THE USE OF INTERACTIVE COMPUTER SIMULATIONS TO ENGENDER CONCEPTUAL CHANGES ABOUT WAVE MOTION

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ABSTRACT

Computers are expensive equipment which most schools in South Africa cannot afford to use as an instructional tool in the same way as they are being used in affluent schools in the country and in the western world. In this study a computer was used as a demonstration tool to help learners to visualise the different aspects of wave motion with the aid of interactive computer simulations. The study investigated how learners alter their intuitive notions of wave motion after experiencing the common teaching techniques in township schools, and then by observing interactive computer simulations. Data was collected by means of field notes, observation, questionnaires and in-depth semi-structured interviews with the participation of twelve Grade 9 learners in a secondary school over a three-week period. A combination of qualitative and quantitative methods was used in the study and the data was analysed within an interpretive framework. A detailed analysis revealed that interactive computer simulations could bring about positive conceptual changes in learners, especially in the micro level aspects of wave motion. The inexperience of the learners in a discovery method of learning and a learner centred approach of teaching seemed to interfere with the teaching techniques. To a considerable extent, language problems also hindered the revelation of conceptualisation.

In writing this report of the research study I agree with Squires and McDougall (1994: 12) that it is difficult to use a non-interactive medium (paper-based text) to report on the interactive medium of computer simulations, as written words cannot bring out all the essential aspects of interactive computer simulations.

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CHAPTER 1

THE RESEARCH PROBLEM AND ITS CONTEXT

1.1 Introduction

One day while I was browsing the Internet for some information, my daughter, a Grade 10 learner came to me with a problem. She could not find out the right answer for a particular question on wave motion. The question dealt with the relative positions of particles in a medium through which a transverse wave moves. My explanations with diagrams and improvisation with matchsticks were found to be a little difficult for the tenth grader to understand. I wished that I could use a model to show the motion of the wave as well as the particle motion in the wave. When I sat staring at the blinking computer monitor the thought of the Internet came to my mind. Browsing through a search engine, I found a few websites, which dealt with wave motion, and some with interactive simulations of wave motion. I asked my daughter to try those simulations to get an insight into the concept of wave motion. Within a few minutes I could see a smile on her face and she could answer the questions similar to the one she asked me earlier quite easily. Then this thought came to me- *"how effective would interactive computer simulations be in enhancing the understanding of Physical Science concepts at schools?"* This incident encouraged me to explore the role of interactive computer simulations in bringing about conceptual changes in the learners in the schools where I used to work.

1.2 Field of Research

The field of research is Information and Communication Technology (ICT) for Education, focussing specifically on the use of interactive computer simulations in the conceptualisation of Physical Science concepts, in particular wave motion. The research study investigates the use of interactive computer simulations to engender conceptual changes about wave motion in Grade 9 learners of a previously disadvantaged school in the Zwelitsha District of the Eastern Cape.

1.3 The context of the research

"Frequently, pre-instructional images from everyday life interfere with the concepts to be learned in Physics instruction so that only limited success results" (Heuer & Wilhelm, 1996 cited in Blaschke, Kissingen & Heuer). In other words, there are many concepts in Physical Science which often run counter to one's intuitive notions, and when new concepts contradict prior beliefs, they are often rejected. One of these concepts, amongst others, is wave motion. Learners find it hard to believe, for instance, that particles of the medium in a transverse wave that is moving horizontally vibrate only in a vertical plane. This is because the learners' experiences of waves when they swim in the sea or watch the waves crash on the beach may develop intuitive notions that conflict with the classroom definition proposed by the teacher and the textbooks. The concept of wave motion is complex as there is a horizontal as well as vertical component of displacement in it. Again, each particle in a medium vibrates the same way as the others, but with a time lag. So the state of vibration or phase of vibration of particles will be different from its neighbouring particles as the wave motion advances through a medium.

From my experience as a teacher in various high schools and as a lecturer in colleges of education I found that learners have profound difficulties in conceptualising wave motion especially the idea that particles in a medium vibrate only as a wave progresses along the medium. Moreover, the different concepts associated with wave motion such as phase difference, frequency and wavelength are hard to visualise and are hence difficult for many learners to understand. According to the Physical Science syllabus (1996) of Eastern Cape Department of

Education the concept of wave motion is to be introduced in Standard 8 (Grade 10). Many phenomena in the later part of the Grade 10 syllabus such as light, sound and electro-magnetic waves etc. can be best explained in terms of wave motion. The wave nature of light also is included in the Physical Science syllabus for Grade 11. An understanding of the principles of wave motion is therefore essential for Physical Science learners in high school.

A ripple tank or slinky springs are commonly used to illustrate various properties of waves (Brink & Jones, 1985). The ripple tank will show the patterns of waves as the learner looks down on the water surface. At low frequencies, it is easy to see the waves, but at higher frequencies the persistence of vision obscures them. Often vertical edges of the tank produce unwanted reflected waves. With water depths below 3mm there is no trouble from reflections, but ripples damp out in a small distance (Rogers & Wenham, 1978). Continuous ripples are very difficult to see without using a stroboscope. In order to study the properties of waves, hand held stroboscopes are some times used to 'freeze' the waves. But for this, learners must practise and learn to 'freeze' ripples with a hand stroboscope. "Young pupils take a long time to 'get going'; and when they are experimenting in a new strange field- as this is, for them – they take still longer" (Rogers & Wenham, 1978:9). Rogers and Wenham (1978) also note that the delay and lack of definite results would seem worrying and disappointing for the teacher who tries ripple tank experiments with a class of younger pupils. Likewise, the use of a slinky spring is problematic as longitudinal waves travel very fast on a slinky.

For a clear understanding of wave motion and its properties, very slow moving wave demonstration is essential. However, in many cases this is not possible and learners find it difficult to view the different aspects of wave motion. In the ripple tank demonstrations, learners cannot effectively control the different parameters associated with wave motion in order to study their effect. Hence these demonstrations may not be appropriate and possibly confuse the learner. From my experience as a Physical Science teacher it is found that concepts related to rapid motion of particles and objects, which cannot be viewed in a still frame, seem to be difficult for learners to understand. Developing mental pictures for the various physical laws and processes is a very important process in the understanding of physics. Unfortunately, many previously disadvantaged schools may not have the appropriate equipment and therefore, the teacher may not be capable of helping the learner to develop an accurate mental picture.

Learning by means of Information and Communication Technology (ICT), includes Computer Assisted Learning (CAL) such as computer simulations and computer-based modelling. De Jong, van Joolingen, Scott, de Hoog, Lapied, and Valent (1994) claim that computer simulations are well suited for exploratory or discovery learning since they contain a model that has to be discovered by the learner. In the contemporary theories of learning and instruction, learners are seen as active participants in the learning process. "The child requires considerable direct learning experience with many concrete instances of a given set of relationships before he or she can acquire genuinely meaningful concepts and generalisations" (Ausubel, Novak & Hanesian, 1968:344). Where these concrete instances cannot be effectively provided in classroom settings, interactive computer simulations may serve the purpose. "In the physical sciences, for example, conceptual understanding can be enhanced through experiences with simulations" (Lunetta & Hofstein, 1991:126). According to de Jong *et al.* (1994) computer simulations are quite popular in instruction in developed countries, but in spite of their popularity there is no conclusive evidence of their effectiveness and efficiency.

" Computer modelling has turned out to be far more powerful and flexible than the older notion of mechanical models. Once a theory has been formulated precisely, imaginary examples of the theory can be constructed which can be turned into computer simulations" (Dolby, 1996:256). According to Tait (1994) most simulation environments allow learners to set up initial conditions and to start and stop the model so that events (in the form of data, graphs, animation and so forth) can be observed. Therefore, a possible solution for the problems associated with the demonstration of wave motion may be the use of interactive computer simulations of waves.

"When an experiment is not feasible we can use computer models to work out what we think would happen" (Dolby, 1996:246). Interactive computer simulations may be helpful to make up for instructional deficiencies of the school laboratory. "Instructional simulations typically use rules to define the parameters of interaction within a model of reality, and their use ultimately results in one of several available conclusions" (Schwier & Misanchuk, 1993:22). They may allow every learner to participate in a new level of conceptualisation and visualization.

Programs containing interactive simulations for science teaching exist but need to be made more available to teachers and learners. There are many physics related interactive simulations available on the Internet like 'The Virtual Laboratory', which is available at http://physicsweb.org/TIPTOP/VLAB/. So what is needed for classroom instruction is a computer with CD ROM or programs downloaded from the Internet, and a data projector.

With the restructuring of the Eastern Cape Education Department, computers and other related accessories will be made available for Education Development Centres and schools in the province. United States Agency for International Development (USAID) funded Information

Technology Initiative of the Eastern Cape Department of Education is planning to install a Wide Area Network (WAN) system that connects the officials in the head office to the district offices via electronic mail, and provide the provincial and district offices with Internet connectivity. The system also provides for the option of expanding to the school level as and when resources become available (USAID Education Strategic Team, 2000). So it may not be too long before teachers and learners in the Eastern Cape use computer simulations in Science classrooms.

1.4 Research Goals

The aim of the research study is to address the following question:

What conceptual changes about wave motion are engendered by interactive computer simulations?

I investigate the learners' conceptualisation of wave motion at three different stages of instruction, defined as pre-instruction stage, traditional instruction stage and interactive computer simulations intervention stage. The three questions central to the investigation include:

- How do learners intuitively conceptualise wave motion?
- What conceptual changes are brought about after classroom instruction on wave motion?
- What conceptual changes are brought about after using interactive computer simulations in the classroom?

1.5 Methodology

Best and Kahn (1999) classify educational research into broad two categories: quantitative research and qualitative research. According to them quantitative research utilizes experimental research methodologies whereas qualitative research uses a variety of interpretive research methodologies. According to Denzin and Lincoln (1994:2) qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. Cohen and Manion (1994:38) point out that the central endeavour in the context of the interpretive paradigm is to understand the subjective world of human experience. This research study is primarily qualitative and interpretive as it attempts to make sense of learners' intuitive concepts of wave motion which are based on their experiences and what conceptual changes are brought about in the natural setting of the classroom. In this qualitative approach in-depth semi-structured interviews and field notes are used as data collection instruments "to get inside the person and to understand him from within" (Cohen & Manion, 1994:38). According to Cohen & Manion (1994:38) an interpretivist researcher begins with the individual and sets out to understand his interpretations of the world around him. In this study I, as an interpretivist researcher, focus on the learners and try to understand how they conceptualise wave motion.

However, in order to establish an initial benchmark of learners' intuitive concepts of wave motion semi-structured questionnaires are used to collect quantitative data. These questionnaires are distributed before and after the traditional instruction stage and interactive computer simulations intervention stage. Although this quasi-experimental technique is usually associated with a positivist paradigm, it was intentionally used in this study within an intrepretivist paradigm. The use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question (Denzin & Lincoln, 1994). Therefore a combination of qualitative and quantitative methods is used in the study. The quantitative data contribute towards capturing the variation in the ways which the learners conceptualise the phenomenon of wave motion after the use of interactive computer simulation. Attempts are also made to find out the percentage shift in the learners' correct responses to the questionnaire from one stage of the study to the other.

Table 1: Data collection plan

	Survey	Interview	Observation
Pre-instruction stage How do learners intuitively conceptualise wave motion?	Questionnaire 1	Interview 1	Throughout
Traditional instruction stage What conceptual changes are brought about after classroom instruction on wave motion?	Questionnaire 2	Interview 2	the
Interactive computer simulations intervention stage What conceptual changes are brought about after using interactive computer simulations in the classroom?	Questionnaire 3	Interview 3	study

1.6 Research process

To address the research questions, I actively engaged in the Physics lessons for a group of twelve to seventeen Grade 9 learners in Thembalabantu High School in Zwelitsha.

The research study was conducted in three stages over a period of 3– 4 weeks. The first stage, which was the pre-instruction stage, consisted of a survey and interviews to find out the intuitive notions on wave motion among the learners. Examples of current instruction and learning were recorded before any interventions. In the second stage I took a facilitative role and participated in five lessons on wave motion using ripple tanks and other available equipment in the selected school. The third stage involved another five lessons on the same topics using interactive computer simulations, which were downloaded from the Internet (The Virtual Laboratory: 1999). The method followed was basically the same in all lessons: to allow learners to see a visual demonstration of wave motion using simulations, often in animated form. The simulations were used in class with a computer and a data projector. This method allowed me to take advantage of all the program's options and features, encourage learner participation, and provide guidance and explanations as needed. In addition, the learners were given the opportunity to manipulate one or more variables underlying the concept such as wavelength, frequency and amplitude and then witness the changes. Successive small changes in the value of one of the parameters were made and the corresponding effects in the simulation observed. Learners were observed as they proceeded through the lessons, guided by the teacher-researcher. The data thus collected were organised and the most important aspects were described and interpreted to arrive at a conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 Performance of South African students in science and mathematics

In 1994 South Africa participated in the Third International Mathematics and Science Study (TIMMS), which considered 45 countries of the World. Reporting the findings of the study, the Sunday Times, a weekly newspaper, mentioned that the South African school children were "at the bottom of the class in every category, its teenagers woefully ill equipped for the demands of a high–tech global economy" (Barber, 1996:1). In that study South Africa was placed at the bottom of the list of 44 countries of the world in both mathematics and science. A survey conducted jointly by the Foundation for Research and Development and Human Sciences Research Council in 1995 (FRD News: 1996) indicated that South Africans lagged behind most countries in scientific and technological literacy. Pretorius (2000:19) reported that teachers who were finalists in the maths and science Teacher of the Year competition held early in the year 2000 as saying that "South African schools need to take mathematics and science education seriously, from Grade 1 to grade 12, if the country is going to extricate itself from the bottom of the global heap". Hence it is important that we encourage our young learners to seriously engage in the study of science and mathematics.

