : 6 : 7	**Less** enjoyable
9	Compared to other units in physics, how difficult did you find this unit?	**More** difficult	1 : 2 : 3 : 4 : 5 : 6 : 7	**Less** difficult

- What are some other differences that you may have observed between this unit and other units in physics? [Use the back of this sheet if necessary.]

SECTION C: Other comments

Please write down any other comments you would like to make about the unit. Feel free to comment on **any** aspect(s) of the unit (the teaching, the practicals, the help you received during the unit, the tests, etc.).

SECTION D: Your suggestions

What would you recommend changing in this unit, in order to make it better?

[NOTE: In the actual questionnaire more writing space was provided.]

APPENDIX C7: Data from the semantic differential probes in the questionnaire used in Phase 3

The data generated from student responses to the semantic differential probes are presented in this appendix. The procedures used for the statistical analysis are also outlined.

The data

The probes required students to compare the unit on electromagnetism to other units in physics, and to compare the different activities conducted during the unit. These responses were rated on a 1 to 7 scale. The number of responses for each category along the scale are given in the following tables.

Activities conducted during the unit

Table C7.1a: The ratings given by boys in the Maldives

Activity	Interest [1]	[2]	[3]	[4]	[5]	[6]	[7]
Talking about telecommunications	8	7	7	6	2	2	1
finding out how a telephone and a baby monitor work	7	9	5	9	3		
making a speaker	28	3	1		1		
looking at the physics of a speaker	13	9	5	1	2	1	2
looking at electromagnetism in other applications	13	7	1	5	2	3	2

Very interested [1], not interested [7]

Table C7.1b: The ratings given by girls in the Maldives

Activity	Interest [1]	[2]	[3]	[4]	[5]	[6]	[7]
Talking about telecommunications	5	5	2	1		3	2
finding out how a telephone and a baby monitor work	6	4	2	5			1
making a speaker	16			2			
looking at the physics of a speaker	7	4		3			3
looking at electromagnetism in other applications	9	2	1	4			1

Very interested [1], not interested [7]

Table C7.2a: The ratings given by boys in New Zealand

Activity	Interest [1]	[2]	[3]	[4]	[5]	[6]	[7]
Talking about telecommunications	1		6	1	1	1	
finding out how a telephone and a baby monitor work		1	4	3	3		
making a speaker	4	6					
looking at the physics of a speaker		1	3	3	2	1	1
looking at the physics of the microphone			3	2	4	0.5	
looking at electromagnetism in other applications		2	4	3	1	1	

Very interested [1], not interested [7]

Table C7.2b: The ratings given by girls in New Zealand

Activity	Interest [1]	[2]	[3]	[4]	[5]	[6]	[7]
Talking about telecommunications		1.5[1]	3.5	2			
finding out how a telephone and a baby monitor work		4	0.5	1	1.5		
making a speaker	3.5	2.5	1				
looking at the physics of a speaker		1.5	2.5	1	0.5	0.5	1
looking at the physics of the microphone		0.5	2	1	2.5	1	
looking at electromagnetism in other applications	1	2	1	2		1	

Very interested [1], not interested [7]

[1] Fractions result when a student marks a position between two scores.

Comparison of the trial unit to other units in physics

Table C7.3a: The ratings given by boys in the Maldives

Probe	Rating [1]	[2]	[3]	[4]	[5]	[6]	[7]
activities (different -same)	22	8		1	1		1
teaching (different-same)	17	7	4	3		2	
participation (more-less)	13	8	7	2	1	1	1
learning (more-less)	9	6	5	6	2	2	3
informative (more-less)	8	12	6	3	1	1	2
relevant (more-less)	6	12	4	5	3	1	2
interesting (more-less)	13	7	2	7	3	1	
enjoyable (more-less)	21	3	5	3	1		
difficult (less-more)	2	8	5	6	3	6	3

Table C7.3b: The ratings given by girls in the Maldives

Probe	Rating [1]	[2]	[3]	[4]	[5]	[6]	[7]
activities (different -same)	12	2	1	2			1
teaching (different-same)	9	3	1	3		1	1
participation (more-less)	7	4	3	3			
learning (more-less)	6	4	1	4	1		2
informative (more-less)	8	5	1	2			1
relevant (more-less)	2	2	5	6		1	1
interesting (more-less)	5	3	4				2
enjoyable (more-less)	9	1	1	2	1		2
difficult (less-more)	1	5		3	1		5

Table C7.4a: The ratings given by boys in New Zealand

Probe	Rating [1]	[2]	[3]	[4]	[5]	[6]	[7]
activities (different -same)	2	2	1	1	2	1.5	1.5
teaching (different-same)	1	4	3	1	1	0.5	0.5
participation (more-less)	2	2		7			
learning (more-less)		3		1	3	3	1
informative (more-less)	1	3	4	1	1	0.5	0.5
relevant (more-less)	3	3	1	3			
interesting (more-less)	1	3	4	2	0.5	0.5	
enjoyable (more-less)	1	3.5	1.5	3	2		
difficult (less-more)		5	2	3	1		

Table C7.4b: The ratings given by girls in New Zealand

Probe	Rating [1]	[2]	[3]	[4]	[5]	[6]	[7]
activities (different -same)	0.5	2.5	4				
teaching (different-same)	1.5	1	4	0.5			
participation (more-less)	1.5	2.5	2				1
learning (more-less)	0.5	2.5	1	1		2	
informative (more-less)	0.5	2	1.5	1.5	1.5		
relevant (more-less)	3.5	1	1.5		1		
interesting (more-less)	2	0.5	1.5	2	1		
enjoyable (more-less)	1	1.5	2.5	2			
difficult (less-more)	1.5	2.5		1	1	1	

Data analysis

The nonparametric median test (Appendix B6) was used to make interpretations about the comparisons between the interest of different groups of students (e.g. students in the Maldives and New Zealand, girls and boys in each country).