Science and mathematics remain difficult subjects for many, resulting in only one in five Black learners choosing physical science and mathematics in standard 8 at school (Govt. Gazette 1995:30). According to Khoo and Koh (1998) both physics and chemistry are difficult subjects to teach to students and the mastery of these subjects requires considerable effort on the part of the students. White (cited in Pena & Alessi, 1999) noted that much of the research investigating students' difficulties in learning science had their focus on physics. "Although practical aspects of science stimulate the young generation to become actively involved in experimentation, it is possible that the conceptual information may deter them" (Abrahams & Rotchford, 2000:42).

2.2 The importance of laboratory work in science teaching

The Physical Science syllabus (1996) of the Eastern Cape Department of Education recommends that in teaching the syllabus it will be necessary to make use of simplifications, but these simplifications must not be such that the learners are left with serious misconceptions. Practical work forms an integral part of the syllabus and plays an important role in the understanding of scientific principles and phenomena. Woolnough (1991:182) insists that practical investigation must be at the heart of science teaching. According to Lunetta and Hofstein (1991) it is expected that the laboratory practical activities in school science will enable learners to understand the nature of the scientific enterprise as well as to develop problem solving skills, to grow in understanding of scientific concepts, and to experience the relationship between theory and practice. Woolnough (1991) cautions that if practical work aims only to develop theoretical insight, it does little to enhance learners' understanding of the concepts of science. Laboratory experiences can no longer serve merely to verify previously stated principles. Instead, laboratory work must aim to teach learners how to work as scientists, giving emphasis on developing not only scientific skills but also scientific capability (Woolnough, 1991). Laboratory work must encourage pupils to discover ideas for themselves and to learn science by developing, as far as possible, the viewpoints and modes of attack of scientists confronting problems. Woolnough (1991:182) insists that the learners must take personal responsibility for the experiment and acquire ownership of it. Hence laboratory work must be regarded as an essential aspect of 'active, generative' (Woolnough, 1991) science learning.

2.3 Need for transformation of education in South Africa

" The neglect of the quality of African education, combined with a rapid increase in the number of students, led to the disintegration of learning environments and the death of a culture of learning in many black schools" (Task Team on Education Management Development, 1996:18). In most black schools education is carried out in overcrowded classrooms. According to Meighan (1981) classrooms tend to signal social distance and teaching styles which are authoritarian, where the learners depend on the teacher throughout. In such environments the teacher is usually regarded to be the major source of instruction and the learners' role is to receive without question decisions made by the teachers, or to engage in discussions and negotiations of the teachers' initiatives (Meighan, 1981:187). Teaching in this situation is considered a matter of presenting the material to be learned and reinforcing the correct answers that the learner gives back to the teacher (Kamii, 1974). According to Kamii (1974) even when the discovery method is used, *discovery* usually means to discover only what the teacher wants to have discovered. Such traditional authoritarian forms of classroom environments are however restrictive in nature as they have very few tools for manipulating and observing content, making explorations and solving problems.

"South African Education System is in the process of change; sweeping and widespread change, involving not only the essential remodelling of an outdated system, but a shift, a paradigm shift, in the attitude we adopt to the entire educational process" (Cockburn, 1997:4). The outgoing, traditional system of education has not served the country well and is out of step with world trends. In a democratic society traditional authoritarian classroom environments are not suitable and should be transformed into democratic environments. According to Fone (1995) classroom democracy should give learners ownership of the learning process. A democratic system of education is a participatory, open system in which all participants have a share in the learning process (Fone, 1995: 88). For that the educational practice should move away from the traditional teacher-centred approach to a learner-centred one. "All educational inputs should have the development of critical, independent and responsible individuals as their aim" (Fone, 1995:77). According to French (1999) instructivist, teacher-directed learning and constructivist learner-centred learning represent two poles in a continuum of teacher and student behaviour. Self directed learning (French, 1999), learner centred education or mediated learning experience (Fone, 1995) follow the tenets of constructivism and place the learner rather than the teacher in charge of some or most of the learning process. So, in line with the democratic changes in the country, South African education system adopted a new educational approach entitled Curriculum 2005, which revolves around the philosophy of constructivism. The Curriculum was later reviewed and the C2005 Review Committee (2000) proposed that a revised and streamlined outcomes based curriculum be introduced within manageable time frames to achieve the social and educational goals of a curriculum for the 21st Century.

2.4 Constructivism in learning

A great deal of literature argues that learning is more meaningful when learners construct their own knowledge, following the views of the learning theory known as constructivism. Constructivism has its roots in philosophy, psychology, sociology, and education and is influenced by the pedagogical principles of Jean Piaget (1896-1980), a Swiss Psychologist. Kamii (1974) identifies the basic pedagogical principles from Piaget's theory as the view that learning has to be an active process since knowledge is a construction from within. Kamii (1974:83) quotes the highlight of the statement Piaget made on education in 1964:

> As far as education is concerned, the chief outcome of this theory of intellectual development is a plea that children be allowed to do their own learning... You cannot further understanding in a child simply by talking to him. Good pedagogy must involve presenting the child with situations in which he himself experiments, in the broadest sense of the term – trying things out to see what happens, manipulating symbols, posing questions and seeking his own answers, reconciling what he finds one time with what he finds at another, comparing his findings with those of other children.....

Another pedagogical principle Kamii (1974) recognises is the importance of social interactions of children at school. For intellectual development, learners must interact with other learners and adults. This encourages group work when possible and challenges the learners to learn interacting with each other. Learners will attain multiple perspectives of whatever they learn from different sources. Thus they construct and develop shared knowledge through social interaction.

Therefore the central idea of constructivism is that human learning is *constructed*, that learners build new knowledge upon the foundation of previous learning. The view that learners construct their knowledge from individual and/ or interpersonal experiences and from reasoning about these experiences is called constructivism. This view of learning is opposed to the traditional behaviourist view in which learning is the passive transmission of information from one individual to another, a view in which the learners are recipients of knowledge, not constructors. Two important notions revolve around the simple idea of constructed knowledge. The first is that learners have intuitive ideas and vague notions based on which they construct new understandings. There is no *tabula rasa* on which new knowledge is etched. Instead, learners come to learning situations with knowledge gained from previous experience, and that prior knowledge determines what new or modified knowledge will be constructed from new learning experiences.

The second notion is that learning is active rather than passive. According to Kamii (1974) the criterion of what makes an *active* method active is not the external action of the learner but the engagement of the learner in actively constructing his/her own knowledge. Learners confront their understanding in light of what they encounter in the new learning situation. If what learners encounter is inconsistent with their current understanding, that understanding can change to accommodate new experience. Learners remain active throughout this process: they apply current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge, and based on that judgment, they can modify knowledge.

South West Educational Development Laboratory (SEDL, 1996) outlines the important practical implications of constructivism for teaching. Firstly, teaching cannot be viewed as the transmission of knowledge from enlightened to unenlightened. Constructivist teachers do not take the role of the "sage on the stage" but act as "guides on the side" who provide learners with opportunities to test the adequacy of their current understandings. Secondly, if learning is based on prior knowledge, then teachers must note that knowledge and provide learning environments that exploit inconsistencies between learners' current understandings and the new experiences before them. This challenges teachers; for they cannot assume that all children understand something in the same way. Further, children may need different experiences to advance to different levels of understanding. Thirdly, if learners must apply their current understandings in new situations in order to build new knowledge, then teachers must engage learners in learning, bringing learners' current understandings to the forefront. Teachers can ensure that learning experiences incorporate problems that are important to learners, not those that are primarily important to teachers and the educational system. Teachers can also encourage group interaction, where the interplay among participants helps individual learners become explicit about their own understanding by comparing it to that of their peers. Fourth, if new knowledge is actively built, then time is needed to build it. Ample time facilitates learner reflection about new experiences, how those experiences line up against current understandings, and how a different understanding might provide learners with an improved (not "correct") view of the world.

2.4.1 Role of constructivist teacher

If learning is a constructive process, and instruction must be designed to provide opportunities for such construction, then teachers should assume new roles. French (1999:14) lists twelve practical strategies for developing constructivist teaching:

1. Constructivist teachers encourage and accept learner autonomy and initiatives.
2. Constructivist teachers use raw data and primary sources, along with manipulative, interactive and physical materials.
3. When framing tasks, constructivist teachers use cognitive terminology such as "classify", "analyse", "predict" and "create".
4. Constructivist teachers allow learner responses to drive lessons, shift instructional strategies, and alter content.
5. Constructivist teachers inquire about learners' understanding of concepts before sharing their own understanding of those concepts.
6. Constructivist teachers encourage learners to engage in dialogue, both with the teacher and one another.
7. Constructivist teachers encourage learner inquiry by asking thoughtful, open-ended questions and encouraging learners to ask questions of each other.
8. Constructivist teachers seek elaboration of learners' initial responses.
9. Constructivist teachers engage learners in experiences that might engender contradictions in their initial hypotheses and then encourage discussion.
10. Constructivist teachers allow waiting time after posing questions.
11. Constructivist teachers provide time for learners to construct relationships and create metaphors.

12. Constructivist teachers nurture learners' natural curiosity through frequent use of the learning cycle model, which consists of discovery, concept introduction and concept application.

The constructivist approach of education exerts a growing influence on educators. A good teacher has to assume new roles to ensure that learners learn. The Norms and Standards for Educators (Department of Education, 1997: 69) outlines the following seven roles for teacher:

- A mediator of learning
- A designer and interpreter of learning programmes and materials
- A leader, administrator and manager
- A scholar, researcher and life-long learner
- A citizen and community developer
- A learning area or phase specialist
- A 'pastoral' role.

While it is important for educators to understand constructivism, it is equally important to understand the implications this view of learning has for teaching and teacher professional development. It is obvious, therefore that teachers should be trained in "designing original learning programmes", "adapting and/ or selecting learning resources" and "using a common word processing program for developing materials" ((Department of Education, 1997:73). According to Rogan and Nel (2000) educators are no longer to be regarded as the technicians that implement a curriculum designed by an agency external to the school, but will be empowered to take curricular decisions and to design curricular materials.

2.4.2 Constructivism and science education

In line with much of the world the South African Education System has also moved towards Outcomes Based Education (OBE), which follows the principle of constructivism. The most profound effects of this change will be felt in changed attitudes to both teaching and learning strategies in science education. There is probably very little opportunity for change in the content of the Physics and Chemistry curricula and if anything, the scope should be broadened and deepened to accommodate relevant examples (Sewell & Burger, 1995).

The new approach to science education is based on a constructivist view of learning (Kuiper, 1998). Knowledge has to be constructed by learners based on a variety of experiments, investigations, observations and measurements, and the interpretations of the results of the experiments. The constructivist approach aims at giving learners a conceptual understanding of the matter that is taught. Conceptual understanding differs importantly and principally from memorising facts. Memorising can be done without any real understanding. Sirestarajah (2000:526) claims that one of the problems of science education in South Africa is rote learning. Science must be taught and learned with conceptual understanding. Conceptual understanding means that the learners grasp a concept in such a way that they can use it to solve problems. Understanding does not mean being able to give the definition; understanding means being able to use the concept correctly in any situation (Kuiper, 1998).

2.4.3 Constructivist approach to science teaching

Kuiper (1998) suggests three steps for a constructivist approach to science teaching:
Firstly, the teacher should find out what ideas the learners have about the topic to be taught. This is necessary because learners come to science classrooms with specific notions about the content of instruction. The second step is to let learners work by themselves or in groups on some problem situations, which deal with the topic, and in which they need to use their already existing ideas. Thirdly the results of this work need to be discussed with the teacher and the class so that

the teacher now has the opportunity to correct or further develop the preconception of the learners into more mature, scientific ideas.

Learners enter the classroom with informal ideas (alternative conceptions) about scientific phenomena and these ideas affect how corresponding scientific explanations are learned (Windschitl & Andre, 1998:145). "These notions, expectations, or descriptive and explanatory systems are, in many cases, in marked contrast with scientific conceptions that the learners are expected to learn. Consequently, science educators are becoming aware that prior knowledge can hinder the acquisition of science concepts in some cases, as well as foster that acquisition in other cases" (Hashweh, 1988:121). So the first stage in teaching should definitely be asking learners what their ideas are about the content of instruction. This will assist the teacher to devise instructional strategies, which facilitate the correction and further development of the pre-conception into more mature ideas (Kuiper, 1994). Thus conceptual change occurs in the learner.

2.4.4 Conceptual change strategies

Conceptual change has been described as a process of learning science in a meaningful way that requires the learner to realign, re-organise, or replace existing misconceptions in order to accommodate new ideas (Sanger & Greenbowe, 2000:522). Windschtl and Andre (1998) summarise the conditions for conceptual change as follows:

- The learners must experience dissatisfaction with their existing conception.
- The new conception must be intelligible. The learners must be able to understand the new conception.
- The new conception must seem plausible to the learners.
- The new conception must be fruitful and appear to be better at explaining their experiences and observations than their previous conception.

If these conditions are met learners are assumed to experience conceptual change, discarding their intuitive notions, or misconceptions or alternative conception for a scientifically accepted conception.

2.4.5 The role of the constructivist science teacher

The role of the constructivist science teacher has to be radically different from the traditional role of the teacher. Learners and teachers work in collaboration on the voyage of knowledge creation where learners gradually create knowledge, as far as possible unaided. The teacher's role is not just to stimulate learners in the path of knowledge creation but also to facilitate the process by providing more science experiences, acting like a catalytic agent. The meaning of classroom instruction changes to the interaction of learners among themselves and with their teacher to learn something.

2.4.6 Constructivism and instructional design

Jonassen (1994) summarizes what he refers to as "the implications of constructivism for instructional design". The following principles illustrate how knowledge construction can be facilitated:

1. Provide multiple representations of reality;
2. Represent the natural complexity of the real world;
3. Focus on knowledge construction, not reproduction;
4. Present authentic tasks (contextualizing rather than abstracting instruction);
5. Provide real-world, case-based learning environments, rather than pre-determined instructional sequences;
6. Foster reflective practice;
7. Enable context and content dependent knowledge construction; and
8. Support collaborative construction of knowledge through social negotiation (p.35).

2.5 Constructivism and Information and Communication Technology (ICT)

Although there are those who will argue that constructivism does not provide a model for implementation, numerous researchers, educators and authors are actively engaged in using constructivist principles to design and implement new learning environments (Murphy, 1997). Increasingly, researchers and educators are linking constructivism, technology and learning. This is not surprising since many see in computer-based learning environments strong support for the principles of a constructivist philosophy. Information and Communication Technology (ICT) is increasingly being used as an optimal medium for the application of constructivist principles to learning.

Use of simulations, E-mail, Listservs, Usenet groups, Electronic Performance Support System (EPSS), Internet Relay Chat (IRC) and the World Wide Web in general provide environments, contexts and authentic 'worlds', which learners and teachers can experience and explore. Other computer-based projects and environments make partial use of the Internet to provide learners with rich learning environments and sophisticated cognitive tools (Murphy, 1997).

2.5.1 The Internet and World Wide Web (WWW)

The capabilities of information technology have advanced significantly in recent years and, in conjunction with delivery technologies such as the Internet and World Wide Web (WWW), it is now possible to view IT networks as a medium through which entire learning programmes can be conducted remotely. The Internet is millions of computers interconnected through the worldwide telecommunication systems. All these computers can share information with each other as they use the same communication protocols. Collis and Meeuwsen (1999) claim that the learning opportunities provided by the Internet and World Wide Web are enormous and it is possible for learners to have the world at their fingertips. "People and resources from all over the world can be at a student's computer at the click of a search engine" (Collis & Meeuwsen, 1999: 25). Maddux, Johnson and Willis (1997) point out that the Internet and World Wide Web provide educators with vast new opportunities to engage in research and enhance teaching and learning. Internet–based learning is the electronic delivery of information via computer, modem and a telephone line. "Self–directed learning places the learner rather than the teacher in charge of some or most of the learning process" (French, 1999:10). This kind of learning is in line with constructivist approach of teaching and is appropriate in the Outcomes Based Education (OBE), which is now being implemented in South African Schools. Internet-based learning is growing rapidly in the higher education sector in South Africa. The Internet-based learning tools include World Wide Web (WWW) containing web pages; web based bulletin boards, e-mail and online courses. " WWW is a standardized system of creating 'pages' on the Internet" (Maddux, Johnson and Willis, 1997: 155). Web pages are multimedia and hypermedia. They are multimedia because they can contain high-resolution colour graphics, voice, and video as well as text. They are hypermedia as it is possible to jump from one location to another.

According to French (1999) the Internet has the potential for effecting fundamental changes in the design of learning processes. Effective use of the Internet as a teaching tool requires that the concept of 'self-directed learning' (French, 1999) be understood in order to release more control of the learning process to the learner. Internet-based learning involves the electronic delivery of information via computer, modem, and a phone line. Because web-based environments offer non-linear navigation of hyper linked resources, the learners, in theory, have at their fingertips a cyberlibrary of resources from all over the world. (Collis & Meeuwsen, 1999:29). Therefore teachers as well as learners must learn to learn in World Wide Web (WWW) environment and sift through large amount of web material, developing the wisdom and perception to select only those materials with the most meaningful application to their work.

2.6 Information and Communication Technology and science education

Sewell and Burger (1995) believe that Computer Based Education (CBE) has tremendous unfulfilled potential for use in science education at secondary level. They are convinced that CBE is a key resource in science education and its use will improve the quality of learning. The outcomes based model accords well with the use of computers at a variety of levels and computers can be used to support teachers in the "teacher as facilitator" paradigm. Computers can be used to support science teachers (and indeed learners) in every aspect of their work. But with these caveats the overwhelming conclusion is that CBE is effective both at increasing exam performance and increasing learner involvement and motivation (Sewell & Burger, 1995).

The potential uses of computers in the science classroom include:

- access to information stored either locally or remotely
- testing, either for revision or assessment purposes
- record keeping
- simulations
- data visualisation
- experimental analysis
- presentation using standard office tools
- communication
- data logging

It is obvious from the list that computers can be used to support or enhance every aspect of science teaching and learning. Some applications require access to a computer by individual learners whereas others require that the teacher have access to some form of video-projection facilities.

On an advanced level, "computers can enhance or even replace existing pieces of laboratory equipment to provide facilities such as measurement (e.g. via analogue and digital converters) and data logging with immediate data processing and graphical display of results" (Boardman, Cooper, James, Keller & Swage, 1988:29). Fig. 2.1 shows the classification of software for undergraduate Physics made by Boardman *et al.* (1988) which is modified to include new trends in simulations, with the modified part given in italics.

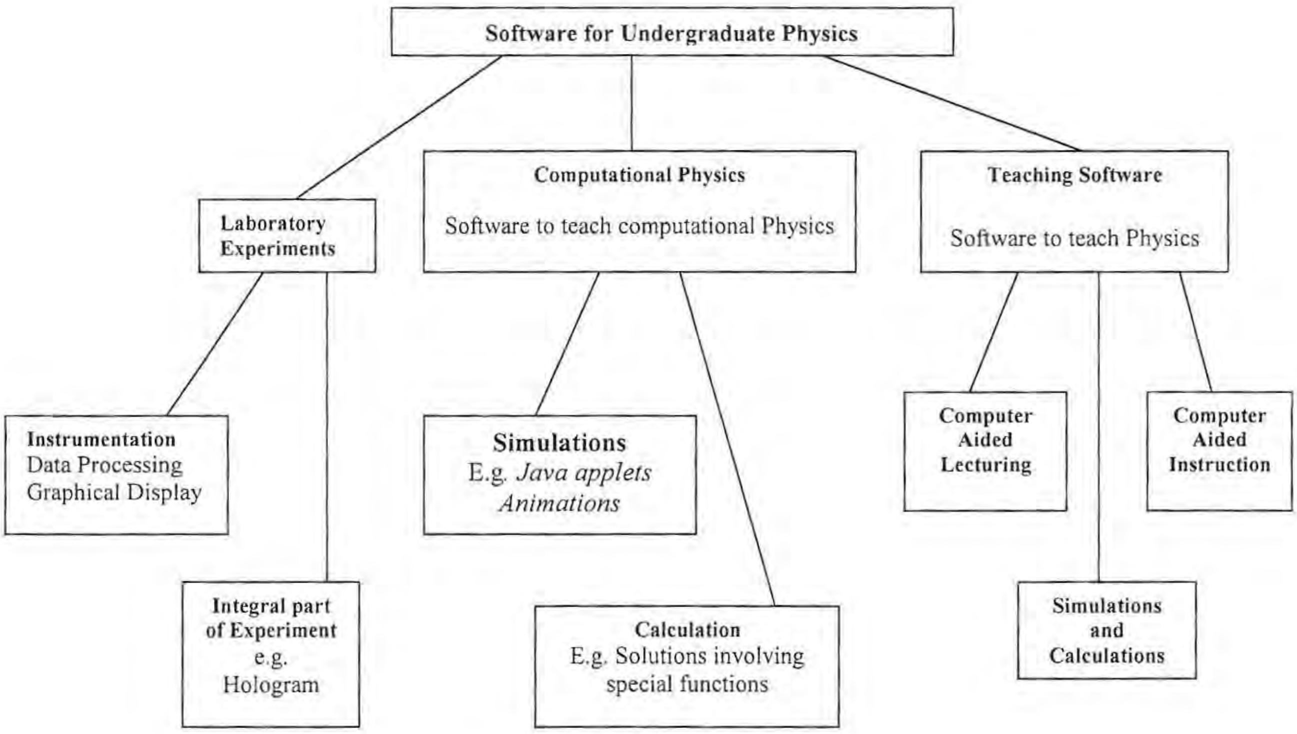


Fig. 2.1

Adapted from Boardman *et al.* (1988)

2.6.1 Simulations

"In an educational context, a simulation is a powerful technique that teaches about some aspect of the world by imitating or replicating it. Students are not only motivated by simulations, but learn by interacting with them in a manner similar to the way they would react in real situations" (Alessi & Trollip, 1991:119). According to Boardman *et al.* (1988) simulations are user friendly, interactive (usually menu driven) and can make extensive use of graphics to expose conceptual structures in a non-numeric manner.

Alessi & Trollip (1991) suggest that simulations may be used for four phases of teaching: presenting the learner with information, guiding the learner in acquiring the information or skills, providing practice to enhance retention and fluency and assessing learning or for any combination of these. "Instructional simulations typically use rules to define the parameters of interaction within a model of reality, and ultimately result in one of several available conclusions" (Schwier & Misanchuk 1993:22). Which conclusion is reached is determined by choices and decisions made by the learner. In a simulation the learner learns by actually performing the activities to be learned in a context that is similar to the real world. According to Schwier and Misanchuk (1993:22) simulations provide an abstraction or simplification of reality – some level of mimicry, in which the learner encounters circumstances and tries to respond to them.

"In a computer-based physical simulation, a physical object or phenomenon is represented on the screen, giving the student an opportunity to learn about it" (Alessi & Trollip, 1991:119).
A typical physical simulation, for example, is one of a mechanics experiment in which the learner propels an object out of a cannon with varying velocity, angle, and other parameters. The benefit

of doing this experiment through a simulation is that the learner can complete many more trials with less effort than could be done in a laboratory with real objects. Physical simulations, then, are generally used to inform learners about some phenomenon. Learners learn from the simulation by manipulating some aspect of the world they are working with or merely by observing how change occurs.

2.6.2 Simulations and science teaching

Lunetta and Hofstein (1991) state that laboratory practical activities have long played a central role in the science curriculum. They suggest that the science curriculum can be improved by complementing school laboratory activities with simulations. Lunetta and Hofstein (1991) claim that interacting with an instructional simulation can enable learners better to understand a real system, process or phenomenon. Both practical activities and instructional simulations enable learners to interact with models of reality. Within purposefully contrived settings, both can enable learners to confront and resolve problems, to make decisions, and to observe effects. Through guided exploration in a simulation learners will be able to construct the ideas and concepts to be learned (Lunetta & Hofstein, 1991:125). Computer-based simulations are a relatively new resource in science education and many have begun to explore their potential. Emerging technologies like CD-ROMs and digital video discs (DVD), when combined with interactive computing, have great potential to serve as valuable resources in science teaching and learning. Lunetta and Hofstein (1991:126) claim that good practicals and good simulations engage students in dynamic problem solving and inquiry. "Since simulations provide experiences with representation of reality, it is not appropriate to replace important experimental work in science with simulations" (Lunetta & Hofstein, 1991:125). Dolby (1996:256) suggests that before doing an experimental study, it is possible to work out how things ought to happen according to the theory by running a simulation. Computers form an immediate reality controlled by the programmer. To promote meaningful learning in science, the challenge is to develop an optimal mix of 'wet' and 'dry' labs of laboratory activities and simulations (Lunetta & Hofstein, 1991:126).

Expectations in most science courses include the learning of an array of scientific concepts as well. In the physical sciences, for example, conceptual understanding can be enhanced with simulations of the Bohr model, nuclear or chemical reactions, the kinetic-molecular model or the nature and flow of electric charge (Lunetta & Hofstein, 1991:126).

The Internet provides a large number of educational web sites suitable for science teaching. The advent of Java applets in creating interactive simulations and increasing interactive multimedia capabilities make it possible to create instructional materials which prompt learners to use various senses. A Java applet is a software program written in the Java language, a programming language used primarily on the World Wide Web. A Java applet is a separate file referenced by an HTML document and may be used, for example, to add animation, music and database operations. With rapid development of Internet technology, more and more interactive simulations can be downloaded from the web.

2.6.3 Interactive computer simulations

Research on the effects of instructional simulations is rapidly increasing. After considering a series of such studies Lunetta and Hofstein (1991:133) suggest that instructional simulations are generally not as effective as hands-on experiences in promoting manipulative skills. On the other hand most studies have found that computer simulations are at least as effective as conventional laboratory work in promoting concept learning. In general simulation activities took considerably less time than did the activities in school laboratory. Some commonly used laboratory activities involve excessive effort and time to set up equipment and to gather data. The supplemental use of simulations may be a more appropriate way to involve learners in active encounters with important concepts than experiences in more conventional laboratory activities. Some phenomena are not accessible experimentally because they take place too rapidly or they require conditions that are not available in the laboratory. Pena and Alessi (1999:442) note that simulations provide learners with a degree of control not available in the real world. Thus simulations allow for a more detailed analysis of phenomena and provide greater control over phenomena than is available through casual, real world observation. Lunetta and Hofstein (1991) claim that instructional simulations provide new opportunities for scientific investigation and inquiry with concepts and systems that are often not possible or appropriate to investigate with real materials in introductory courses. "While simulations are not always suitable substitutes for practical activities in the school laboratory, they can enhance concept learning and provide a sense of scientific practice" (Lunetta & Hofstein, 1991:137).