When the values of A, B, C, and D are less than 5, Fisher exact test (Appendix B6) was used for processing the two-by-two contingency table. If the values are not less than 5, and N was greater than 20, the chi-square test with df=1 was used

The comparisons

Table C7.5: Responses of all students in the New Zealand sample compared to the responses of all students in the Maldives sample.
[Chi-square used except for the shaded entry where Fisher exact text was used]

All students	m	n	A	B	C	D	chi-square	significance
activities (different-same)	18	51	6	6	12	45	2.94	at 0.05
teaching (different-same)	18	51	3.5	10	14.5	41	p>=0.25	n/s
participation (more-less)	18	50	8	8	10	42	4.46	at 0.025
learning (more-less)	18	51	9	10	9	41	4.73	at 0.025
informative (more-less)	18	50	6	10	12	40	0.66	n/s
relevant (more-less)	17	50	6.5	28	10.5	22	0.95	n/s
interesting (more-less)	18	47	6	12	12	35	0.09	n/s
enjoyable (more-less)	18	49	7	9	11	40	2	n/s
difficult (more-less)	18	48	7	27	11	21	0.94	n/s

NOTE: When the factorial of a fraction results in the calculation the fraction is rounded to the nearest whole number

Table C7.6: Responses of girls compared to the responses of boys in the New Zealand sample.

New Zealand	m	n	A	B	C	D	p>=	p(extr)	p (total)
activities (different-same)	7	11	6.5	9	0.5	2	0.157		n/s
teaching (different-same)	7	11	4.5	6	2.5	5	0.139		n/s
participation (more-less)	7	11	3	7	4	4	0.264		n/s
learning (more-less)	7	11	3	8	4	3	0.181		n/s
informative (more-less)	7	11	4.5	7	2.5	4	0.156		n/s
relevant (more-less)	7	10	1	3	6	7	0.353		n/s
interesting (more-less)	7	11	4.5	7	2.5	4	0.373		n/s
enjoyable (more-less)	7	11	4.5	6.5	2.5	4.5	0.215		n/s
difficult (more-less)	7	11	2	1	5	10	0.283		n/s

NOTE: When the factorial of a fraction results in the calculation the fraction is rounded to the nearest whole number

Table C7.7: Responses of girls compared to the responses of boys in the Maldives sample.

Maldives	m	n	A	B	C	D	p>=	p(extr)	p (total)
activities (different-same)	18	33	6	11	12	22	0.243		n/s
teaching (different-same)	18	33	9	16	9	17	0.229		n/s
participation (more-less)	17	33	6	12	11	21	0.243		n/s
learning (more-less)	18	33	8	18	10	15	0.183		n/s
informative (more-less)	17	33	4	13	13	20	0.139		n/s
relevant (more-less)	17	33	8	11	9	22	0.155		n/s
interesting (more-less)	14	33	6	11	8	22	0.212		n/s
enjoyable (more-less)	16	33	7	12	9	21	0.215		n/s
difficult (more-less)	15	33	6	12	9	21	0.243		n/s

APPENDIX C8: Data describing student learning in Phase 3

The following data were used:

- performance of the student samples in class tests, assignments, and practicals before the interventions (average);
- performance of the student sample from the Maldives in the pre- and post-tests (pre-test and post-test).

Table C8.1: The Maldives sample

Boys	Average	pre-test	post-test		Girls	Average	pre-test	post-test
M23	95	58	100		F3	91	38	92
M9	94	58	92		F12	85	23	85
M10	92	62	100		F11	70	27	85
M15	85	54	85		F13	65	15	92
M3	83	35	77		F15	64	23	69
M2	79	31	81		F9	61	23	85
M6	77	23	73		F8	55	23	85
M7	65	27	77		F7	53	23	88
M21	62	31	88		F17	52	15	81
M5	59	23	73		F10	50	19	81
M25	58	23	81		F5	49	15	85
M18	58	35	85		F6	48	15	69
M26	57	23	73		F14	46	19	85
M17	54	31	73		F1	42	7.7	92
M19	54	23	77		F16	38	7.7	62
M13	52	27	73		F2	35	7.7	73
M12	49	19	73		F4	31	3.8	73
M4	49	23	73		F18	25	7.7	62
M22	48	19	73					
M16	45	19	69					
M1	45	15	88					
M20	44	19	81					
M8	42	19	81					
M11	42	15	92					
M28	39	12	81					
M27	35	3.8	69					
M14	34	12	77					
M24	33	3.8	73					

Table C8.2: The New Zealand sample

Boys	Average	pre-test	post-test		Girls	Average	pre-test	post-test
M4	88	50	83		F1	91	58	96
M6	87	33	96		F7	89	50	83
M2	81	42	88		F2	74	29	75
M3	70	29	83		F4	60	21	71
M7	54	29	83		F6	51	25	58
M1	52	13	88		F3	46	25	67
M5	45	17	75		F5	45	4.2	96
M8	31	13	25					

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