2.7 Research findings on the use of computers and simulation tools in science teaching

Khoo and Koh (1998) have used computational science techniques in teaching Physics and Chemistry. They introduced computer modelling and interactive simulations to teach chemical bonding and crystal structure. Molecular simulations software was used to model and simulate three-dimensional animated images of molecules. Feedback from their learners showed that the use of these animated coloured images and the demonstration of computational experiments provided a fast and effective way of communicating information and ideas. Not only were these simulations interactive, but they also extended the size and time scales over which the learners could naturally observe, opening up to study, phenomenon that would otherwise be inaccessible to experiment. Khoo and Koh (1998) from their experience affirm that the use of computer models and simulations has been valuable in explaining many aspects of science and, at the same time, encouraging critical assessment of some scientific concepts. The element of variability due to interactive nature of simulation program modules where the learners could change the parameters and verify experimental facts like the bond angle, bond length and type of crystal structure, serve to motivate the learners by boosting their confidence when they achieved successes in observing and proving the concepts and facts they learned. Hence the use of simulation tools can be considered as complementary educational tools to reinforce the learner's learning.

Ronen and Eliahu (2000) examined the role of a simulation as a potential aid that may help learners to bridge the gap between theory and reality, in the case of electric circuits. Their study involving learners aged 15 years revealed the role of simulations as a source of constructive feedback, helping learners identify and correct their misconceptions and cope with the common difficulties of relating representations to real circuits and vice versa. They realised that simulations can provide unique advantages for enhancing learners' understanding of theoretical principles and for bridging the gap between the theoretical idealised models, their formal representations and reality.

Hargrave and Kenton (1999) argue that simulations designed for learners to use prior to formal instruction changes their learning experiences. In addition, instruction time can be used to address learners' alternative conceptions and further develop their conceptual understanding. Hargrave and Kenton (1999) claim that pre-instructional simulations set the context for formal instruction, illustrate the dynamic nature of science phenomenon, and provide learners with opportunity to develop new conceptions. They outline the following characteristics of pre-instructional simulations:

- Pre-instructional simulations are exploratory environments
- Pre-instructional simulations contain variables that can be manipulated by the learner
- Pre-instructional simulations allow the learner numerous attempts to complete the task
- Pre-instructional simulations provide feedback that is consistent with phenomenon it models (Hargrave & Kenton, 1999:50-51)

Pre-instructional simulations in which learners can manipulate variables, explore the environment, and test hypotheses before formal instruction, allow learners to create robust conceptions of science topics. When learners enter into formal instruction having had exposure to and experience with the topic of study by way of simulation, they become active creators of knowledge before and during formal instruction and assume greater control of the content and learning. According to Hargrave and Kenton (1999) the use of pre-instructional simulations challenge the traditional classroom power structure, change teachers' class preparation tasks and make teaching more dynamic and spontaneous and provide teachers with timely information regarding student learning.

A study conducted by Pena and Alessi (1999) investigated the effects of Microcomputer Based Laboratory (MBL), simulations and computer-based text on individuals' ability to understand concepts in Physics. A significant finding of this study concerned the relative effectiveness of both MBL and simulations compared to computer based text instruction. Both MBL and simulation were more effective than computer based text in facilitating comprehension of concepts in free fall.

Edison and Simmons (1998) conducted a study to examine the relationship of microcomputer simulation graphics and alphanumeric mode of data presentation to learners' science process skills and conceptual understanding of selected science concepts. The results from this study led to the conclusion that the graphics or alphanumeric modes of data presentation enhanced certain process skill performance and conceptual understanding of the concept introduced after treatment with the microcomputer simulation. The use of microcomputers and appropriate software can enhance learners' learning and understanding of science and scientific problem solving. The interaction between the learner and the software can facilitate problem solving skills development and conceptual understanding and help learners and their teachers engage in more meaningful learning experiences (Edison & Simmons, 1998: 56).

On a more advanced level, Kalkanis and Sarris (1999:61-80) investigated the effect of a specific simulation program for the study and detection methods of the cosmic rays passing through several light transparent materials. The program has been used by university students and high school students as well as by in-service training teachers with encouraging results. All students and future or current teachers agreed that the program made the lessons more attractive and interesting. In general, Kalkanis and Sarris (1999) think that the educational software, making use of specific simulation techniques, is very effective way of teaching phenomenon such as microcosm phenomena and their processes. "Microcosm processes cannot be observed with the naked eye, so the only way to observe the cosmic rays is through computer simulation or/and their detection" (Kalkanis & Sarris, 1999:61).

Olson (1988) claims that computers can play an important role in supporting the use of simulations in schools, thereby helping teachers do a better job of teaching their subjects. While the computer can provide appropriate challenges, it is the teacher who must help learners understand what those experiences signify. But the help given by the teacher depends on what conception learners bring to their experience. Olson (1988) argues that the computer itself cannot be relied upon to make learners make sense of their experiences since it cannot be programmed in advance to anticipate how different learners make sense of their experience. Sanger and Greenbowe (2000) suggest that novice learners may not know how to attend to relevant cues provided by computer animations and should be prompted to watch for relevant details. Therefore the role of the teacher in a learning situation cannot be completely ruled out, especially when it deals with conceptual changes in the learner.

Chuang (2000), in his study to investigate the differences in learning outcomes between using computer simulated courseware and a conventional textbook approach, realised that computer simulation courseware most helped learners to gain procedural knowledge while the conventional textbook approach most helped learners to get factual knowledge. Chuang (2000) indicates that computer simulations are usually comprehensive, timesaving and self-paced which are beneficial features for learners with different levels of computer literacy.

De Jong, Martin, Zamarro, Esquembre, Swaak and van Joolingen (1999: 597) indicate that discovery learning with computer simulations is generally seen as a promising area for learning and instruction. According to de Jong *et al.* (1999) investigation assignments, which point to specific elements of the simulation model, prompt learners to find relationships between two or more variables.

2.7.1 Computer Simulations to enhance conceptual change

Windschitl and Andre (1998) investigated the effects of a constructivist versus objectivist learning environment on college students' conceptual change using a computer simulation as an instructional tool in a physiology class. The study provided some evidence that an exploratory constructivist simulation experience could be more effective in altering learners' misconceptions than a confirmatory simulation experience. Learners with greater epistemological sophistication did better in the exploratory simulation environment, while students with less sophisticated beliefs about knowledge and learning achieved best in the more prescribed, confirmatory simulation environment.

Tao and Gunstone (1999) investigated the process of learners' conceptual change during a computer supported physics unit in Grade 10 science class. It was found that many learners vacillated between alternative and scientific conceptions from one context to another during instruction, i.e. their conceptual change was context dependent and unstable. The few students who achieved context dependent and stable conceptual change appeared to be able to perceive the commonalities and accept the generality of scientific conceptions across contexts.

2.8 Summary

The performance of South African secondary school learners in science and mathematics is appalling compared to world standards. One of the reasons for this awful performance of learners can be attributed to the current practices of science education, which is in line with the traditional, objectivist and instructivist, teacher–centred education. It is assumed that a constructivist approach in education may help the learners to learn science in a meaningful way. Information and Communication Technologies, which include computer simulations, are tools that can support constructivist education. Interactive computer simulations when used wisely in science classroom have great potential in bringing about conceptual changes in learners.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter aims to locate the research paradigm in which the study was conducted as well as to describe the research strategies and procedures adopted in the study. This is done by first locating the study within the interpretivist paradigm of research and then discussing the qualitative and quantitative approaches. This is followed by a discussion on the chosen methodology, which includes the research strategies and procedures; data collection tools; location and sample selected for the study.

3.1 Research Question

The aim of the research study, as mentioned in chapter 1, is to address the following question:

What conceptual changes about wave motion are engendered by interactive computer simulations?

I investigate the learners' conceptualisation of wave motion at three different stages of instruction, defined as pre-instruction stage, traditional instruction stage and interactive computer simulation intervention stage. The three questions central to the investigation include:

- How do learners intuitively conceptualise wave motion?
- What conceptual changes are brought about after classroom instruction on wave motion?
- What conceptual changes are brought about after using interactive computer simulations in the classroom?

3.2 Research Paradigm

According to Cantrell (1993) assumptions underlying three distinctly different paradigms- "positivism, interpretivism and critical science"- currently guide educational research. Intrepretivist researchers interact dialogically with the participants. Cantrell (1993) notes that researchers from this orientation seek to understand phenomena and to interpret meaning within the social and cultural context of the natural setting. "At root interpretivism is about contextualised meaning. Interpretivist logic rejects the primacy of scientific realism, in either its traditional or more contemporary forms along with its accompanying corresponding theory of truth. In interpretivism, social reality is viewed as significantly socially constructed, based on a constant process of interpretation and reinterpretation of the intentional, meaningful behaviour of people – including researchers" (Greene, 1994:530).

In this study I endeavoured to find out the different ways in which the learners experienced and conceptualised the phenomenon of wave motion and an interpretive approach helped to capture the variation in the ways which the learners conceptualised wave motion. In this qualitative approach in-depth semi-structured interviews and participant observation schedules are used as data collection instruments "to get inside the person and to understand him from within" (Cohen & Manion, 1994:38). Besides identifying conceptual changes, why and how the learners conceptualised wave motion differently was also my concern. So the focus of my study was to understand the subjective world of human experience.

To obtain detailed descriptive data, I became a **participant observer** in five lessons using traditional methods and 12 demonstrations using interactive computer simulations over a period of three weeks in a Grade 9 science classroom in which the basic ideas of wave motion were taught. I obtained detailed descriptive information through classroom observation noted in field notes, questionnaires, in-depth semi-structured interviews and by examining student worksheets. The interpretation of the data and generation of my assertions followed accepted interpretive methods. Denzin and Lincoln (1994:14) outline the interpretive methods as follows. "The researcher does not just leave the field with mountains of empirical materials and then easily write up his findings. Qualitative interpretations are constructed. The researcher first creates a field text consisting of field notes and documents from the field. The writer as interpreter moves from this text to a research text: notes and interpretations based on the field text. This text is then re-created as a working interpretive document that contains the writer's initial attempts to make sense out of what he or she has learned. Finally the writer produces the public text that comes to the reader".

From the above deliberations it is clear that this research study was set within an interpretivist paradigm in which a combination of mainly qualitative methods with quantitative analysis techniques were used to add rigour to the study. Pre-instruction, post-instruction and post-intervention questionnaires were used to collect quantitative data although these tools are usually associated with a quasi-experimental approach within a positivist paradigm. The data collected from these questionnaires helped to quantify the variation of learners' ideas on different aspects of the concept of wave motion after the use of interactive computer simulation in the classroom. The percentage variation in the number of learners who selected the correct responses was calculated to identify the shift in conceptualisation.

3.3 Qualitative and quantitative approaches to research

Leedy (1992: 139) classifies research methodology as follows: If the data is verbal, the methodology is *qualitative*, if it is numerical the methodology is *quantitative*. An alternative to this strict dichotomy is triangulation. Denzin and Lincoln (1994:2) indicate that triangulation, or the use of multiple methods, reflects an attempt to secure an in-depth understanding of the phenomenon in question. Cantrell (1993) suggests that by using a combination of data collection techniques, the researcher can capitalise on the strengths of each and minimise weaknesses inherent in single strategies. Triangulation adds rigour, breadth and depth to any investigation.

According to Van Maanen (1983) the label "qualitative methods" is at best an umbrella term covering an array of interpretive techniques which seek to describe, decode, translate, and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena. Van Maanen (1983:10) compares qualitative methods to the interpretive procedures we make use of as we go about our everyday life. The data that we collect and act upon every day life are of the same sort that a qualitative researcher explicitly attempts to gather and record. Such data are symbolic, contextually embedded, cryptic, and reflexive, standing for nothing so much as their readiness or stubbornness to yield to a meaningful interpretation and response. Van Maanen (1983: 10) clearly distinguishes qualitative methods from quantitative methods by the following example:

"When crossing the street, for example, the sight of a ten-ton truck bearing down on us leads to an immediate and presumably prudent action. We do not first stop to ask how fast the truck is travelling, from where did it come, how often does this occur, or what is the driver's intention. We move. Our study of the truck involves little more than a quick scan, a glance up the road which reveals to most of us a menacing symbol of such power that a speedy, undeliberated response is mandatory. It is the aim of qualitative researchers to identify such symbols and, as a way of assessing their meaning, to record the pattern of responses these symbols elicit".

Denzin and Lincoln's (1994:2-7) ideas on qualitative research are briefly summarised as follows:

- Qualitative research, as a set of interpretive practices, privileges no single methodology over any other. It has no theory, or paradigm, that is distinctly its own. Nor does qualitative research have a distinct set of methods entirely its own. It is multi-paradigmatic in focus.
- Qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. The word qualitative implies an emphasis on processes and meanings that are not rigorously examined, or measured (if measured at all), in terms of quantity, amount, intensity, or frequency. In contrast, quantitative studies emphasize the measurement and analysis of causal relationships between variables, not processes. Qualitative researchers stress the socially constructed nature of reality, the intimate relationship between the researcher and what is studied, and the situational constraints that shape inquiry (Denzin and Lincoln: 1994).
- Qualitative researchers can isolate target populations, show the immediate effects of certain programs on such groups, and isolate the constraints that operate against policy changes in such settings.

Van Maanen (1983:10) insists that qualitative methodology and quantitative methodology are not mutually exclusive. Significant progress has been made towards the desirable goal of combining quantitative and qualitative methods within the same study in research on classroom learning environments (Fraser & Tobin, 1991 in Fraser, 2000:16).

3.4 Research strategy and procedure

According to Leedy (1992) the nature of the data and the problem for research dictate the research methodology. In this particular study in which the conceptual change brought about by interactive computer simulation was explored, data was collected by means of field notes, observation, questionnaires and in-depth semi-structured interviews.

I chose an interpretive, participatory observation study as the appropriate strategy for addressing the questions of the research. According to Narayan (1996) participatory research embodies an approach to data collection that is two-directional (both from the researcher to the subject, and from subject to researcher). Therefore there is considerable interaction between the subjects and the researcher throughout the research. Participant observation can be considered as qualitative research method. According to Cohen and Manion (1994) participant observation is a form of research that is eminently suitable to many of the problems that an educational investigator faces. In this study, I actively engaged in the Physics lessons for a group of seventeen Grade 9 learners. During instruction, as a participant-observer, I helped the learners to complete exercises and worksheets by asking procedural questions. I asked the learners to explain their understanding of the tasks that they had completed, but did not explain concepts to them.

The data from interviews consist of direct quotations from learners about their personal perspectives and experiences, opinions, feelings and knowledge. The data from observations consist of detailed descriptions of the learners' activities, their enthusiasm and actions. Survey analysis yields excerpts of learners' opinions; quotations and open ended written responses from questionnaires. The methodology adopted could thus be considered qualitative. However, attempts were also made to find out the percentage shift in the correct responses from one stage of the study to the other and the confidence rating to obtain information about learners' state of partial and total knowledge. The methodology thus also included a quantitative aspect.

In this study I approached the sample without any overt hypothesis. No attempt was made to compare the two interventions - the one using ripple tank experiments and the other using interactive computer simulations. My intention during the traditional instruction stage was to raise learners' conceptualisation of wave motion to a post-instruction level by means of traditional methods and demonstration techniques that were used in township schools in South Africa. This was necessary in order to find out how computer simulations could enhance conceptualisation of wave motion in the learners in townships. To study further conceptual changes in the learners by the use of interactive computer simulations, the demonstrations using interactive computer simulations were conducted.

3.5 The location of the study

The research was carried out in Themabalabantu High School in Zwelitsha, a township five kilometres from King William's Town, South Africa. The school, which was under the now-defunct Ciskei Department of Education until 1994, caters for African children and has classes from Grade 8 to Grade 12. The Matric pass rates of the school for the past two years were 46 % and 40% respectively. There are two science teachers in the school, the one teaches General Science in Grade 8 and Grade 9, and the other teaches Physics and Chemistry in Grade 10, 11 and 12. The school has a laboratory that serves as a classroom at times for other subjects because of the lack of adequate classrooms in the school. Hence the science teachers have very few opportunities to arrange laboratory work for science students. The teachers do not use any technology for instruction, as they do not have even an overhead projector in the school, but there is hope on the horizon. The principal of the school is trying to introduce computer studies as a subject from the year 2001. The school has obtained a few computers which were donated by one of the leading automobile manufacturers in South Africa. I was involved in setting up a few of these computers in the computer room, which will most probably be used for computer lessons for the learners very soon. There are plans to involve more donors to obtain additional computers in order to introduce Internet and Communications Technology for administration and teaching.

In this research study I investigate the use of interactive computer simulations to engender conceptual changes about wave motion in the learners of a previously disadvantaged school. Thembalabantu High School is a township school and its learners belong to the previously disadvantaged community. Moreover, the school is keen to introduce computer lessons and use computers for instruction. The findings of my research study may therefore be beneficial for township schools in general and Thembalabantu High School in particular. The school was thus found to be suitable for this study.

The principal of the school had no objection and was happy to have such a study conducted in the school. The science teachers were always there to help in organising the laboratory for the study. The school was approached in early September 2000 and permission was sought from the School Governing Body through the Principal of the School. Because of the quarterly holidays and end of the year test period the study could begin only in the middle of October 2000.

3.6 The Sample of the Study

The Physical Science syllabus for Grade 10 begins with wave motion as the first unit of study and teachers usually teach wave motion at the beginning of the year. By the time I approached the school the topic had already been 'covered' by the teacher in his Grade 10 class. The aim of the research was to study the learners' conceptual changes about wave motion before, during and after traditional classroom instruction and interactive computer simulations. In the light of this, learners who had already been exposed to wave motion imparted by traditional methods of teaching would not be a good sample for the study. So the alternative to the Grade 10 pupils was the class of Grade 9. These Grade 9 pupils had completed their General Science syllabus and were preparing for the year-end examination. The concept of wave motion had not been introduced to them yet. So they were best suited as the sample for the study.

The sample used for the study was a convenient sample. According to Cohen and Manion (1994) convenience sampling involves choosing the nearest individuals to serve as respondents. The sample consisted of 17 Grade 9 learners who were selected as they all had passed the mid-year General Science examination and were interested in learning Physical Science in future. In a meeting with the group I briefed them about the purpose of the study and the use of computers in education. The learners showed enthusiasm to participate in the study and committed themselves to attend all the lessons and activities during the period of study. Despite this, during the period of this study five learners did not attend all the lessons intended for them. So in effect the sample had to be reduced to twelve learners who were involved in all the lessons and activities conducted.

3.7 The Data Collection Tools

As indicated in section 3.4 of this chapter the following tools were used in this investigation.

3.7.1 Questionnaires

Three questionnaires were used in each of the corresponding stages, i.e.: pre-instruction, post-instruction and post-intervention questionnaire (Appendix A and B). The questions in both post-instruction and post-intervention questionnaires were the same. The multiple-choice questions required the learners to circle the best answer contained in the alternative responses and to indicate their confidence in their answer. In order to measure the accuracy the responses were scored by limiting them to a 1 or a 0 if the answer was right or wrong respectively. The results of the post-instruction questionnaire and the post-intervention questionnaire were analysed to identify the possible impact of interactive computer simulations on the teaching and learning of the concept of wave motion. The percentage variation in the number of learners who selected the correct responses was calculated to identify the shift in conceptualisation. Confidence ratings are used for scaled scores as given below.

Confidence rating	**Answer**	
	if correct	**if wrong**
Very confident	8 points	1 point
Fairly confident	7	2
Not very confident	6	3
Guessing	5	4

Previous research indicates that the use of confidence rating scale results in higher internal consistency and stability than conventional multiple choice testing and provides information about learners' state of partial and total knowledge (Sieber, cited in Pena & Alessi, 1999).

Data from questionnaires included both qualitative and quantitative data. Student responses to individual items were used to form an interview schedule to clarify whether students had interpreted items consistently.

3.7.2 *Observation and field notes*

Throughout the period of instruction and intervention the following were observed: learners' actions and behaviour; the questions they asked; the difficulties they faced and when they sought help. Field notes prepared during these period served as valuable tools to identify any shifts in the learners' conceptualisation of wave motion.

3.7.3 Interviews

Denzin and Lincoln (1994) state that both quantitative and qualitative studies are concerned about the individual's point of view. However, qualitative investigators hope to get closer to the learner's perspective through detailed interview and observation. Therefore the data collected using the questionnaires was used to design semi-structured in-depth interviews. Questions asked during the interview focussed on specific items from the questionnaire, but varied depending on the responses given by the learners. These interviews were intended to probe the reasons for the answers given by the learners in the questionnaire or their particular behaviour during the lessons. Questions such as 'how would you explain wave motion to a friend?' were included to encourage the learner to reflect on their own conceptions and thus to elicit 'status formation'. Factors related to the status of learners' conceptions were identified from the interview to help in the process of classifying learners' conceptions of wave motion as being intelligible, plausible or fruitful.

CHAPTER 4

RESEARCH PROCEDURES

In this chapter the procedures, which were adopted in the classroom during the research study, are described. The learning unit on 'waves' was exposed to the learners by means of traditional instruction and by using interactive computer simulations. Three distinct stages are identified in the procedures – the pre-instruction stage, the traditional instruction stage and the computer simulations intervention stage.

4.1 Physical Science syllabus for grade 10

The syllabus for Physical Science, which was introduced by the Eastern Cape Department of Education in the year 1996, is still followed in Grade 10, 11 and 12. Both the Higher Grade and Standard Grade syllabus contain a learning unit on 'waves'.

4.1.1 Learning unit on 'waves' in the syllabus

In this research study I tried to stick to the syllabus for Grade 10. The unit on 'waves' is the first topic in the Grade 10 syllabus. An extract of the syllabus containing the unit 'Waves' is given in Appendix E. However, the relationship between velocity, frequency and wavelength $v = f\lambda$, and the interference of waves were excluded due to time constraints.

4.1.2 Key elements of the concept of wave motion

The most important elements in the concept of wave motion to be dealt with in Grade 10 are those of mechanical wave motion. They are:

- Waves carry energy

- Particles in the medium through which the wave travels, do not move with the wave but vibrate only
- In transverse waves, particles of the medium vibrate perpendicular to the direction of motion of the wave
- In longitudinal waves, particles of the medium vibrate parallel to the direction of motion of the wave

In order for the learners to develop these concepts of wave motion, along with characteristics of wave motion and wave phenomena like reflection and refraction, five lessons were included in the study. The study was conducted in three stages over a period of three weeks.

4.2 Stage 1: Pre-instruction stage

"The most important single factor influencing learning is what the learner already knows; ascertain this and teach him accordingly" (Ausubel, cited in Freyburg and Osborne, 1985:82). Hence before any intervention, a **pre-instruction questionnaire** (Appendix A) was given to the learners in order to identify their intuitive notions about wave motion. The questionnaire consisted of two sections, Section A which contained three open ended questions and a space for diagrams representing the concept of wave motion, and Section B which contained multiple choice questions and spaces for drawing diagrams showing the motion of a plastic ball thrown into the sea and into a pool.

Once Section A of the questionnaire was completed learners were invited to share and discuss their intuitive notions of wave motion. After a brief discussion on sea waves and other type of water waves, the learners' intuitive notions about the nature of waves were sought by means of

Section B of the questionnaire. The questions in this section centre on the way in which water moves as waves. The learners were asked to draw diagrams showing the motion of a plastic ball thrown into the waves in the sea or into the ripples in a pool. This part of the questionnaire was designed to gather learners' ideas regarding the motion of particles in a wave motion. After studying the responses in the questionnaire, the intuitive notions of the learners were mapped out.

Pre-instruction interviews were then carried out. The interviews were aimed at finding out why the learners have specific ideas on wave motion and why they drew the diagrams as they did in the questionnaire. A learner whose intuitive notions were similar to the most common notion of water wave and two learners whose ideas were different from water wave were selected for the interview. The interviews served to throw light on the learners' pre-instructional conception of wave motion and how and why these ideas were developed.

4.3 Stage 2: Traditional instruction stage

The first intervention was undertaken after the pre-instruction interviews. This stage of the study involved instruction on wave motion by the researcher. There were five lessons which consisted of demonstrations and discussions. The five lessons included the following aspects of wave motion:

- Vibrations
- Pulses: Longitudinal pulse and transverse pulse
- Demonstration of mechanical waves using strings and a ripple tank
- Wave characteristics: amplitude, wavelength and frequency
- Demonstration of wave phenomena – reflection and refraction of water waves

4.3.1 Lessons on wave motion

After finding out the intuitive notions of the learners about wave motion during the pre-instruction stage, the scientific conception of wave motion was compared with real waves, in the form of ripples in a ripple tank. This was not the stage for diagrams in time and space or formal definitions, or a talk on wave properties. This was the time for acquaintance with reality. To introduce more ideas on wave motion the first lesson was given on vibrations.

4.3.2 *Lesson 1: Vibrations*

The first lesson was on vibrations. In this lesson the concept of regular repetitive motion was introduced by using a simple pendulum, loaded helical spring and vibrating hacksaw blade. Learners were asked to do the experiment to determine the relationship between the frequency and period of the pendulum.

4.3.3 *Lesson 2: Pulses – Longitudinal pulse and transverse pulse*

Learners were shown how to send transverse pulses along a slinky spring and a string. Learners were asked to observe the movement of individual turns of the spring or markings made on the string as the pulse advanced along the spring and the string. Similar treatment was given to demonstrations of a longitudinal pulse, produced on a slinky. Learners used worksheets (Appendix D) to record their observations and were encouraged to explain the concept of transverse and longitudinal pulse based on their observation.

4.3.4 *Lesson 3: Demonstration of mechanical waves using strings and a ripple tank*

Successions of transverse pulses were transmitted along a string and helical spring to produce progressive transverse waves, and longitudinal pulses on a helical spring. Learners were encouraged to define the concepts of transverse wave and longitudinal wave.

4.3.5 *Lesson 4: Wave characteristics: amplitude, wavelength and frequency*

Transverse waves were graphically represented. The wave characteristics like crests, troughs, compressions, rarefactions, wavelength, amplitude and frequency were introduced by using charts and diagrams.

4.3.6 *Lesson 5: Demonstration of wave phenomena*

Circular waves and straight waves were demonstrated in a ripple tank. The reflection of circular waves and straight waves and refraction of plane waves were demonstrated and learners were asked to draw diagrams to represent their observations. Based on the diagram showing the reflection of straight waves learners were directed to draw up the laws of reflection.

4.3.7 The role of the researcher

In all these lessons I assumed the role of a facilitator and demonstrator encouraging and helping the learners whenever necessary. The learners were told where to look for relevant observations, but not what to look for. Thus the learners were encouraged to create their own ideas regarding pulses and waves. The learners recorded their observations and completed the tasks given in the worksheet. The sample worksheets, which the learners used, are given as Appendix D.

Throughout the lessons I acted as a participant observer, conducting the demonstrations and participating in classroom discussions. The school did not have a single ripple tank with accessories. So I could only demonstrate the experiments using a ripple tank that I borrowed. Even though the learners were not given an opportunity to do the ripple tank experiments on their own, they were encouraged to observe the demonstrations and note their observations verbally or graphically in a given worksheet.

The ripple tank was used together with an overhead projector to show the patterns of wave motion. It consists of a rectangular, optically transparent tray made of perspex. The tray, filled with a little water can be placed over an overhead projector. When waves are generated in the water the light from the projector shines through the bottom of the tray and water. The image of water waves is then projected on a screen. The ripple tank demonstrations provided an opportunity for learners to see concrete examples of wave motion as ripples in a ripple tank.

Strings with markings, representing particles, were used to show both transverse and longitudinal pulses and waves. I observed the learners while they were watching the demonstrations and collected and analysed their responses on the worksheets that were provided. The period between demonstrations gave me the opportunity to take down important notes on the learners' behaviour. Detailed **field notes** were developed at the end of the lesson.

At the end of the lessons the learners were asked to complete the **post-instruction questionnaire** individually. This questionnaire consisted of 16 multiple-choice questions, 3 open-ended questions and a space to draw a diagram to represent wave motion. The first seven multiple-choice questions dealt with energy transmission by waves and the behaviour of particles in a wave motion. The next nine questions covered wave characteristics such as amplitude, wavelength and frequency and involved simple calculations and graphical interpretation of wave diagrams. The open-ended questions and the diagram aimed at identifying shifts, if there were any, in the learners' pre-instruction conception of wave motion.

Post-instruction interviews were held next. Three learners who displayed different conceptual status were questioned about their conceptualisation and counterintuitive notions of wave motion.

The scientific notions they failed to learn were discussed with them. These interviews were audio taped and transcribed. The data from interviews consists of direct quotations from learners about their personal perspectives and experiences, opinions, feelings and knowledge.

4.3.8 Difficulties encountered during the lessons

It took considerable time to set up the ripple tank to project satisfactory images of wave motion. Between the trials of experiments, much time was wasted while the disturbances in the water settled. Draughts coming through broken windows of the classroom also interfered with some of the observations such as the movement of cork particles in water. While the learners tried to produce longitudinal waves in the slinky, the reflection of the waves from the other end of the slinky caused the production of stationary waves. Learners struggled to identify the right observations as the longitudinal pulses travel very fast on a slinky. The interference of ripples with reflected ripples made it difficult for learners to make relevant observations on their own.

4.4 Stage 3: Computer simulations intervention stage

The final stage of the study comprised the intervention using interactive computer simulations. Interactive computer simulations downloaded onto a computer from various websites were used during this stage. The simulations were projected onto a screen using a data projector so that all the learners could clearly see the simulations. Here the computer was used as a demonstration tool to provide an opportunity for the learners to see the particle motions in a wave using interactive computer simulation. The interactivity allows the demonstrator to vary the parameters and see the effects. The interactivity allowed me to vary the different parameters associated with wave motion in order to demonstrate the corresponding effects. As in the previous stage learners observed, discussed their observation and completed the worksheets. During this time I observed the learners and wrote the **field notes**. This intervention was followed by the **post-intervention questionnaire,** which contained the same questions used in the post-instruction questionnaire. This enabled me to make a follow-up on the conceptual changes brought about by the intervention. The worksheets completed by the learners during instructions were also analysed to identify any conceptual changes. According to Freyburg and Osborne (1985) probing children's ideas and asking them to explain why they believed what they did reveals a range of thinking. Hence **post-intervention interviews** of selected learners were conducted to probe any conceptual changes brought about by interactive computer simulations.

4.4.1 Computer Simulation in the classroom

The problems encountered in the traditional instruction were overcome using computer simulations. The computer was used as a demonstration tool throughout these lessons. It was not possible to give each learner a computer to run the simulations several times and create their own concepts about wave motion. Therefore the computer simulations were presented to the learners as follows. I controlled each demonstration on a Personal Computer (PC). Using a data projector, the simulations were projected on a screen that could be seen by all learners. During the course of demonstrations, where parameters could be changed I paused the computer simulation and asked the learners to predict what was about to occur when a particular parameter was varied. After the learners made their predictions, they viewed the effects of changing the parameter and recorded their observations in the worksheets provided. However, not all features of the simulations were used as they were not relevant for Grade 10.

4.4.2 Websites containing simulation of wave motion

After browsing through a number of educational web sites I downloaded web pages, which contained interactive simulations dealing with basic concepts of wave motion. The simulations were not taken from a single website. Simulations found in various websites were reviewed and web pages which were relevant for Grade 10 learners were downloaded and saved for future use. These web pages contained mostly interactive simulations, which were simple, but clearly showed the important features of wave motion. The Universal Resource Locator (URL) of the web sites selected is given below.

- Exercise the pendulum
  http://www.cath-mem.org/physics/java/pend1/index.html
- TextSnake the cursor-hunting beast
  http://www.cath-mem.org/physics/Wave.htm
- TransverseWaves-1
  http://members.nbci.com/surendranath/Twave/Twave01.html
- LongitudinalWaves-1
  http://members.nbci.com/Surendranath/Lwave/Lwave01.html
- Transverse Wave and Longitudinal Wave
  http://wigner.byu.edu/WaveTrans/WaveTrans.htm
- Introduction to waves
  http://id.mind.net/~zona/mstm/physics/waves/introduction/introductionWaves.html
- Wave Parts
  http://id.mind.net/~zona/mstm/physics/waves/partsOfAWave/waveParts.htm#pictu
- Circular Waves
  http://member.aol.com/nicholashl/waves/circularwaves.html
- Moving Waves
  http://member.aol.com/nicholashl/waves/movingwaves.html
- Reflection of Circular Waves
  http://member.aol.com/nicholashl/waves/circular_reflection.html

- Reflection of straight waves
  http://member.aol.com/nicholashl/waves/reflection1.html

- Refraction of straight waves
  http://member.aol.com/nicholashl/waves/refract1.html

A demonstration menu was constructed by hyperlinking each of the demonstrations to a specific website. The demonstration menu is given in Appendix F.

4.4.3 *Demonstration 1:*

The applet in this demonstration showed a simple pendulum that was suspended on a 'rigid string'. The pendulum was made oscillating by dragging its bob with the mouse and releasing it. One can drag the pendulum to various positions thereby varying its length and amplitude. Once in motion, the pendulum can be 'caught' by clicking and holding the bob when it has reached its maximum amplitude. Thus, the pendulum can be brought to its new starting position.

During the demonstration the lengths of the pendulum were varied and the corresponding values of the period were noted by the learners from a panel above the pendulum. The learners were asked to answer the questions in the worksheet (Appendix D) and establish the relationship between the length of the pendulum and its period of oscillation. The learners were also introduced to the concept of amplitude by displacing the bob of the pendulum to different positions.

4.4.4 *Demonstration 2:*

This web page contains a Java applet 'CATHOLIC MEMORIAL', the end of which can be moved up or down using a mouse to produce transverse pulse or wave. By moving the end of the applet to and fro longitudinal pulse or wave can be produced. Each letter of the sentence represents a particle in the wave motion.

During this demonstration, by moving the mouse appropriately I produced transverse pulse and waves as well as longitudinal pulse and waves. In each part of the demonstration the learners were asked to make two observations - the direction of motion of the wave or pulse as well as the particle motion in them. In order to see the particle motion in the pulse or wave learners were asked to focus their attention on an individual letter of the applet. Learners were encouraged to define the two types of pulses and waves based on their observation.

4.4.5 *Demonstration 3:*

This simulation was interactive in different ways. One can select and modify the wave patterns between progressive wave, pulsed crest, pulsed trough and string fixed at one end or both ends. The amplitude, frequency, wavelength and animation speed also can be varied between small, medium and big. It is possible to stop the animation or run the animation step by step.

I used this simulation for the demonstration of particle motion as well as dependency of wave characteristics among themselves. The interactive features of the simulation were used to show the following aspects of transverse waves to the learners:

- The difference between a transverse pulse and a transverse wave
- The relationship between particle motion and direction of propagation of transverse wave
- The change in wave pattern as wavelength, frequency or amplitude of the wave changes
- The relationship between frequency, wavelength and speed
- The relative position of a single particle as the wave progresses

4.4.6 *Demonstration 4:*

This simulation, which deals with longitudinal pulse and waves, has the same interactive features as the previous one. We can select and modify the wave patterns between progressive wave, pulsed compression, pulsed rarefaction and pipe closed at one end or open at both ends.

As in the previous demonstration, I used this simulation for the demonstration of particle motion as well as dependency of wave characteristics among themselves. The interactive features of the simulation were used to show the following aspects of longitudinal waves to the learners:

- The difference between a longitudinal pulse and a longitudinal wave
- The relationship between particle motion and direction of propagation of longitudinal wave
- The compressions and rarefactions in a longitudinal wave
- The change in wave pattern as wavelength, frequency or amplitude of the wave changes

4.4.7 *Demonstration 5:*

In this demonstration the simulation was used to show particle motion in a wave. The pattern was changed from transverse wave to longitudinal wave and vice versa and was used to reinforce the concepts of transverse and longitudinal wave.

4.4.8 *Demonstration 6:*

The web page used in this demonstration contains transverse wave and longitudinal wave animated on the same axes. In this demonstration learners were prompted to make a comparison between crests and compressions, and troughs and rarefactions.

4.4.9 *Demonstration 7:*

In this demonstration the parts of a transverse wave such as crest, trough and characteristics like wavelength, amplitude and frequency were illustrated graphically with text. It was easy to navigate from one aspect of a wave to another easily using hyperlinked hot spots. The frequency of the transverse wave pattern was varied to see the effects. Once again, this demonstration was used to reinforce the concepts by means of textual description.

4.4.10 *Demonstration 8:*

This site was used to demonstrate the inter relationship between wave characteristics such as wavelength and frequency. The amplitude, frequency and wavelength and were changed one after another and the corresponding effects were noticed.

4.4.11 *Demonstrations, 9, 10, 11 and 12*

The simulations selected for these demonstrations showed the wave phenomena like reflection and refraction of circular wave fronts and straight wave fronts. During the demonstrations the learners observed the simulations and the wave patterns produced were drawn in the worksheets (Appendix D) provided.

4.5 Conclusion

The learners showed great interest during the demonstrations using interactive computer simulations. But very often they had to be guided to observe the important aspects of the demonstrations. One of the learners remarked that she thought they were going to use computers on their own to learn Physical Science. Five of the learners did not attend the demonstrations of the wave phenomena as they realised they were not going to use the computers on their own.

CHAPTER 5

DATA ANALYSIS AND INTERPRETATION

The data gathered by the methods described in Chapter 3 and 4 was analysed based on the different stages of the investigation: Pre-instruction Stage, Traditional Instruction Stage and Interactive Computer Simulations Intervention Stage.

5.1 Introduction

In this research study, in-depth semi-structured interviews, field notes and semi-structured questionnaires were used as data collection instruments. Using the data from questionnaires, the percentage variation in the number of learners who selected the correct responses was calculated to identify the shift in conceptualisation. Attempts were also made to find out the percentage shift in the correct responses from one stage of the study to the other. The confidence ratings of the learners' responses were used to obtain information about their state of partial and total knowledge. Field notes, prepared from observations, also served as valuable tools to identify learners' conceptualisation of wave motion and their difficulties in various activities during the study.

Data was analysed by listening to recorded interviews several times noting not only literal statements but also non-verbal clues such as sounds in the background in order to provide a context of the emergence of specific themes or units of meaning. Interview notes were categorised into units of meaning relevant to the research goals. Through an iterative process of data analysis, excerpts from the interviews were grouped together through the identification of similarities and differences which revealed the greatest variance, until qualitatively distinct categories of description characterising the conception of wave motion emerged. After redundant meanings were eliminated, units of meanings were clustered under unifying themes. A summary of interviews and questionnaires was then written, incorporating the themes that had been elicited from the data gathered.

5.2 Pre-instruction stage

It emerged from this study that learners come to class with a variety of intuitive notions of waves which I had not expected. From the analysis of learners' responses to the questionnaire and description of their conceptions of wave motion, two distinct aspects can be identified: their experiences of wave motion and the reasons for their misconceptions of wave motion.

5.2.1 Intuitive notions on wave

It was found that the learners have the following pre-conception of waves. A wave is considered as:

- Sea wave
- A hand wave (as a greeting)
- That which brings picture to the TV
- What is seen on the TV screen when there is no picture on the TV screen
- A place where Bushmen lived

All except one in the sample had heard of the word 'wave'. However, the learner who had never heard of waves later in the interview said that she knew about the motion of water at a beach and she called it *'amaza'*. An excerpt from the interview is given below. (I: interviewer S: Learner)

I: *I would like to know more about your answers in the questionnaire.*
S: *Umm.*
I: *You wrote that you haven't heard of the word 'wave' anywhere. Just think.........*

S: *(Silent)*
I: *I shall help you.*
S: *I think you can help me.*
I: *Have you ever been to a beach?*
S: *Yeah, many years ago.*
I: *What did you see there?*
S: *Water .. ummm...*
I: *What do you see, happening to seawater, if you look at the surface of the sea?*
S: *(laughs)*
I: *Is it very calm?*
S: *It moves.*
I: *Yes. What is that called? In Xhosa what do you call it?*
S: *Amaza.*
I: *What is that called in English?*
S: *I didn't know, but I know now.*

(Siphokazi, Pre-instruction interview)

I gathered from the laughter and the expression on the face of the learner that she knew what waves were, but could not identify them as waves. This prompted me to ask her what she called the movement of seawater. The learner had the concept of wave as sea wave but it was not labelled as 'wave' but as the Xhosa equivalent of wave, *'amaza'*.

Six of the learners in the sample linked the concept of wave to sea waves. One among them considered waves as 'removal of top water'; a phrase that has a close link with what he had studied in agriculture - soil erosion is the 'removal of top soil'.

One of the learners considered waves to be that which brought pictures to the television. But he had no idea what they looked like. He considered this to be so because on occasions when there was no picture on the TV, the TV presenter announced that they had 'lost the waves'.
An excerpt of the interview with the learner is given below.

I: *So, you say that you have heard of the word 'wave' on television.*
S: *Umm.*
I: *When you heard that they "lost the waves", what did you understand from that?*

S: *No picture in the TV*
I: *There were no pictures. OK. So what do you think that waves are?*
S: *Umm..*
I: *What idea have you got about waves?*
S: *They bring picture to our homes.*

(Lungisa, Pre-instruction interview)

So the learner's initial conception of waves was that waves brought TV pictures. This does not mean that he had any idea regarding the electromagnetic waves, which carry television signals. The same sort of announcement by the TV presenter gave a different idea to another learner. He thought waves were that which he used to see on the TV screen when there was no picture (the 'grains' or 'snowing' on the TV screen). The diagram drawn by the learner revealed the pattern, which we see on the TV screen if the TV channel is not properly tuned for a station.

The most surprising of it all was that a wave was a place where Bushmen lived. The diagram, which was drawn by the learner depicting waves, pictured a rocky pattern with an entrance into it. Apparently the learner mislabelled 'cave' as wave.

5.2.2 Intuitive notions on particle motion

Section B of the questionnaire was given after a brief discussion of various intuitive notions of learners. The majority of the learners linked waves to sea waves and this idea was found to be more plausible to the learners than the alternative conceptions of the rest of the class. Here the learners shifted their conception on waves to that of sea waves or ripples in the pool. Once the idea of water waves was mentioned those who had other initial conceptions of a 'wave' could recall their experiences with waves. But all of them considered that water moves together with the wave. On analysing the answers and diagrams that were given in section B of the questionnaire, it was found that all the learners believed that water particles move along with sea waves either forward or backward. Two learners pictured the motion of water as upward and downward as well as forward. The differences between sea waves and ripples in a pond were identified as follows: *sea waves were big, stronger, faster and had power*. The ripples are *small, slow and not very 'strong'*. All of them agreed that waves could be produced by disturbing water, by throwing a stone (66.7%) or by wind (25%) or by swimming in a pool (8.3%). So the concept that waves are produced by disturbances is firmly rooted in their mind. But no connection is made between disturbance and energy.

5.2.3 Learners' definitions

The variation in learners' experiences of wave motion was characterised as follows:

- ***Waves are removal of dirty things/ things that are not good in the sea or pool.***

This perception was created as the learners have seen floating debris or leaves were being washed ashore at beaches or in the pool respectively. This experience brought the notion that particles of water move along with the waves.

- ***Wave motion is the up and down, and forward motion of water***

This concept is a complex one. Learners believe that water moves up and down and sideways as the wave travel in the sea or in the pool. On further questioning the learners, it was found that they assume that the water moves in a zigzag manner in a forward direction. Another view is that water moves forward 'like a snake' i.e. in the form of a sine curve. Movement of things floating in the sea as observed from a beach gives this idea to the learners.

- ***Wave motion is formed by wind***

The learners have seen when it is windy waves are seen in the pool. One learner said that by blowing over water waves can be formed.

The data confirms the view that learners come to learning situations with knowledge gained from previous experiences (Kuiper 1998; Windschitl & Andre 1998; Hashweh 1988; Heuer & Wilhelm, 1996). As I examined these ideas I was intrigued to find out more about the process of transition in the conceptualisation of wave motion, which many learners experienced after the first intervention which exposed them to traditional methods of teaching and the second intervention which used computer simulations.

5.3 Traditional instruction stage

During this stage the data was collected during and after instruction. During the lessons learners were observed and after the lessons the post-instruction questionnaires were distributed. After this, the post-instruction interviews were conducted.

5.3.1 Vibrations

The first lesson was on vibration as the concept of regularly repeated motion is important in the conceptualisation of wave motion. During the lesson the teacher demonstrated oscillation of a simple pendulum and loaded helical spring. Learners were given a chance to work in groups and they determined the period of a pendulum and the relationship between period and frequency of a pendulum. It appeared that the learners had no difficulty in conceptualising regularly repeated motion or vibration, but had difficulty in generalising what they had observed. On studying the data collected from worksheets it is found that the learners had the following ideas on vibration.

- *Vibration is a repetitive motion, moving regularly in the same path.*
- *Motion, which is repeated regularly.*
- *Motion that does not stop, always repeating sideways or up and down.*

These definitions show that the learners formed a well-defined concept in their minds regarding vibration. The learners could make generalisation based on their observation in the case of easily visible phenomenon.

- *Moving the pendulum up and down or side by side.*
- *Movement of the pendulum from left to right.*
- *Moving side-to-side or left to right.*

In the three definitions above it is clear that the learners had identified the motion, but the definitions do not show that they are repeated regularly. All the aspects of the motion were not considered. Again the motion is linked to pendulum only and no generalisation is achieved, except for the last one.

- *Something repeated in the same position.*
- *Movement of something in the same path.*

On asking the learner whether vibration is *a 'thing'* she immediately corrected the statement to 'motion of something'. Here the learners identified one important aspect of vibration - that the motion is along the same path.

- *Moving to repeat the thing make one thing.*

The idea of repeated motion is conveyed in this definition.

- *Movement of an object, kind of motion.*

Vibration is considered by the learner as a kind of motion. Its characteristics were not identified.

- *Repetition of the thing you have been doing and keep it doing.*

Here the generalisation is far-fetched. The concept is linked to any activity that is regularly repeated, not necessarily motion.

In general, 25% of this group of learners could give a complete definition of vibration noting all its characteristics. Others have formed partial conceptualisation. On further discussion with these learners all of them could arrive at a satisfactory definition of vibration giving all the characteristics of vibration. The problem with some learners was the difficulty they had in expressing their thoughts. On carefully guiding them to note the different aspects of vibration and prodding their thoughts the learners could give correct definition. They had the right concept in their mind, but could not put it on paper.

5.3.2 Experiment to determine the period of a simple pendulum

In this part of the lesson an inductive approach was used in which the learners were given the opportunity of investigating, observing, exploring, thinking independently and drawing conclusions. The inductive approach was aimed at stimulating the learners to become aware of logical, scientific relationship between physical quantities. It was concerned with the manner in which the learners explore the materials provided and in which they look for answers to questions. Learners moved to the workstations where the apparatus required for the experiment were laid out. There were 4 groups of three to four members and were asked to take turns while doing the trials of the experiment. At times learners were found to be playing with the stop clock, starting and stopping it. Learners were excited to do practical work, but their excitement was not really in finding out the period of the pendulum, but in handling the stop clock and oscillating the pendulum. The learners found it difficult to read the right time from the stopwatch, but managed to do it with the help from the teacher-researcher. I discussed the calculation of the period, taking the observations made by one of the groups. This had prompted one of the groups to accept the period calculated by me as the period of their pendulum, even though their observations were different. This shows the effects of authoritarian traditional teaching style the learners had been exposed to. At the end of the practical activity all the groups could determine the period of the simple pendulum. But whether they understood the concept of period was doubtful as indicated by the way in which they defined period of the pendulum.

Period of vibration was defined as:

- *Moving the object with the help of your hand*

The concept was vaguely formed and apparently the learner had focussed on the experimental procedure only.

- *Number of vibrations per second*

This definition indicates the problem of incorrect labelling of the concept.

- *Time taken by the pendulum in seconds*
- *Time taken by the pendulum.*
- *The seconds with a vibration of 1.*

Here the concept is related to the physical quantity it represents, but not completely defined.

- *It (period) is* $\frac{1}{f}$

For 50% of the learners, the concept is a mathematical relationship, not a physical quantity.

5.3.3 An inductive approach

On completing the experiment, the learners were asked to find out the relationship between frequency and period by using a mathematical method. By knowing the period of the pendulum in seconds (time for one vibration), the number of vibrations in one second (frequency) had to be calculated. The learners found it hard to understand the logic in the relationship even though sufficient analogies of similar arithmetic calculations were given. It was difficult for the learners to generalise their calculations in the form of a mathematical equation. The observations made in this part of the study revealed that the learners were not experienced in inductive approach to teaching and learning. As a result learners were found to be restless and not responding to questions asked by me to elicit the required relationship.

5.3.4 Demonstration of pulses and waves

In these lessons the transverse pulse and transverse waves were demonstrated using a slinky spring. The pulse was demonstrated as a single disturbance travelling along the spring (as the medium) and waves as series of consecutive pulses travelling along the spring. One of the turns of the spring was marked using a piece of red tape to represent a particle in the medium. Demonstrations were shown to each group of learners. A few learners also were given a chance to make pulses and waves along the spring. During the demonstrations the learners were asked to note the directions in which the pulse or wave travels as well as the direction in which the red tape moved. After watching the demonstrations the learners were asked to complete the worksheets provided. Similarly longitudinal pulse and longitudinal wave were demonstrated. The longitudinal pulse travelled fast and at times got reflected from the other end. All learners except one could recognise the direction of motion of transverse pulse and wave correctly. At times when learners demonstrated the waves, reflection of waves caused a little confusion for two

learners. Learners who got wrong ideas regarding the direction of motion of the pulse/wave were asked to view the demonstration further. This helped to eradicate the confusion.
One of the learners believed that the wave was moving side to side. The same learner identified that the marked point B moved 'straightwards'. He could not visualise the linear progression of the pulse/wave as well as the vibration of point B.

The confusion regarding particle motion and direction of the wave motion was more pronounced in the demonstrations of longitudinal pulses. This was due to many reasons. The pulse or wave/ travelled fast and the speed could not be controlled effectively. The reflection of the pulse/ wave could not be avoided. The direction of particle motion relative to the direction of motion of the pulse/ wave could not be generalised by the learners even after repeated demonstrations. Lot of questions and analogies were needed to elicit the relationship between the motion of particles and direction of motion of the wave. The teacher-researcher walking forward by moving a stick sideways or forward to represent particle motion, even though crude could bring forth ideas like motion is 'perpendicular' or 'parallel', but could not establish a link with wave motion.

On asking the learners to draw diagrams showing a transverse pulse all of them represented it by a 'sine curve' like drawing. Apparently learners could not see the difference between a pulse and a wave. The graphical representation of longitudinal waves as compressions and rarefactions could not be done properly by any of the learners. In all these demonstrations and tasks the learners had to be guided to answer the questions in the worksheets, as they could not comprehend the questions. The learners' inability to comprehend both verbal and graphical descriptions of motion was evident from this.

The terms amplitude, crest, trough, compressions, rarefactions, wavelength and frequency were explained based on diagrams and charts. The learners could easily identify crest and trough as well as compressions and rarefactions from the diagrams. The term wavelength could easily be identified as the distance between two consecutive crests or troughs. The idea of frequency was difficult to conceptualise. The learners were asked to indicate on a diagram that represented a transverse wave, a point X moving away from the rest position and a point Y moving towards the rest position. Not a single learner could correctly represent phase of vibration of two named points X and Y in the medium. This showed that it was very difficult to conceptualise the phase of vibration of particles in a wave motion. This supports the view that the concept of wave motion is complex as there is a horizontal as well as vertical component of displacement in it.

5.3.5 Motivating factor

At this stage the learners were very indifferent to the lessons. This was evident from their body language and their unresponsiveness to the questions asked by me. On asking the class what made them behave so it was found that the learners were eager to use computers for learning science. So the researcher thought of stopping the lessons using traditional demonstrations. The post-instruction questionnaires were therefore distributed before any further lessons. A discussion of the responses to the questionnaire is included separately.

5.4 Interactive computer simulations intervention stage

During this stage all the lessons mentioned earlier were taught using computer simulations. The simulation of a vibrating pendulum was used to identify the relationship between the length of the pendulum and its period. By varying the length of the pendulum the period of the pendulum was read directly from the panel of the simulation. Without making any measurements

75% of the learners could easily make the conclusion that the period increases as the length of the pendulum increases and vice versa. The 25% who went wrong found it difficult to make a generalisation in the traditional instruction stage also.

The demonstration of pulses using interactive simulation was carried out next. The learners were asked to observe any particular letter on the phrase 'CATHOLIC MEMORIAL'. Learners said that the letters were moving up and down or to and fro during the demonstration of the two types of waves. The effectiveness of the demonstration was evident from the learners' graphical representation of the particle motion and the direction of wave motion. Eighty three percent of the learners could graphically represent the direction of particle motion and direction of propagation of waves correctly after watching the simulation. Forty one percent of the learners could correctly identify the state of vibration of particles in a transverse wave. This showed remarkable improvement from the previous stage. Learners found it easy to represent the transverse wave and longitudinal waves graphically. But for representing a pulse all except one learner used representation of waves. Even though these learners identified a pulse as a single disturbance the graphical representation did not show this distinction between a pulse and a wave. A pulse was defined as a single disturbance travelling through a medium. The responses which were different from this general response was that a pulse is 'a single distance', 'a single distepends (*sic*) of the pendulum', 'a movement of the wave' etc.

The data obtained from the worksheets showed that the learners could not explain terms like amplitude, wavelength, crest, trough, compressions and rarefactions in words. But when individual learners were asked to identify the wavelength and amplitude they could correctly do that. Looking at the simulations the learners could easily predict the effects of varying the amplitude and wavelength on the wave pattern formed.

The learners seemed not very happy when they found that the computers were only used as a demonstration tool. They were under the impression that each one of them would get a chance to use the computers individually. But this was not possible due to many obvious reasons. This again posed a problem during the study. The learners were found to be answering the questions in the worksheets hastely and without thinking much about them. On questioning them about their responses they could come to the right answer. Rather than concentrating on the important aspects of the simulation, the learners were focussing on the actions taken by the teacher-researcher with the computer. The computer and the data projector were found to be attracting more attention of the learners than the actual simulations. So in many instances they were to be told what to observe. The post-intervention questionnaire was given at the end of the sessions of interactive computer simulations.

5.4.1 Demonstrations of wave phenomena

The wave phenomena like reflection and refraction were demonstrated using a ripple tank first and then by using computer simulations. The learners had no difficulty in drawing diagrams showing the reflection of circular waves by observing the ripple tank demonstrations. The number of learners who could draw the reflected wave pattern correctly increased from 83% to 100% after the simulations were shown. But in both cases none of them could identify the apparent source of the reflected waves. Not a single learner could draw the pattern of reflected, straight waves from a barrier at an angle to the oncoming waves. After the simulations were shown, 75% of the sample could correctly draw the pattern. Only 25% of the sample could recognise that there is change in the direction of the wave as the wave travels from deep to shallow water. The simulation could not improve this situation either. The same 25% of learners could draw the refracted wave pattern correctly even after computer simulations were being used. The poor drawing skill of the learners was the reason for this. The learners found it difficult to communicate graphically what they had observed by means of two-dimensional diagrams. The idea that the speed of the wave changes as they move from deep to shallow water was not easily understood by the learners in both demonstrations. Once again the learners had to be told specifically what observations had to be made.

5.5 Conceptual Changes

The questionnaires had helped to gather enough data to identify the conceptual changes in the learners.

1. There is no change in the number of learners (42%) who think waves carry water or particles. These learners retain the intuitive notion. The number of learners who believed that waves carry vibrations increased from 8% to 17% whereas those who believed waves carry energy dropped from 50% to 42%. It follows that simulations gave learners the idea that vibration of particles move along the medium. It could be argued that 'vibrations are transmitted' means that 'energy is transmitted'. However, simulations could not convey the idea that waves carry energy.

2. There is considerable increase in the number of learners who believed that particles of the medium vibrate as a wave passes through it, from 33% to 58%, and those who have retained the intuitive notion that particles move with waves dropped from 42% to 33%. In this aspect

simulation was found to be useful to produce a positive conceptual change. An excerpt from the post-intervention interview supports this finding.

I: *And what about those letters in that simulation? Do you remember that? There was that sentence CATHOLIC MEMORIAL and when I moved one end of that sentence what were the letters doing?*

S: *moving up and down*

(Siziwe, Post-intervention interview)

3. Simulations did not produce any effect in changing the ideas regarding the position of the particles after the wave has passed. They could have been helpful if the facilitator pointed out to the learners to make the key observation that particles come back to their position after the wave/ pulse had passed. Here the problem arises from the fact that the learners were not used to making observations and arriving at their own conclusions from the observation. A general questionnaire (Appendix C), which was administered later, showed that 90% of the learners were not used to doing laboratory or practical work in science and therefore had never done experiments on their own. As a result of this, learners had to be guided to make the 'right' observations.

4. The descriptive questions in the questionnaire yielded 'wrong' answers while questions with diagrams, on the same concept produced better result. Most learners were not conversant with English and hence they had difficulty in comprehending the questions as well as in writing definitions or descriptions of a term or concept. Learners often battled with English. Language confusion can be mistaken for misconception. So it is important to find out whether one is dealing with a real misconception or with a language problem. "Students with language problems would be unlikely to respond to conceptual change strategies"(Clerk & Rutherford, 2000: 704). The interviews with the learners helped to identify the problem.

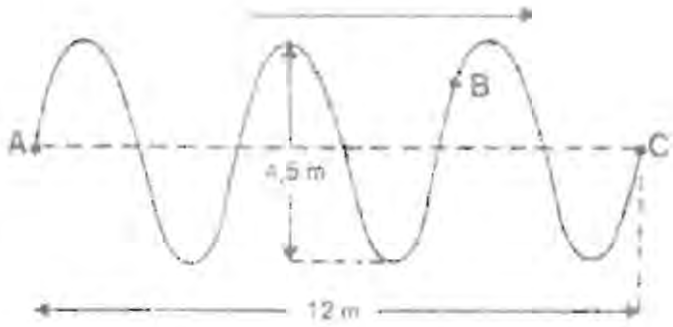
I: *For the fourth question you say the particles will move from east to west only. Can't the answer be both eastwards and westwards? I am asking.... is there any difference between the choices east to west only, and both eastwards and westwards?*
S: *I think that they are different*
I: *Can you explain the difference?*
S: *If I say both eastwards and westwards, I say that they move together. That's why I say east and west only and because they move east and west and come back to the rest position.*
I: *So if you say east and west only, does that mean that it is coming back to the rest position.*
S: *Yes*
I: *So when I say, I am going from East to West, does that mean that I am coming back?*
S: *I think so.*
I: *So if I say I am going from one end of this room to the other end, does that mean that I come back?*
S: *No.*
I: *So if you say that you are moving from east to west, does that mean that you come back?*
S: *No.*
I: *Then, is this answer right?*
S: *No.*
I: *So, now what will be your answer?*
S: *Both eastwards and westwards.*
I: *Are you sure?*
S: *Yes.*
I: *What does that mean by saying both eastwards and westwards.*
S: *It moves to east and come back*
I: *and then ...*
S: *goes to west.* (Lungisa, Post-instruction interview)

5. Incorrect labelling of entities may also be considered as misconception. As noted earlier in the case of frequency and period, some of the learners were confused with transverse wave and longitudinal wave. If the learners jumped to conclusions without analysing a question mislabelling could give the notion of misconception. An excerpt from the interview dealing with question 4 in the post-intervention questionnaire justifies this.

I: *You are right. But in the questionnaire you chose B as the correct answer. Why do you think that you answered like that?*
S: *I think.... I was .... The object will go up and down.*
I: *yeah. Ok. But why did you choose the answer 'both eastward and westward'*
S: *I confused (sic) with longitudinal and transverse wave.*

(Bulelani, Post-intervention interview)

6. For questions 9 and 14 that tested the concept of amplitude, 17% answered correctly in the post-instruction questionnaire. For question 9 this was increased to 25% after simulations were used. But question number 14 in the post-intervention questionnaire which needed to analyse a graphical notation showing measurement of distance, the correct answers dropped to a sparse 8%. Even though learners knew and could identify amplitude correctly they failed to do so in question 14. This was because the learners thought the measurement of 4,5m started from AC (the rest position) to either side (the crest or trough).



The experience of Bulelani with the question was reflected in this excerpt of the interview.

Bul: I think I was doing that .....4,5m was showing a amplitude (sic). I didn't see that it shows a ... this (points to the arrowheads)

Hence learners who have got difficulty in analysing graphical notations also may not respond to conceptual change strategies.

7. Learners who correctly answered questions in the worksheets during the demonstration, failed to answer the questions on the same concept in the questionnaire. Hence, during the interviews I encouraged the learners to use an envisioning strategy. The learners were encouraged to draw diagrams using the given information from the problem situation. It appeared that the learners were never explicitly exposed to this type of problem analysis.

I: Now if you come to question number 5 what will be your answer?
S: (Reads and pauses)

I: *Draw a diagram showing what is described.*
S: *(Reads slowly representing the different motion) longitudinal.*
I: *Now look at your answer here now. (Shows the answer in the questionnaire). You have answered it as......*
S: *Transverse.*
I: *What happened? Just tell me.*
S: *(Pauses)*
I: *You know the answer. But how did you go wrong.*
S: *I don't know how I did it.*
I: *That's OK.*

(Bulelani, post-instruction interview)

On using the envisioning strategy of problem solving the learner could easily find out the answer. Later he used this method to correctly answer the next question in the questionnaire.

8. Simulations had no effect on questions involving numerical problems.

Standard exercises, which are well defined and narrow in focus, are normally solved with an algorithm using a formula and algebraic manipulation of a number of variables. Structured problems requiring productive thinking are implicitly difficult exercises. Noncedo (learner) who answered question number 13 wrongly in the post-intervention questionnaire could correct the mistake during the interview when she was helped to analyse the problem.

I: *How many waves can you see here?*
F: *(no response)*
I: *What makes a single wave?*
F: *A crest and a trough.*
I: *If so how many waves are here?*
F: *3*
I: *What is this distance? (Showing the total length) Length of how many waves?*
F: *3*
I: *So what is the distance of one wave?*
F: *(Silent)*
I: *For 3 waves, the length is 12 m. What is the length of 1 wave?*
F: *4m*
I: *So what is your answer now?*
F: *4m*

(Noncedo, post-intervention interview)

Similarly, Siziwe who knew the relationship between period and frequency did not use it to answer question number 12. Even though she answered the question correctly she said that she was guessing the answer.

I: *For question no. 12 you've answered that as the frequency of the wave increases the period decreases. Why do you say that the period decreases?*
S: *I just guessing.*
I: *Why don't you say the opposite?*
S: *I don't know what to say.*
I: *Did you study any relationship between frequency and period?*
S: *Yes.*
I: *What is the relationship?*
S: *Frequency is... or period is one over frequency.*
I: *So if that relationship is used, will this answer be right?*
S: *(No answer)*

(Siziwe, Post-instruction interview)

5.5.1 Conceptual changes in individual learners

Concise profiles of three learners and the conceptual changes shown by them were drawn up based on the data from observations, questionnaires and interviews. In Fig. 5.1, 5.2 and 5.3 the variation of these learners' responses to the questionnaires (Appendix B), before and after the interactive computer simulation intervention, is graphically represented along with the correct answers. The question numbers are plotted along the X-axis and the responses (A, B, C, D, F and T) are plotted along the Y-axis. In each case I explain a few of the most notable changes in the responses of these learners in relation to the tables.

5.5.1.1 Bulelani

Bulelani who came to the lessons with the pre-concept that a wave is 'the removal of top water' now considers a wave as that which carry energy and the particles of a medium vibrate only as the waves travel along it. But he still has difficulty in identifying the state of vibration of the particle as the pulse has passed. When helped to visualise the problem situation by drawing diagrams, Bulelani could solve problems related to transverse wave and longitudinal waves. Even before computer simulations were used Bulelani could identify wave characteristics and simulations helped to reinforce the ideas. Compared to the rest of the sample Bulelani showed more interest in learning science and was a keen observer. But he lacked problem-solving skills and was not used to inductive learning. At the end of the lessons Bulelani had formed the following concept of wave motion:

It is the object, which is carrying something (post-instruction interview)

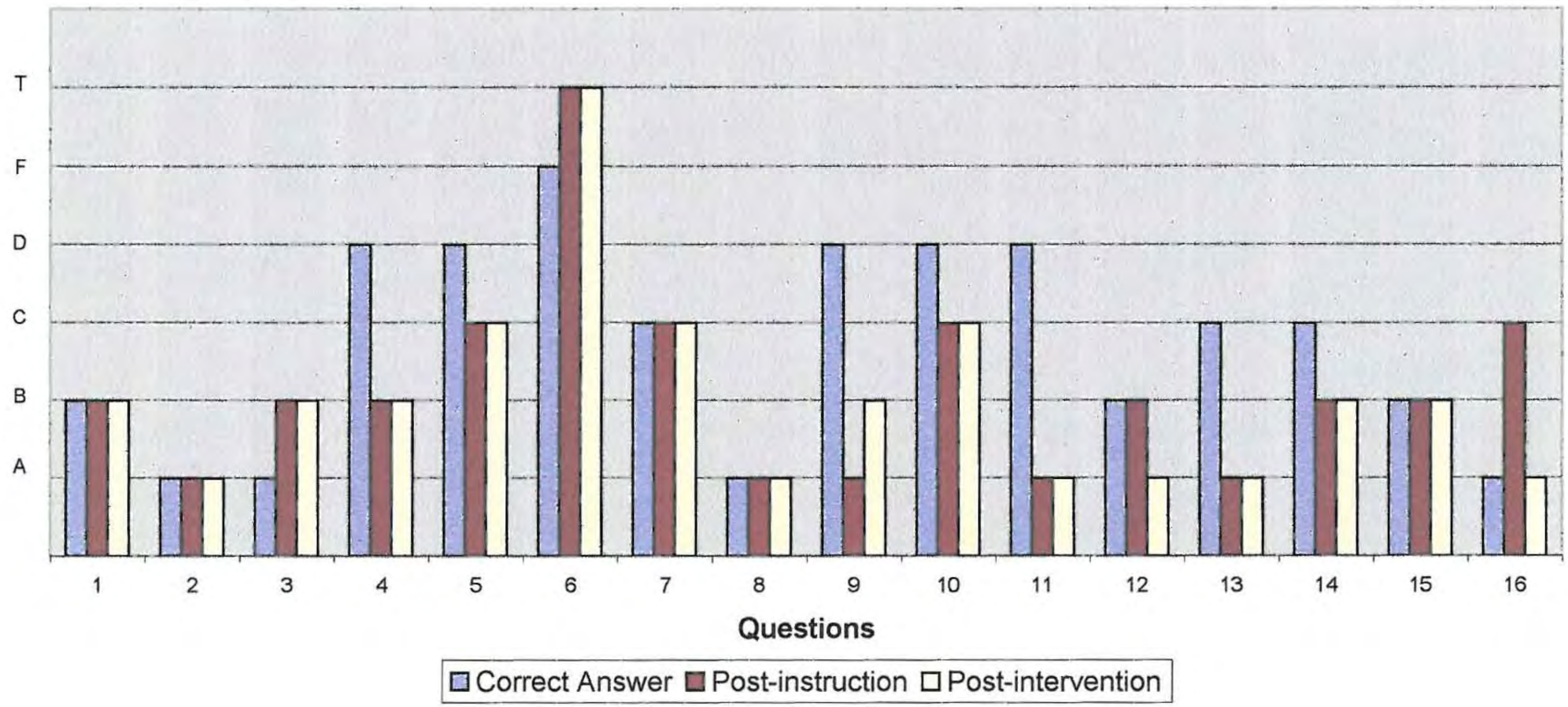
Method of carrying energy by vibrating particles (post-intervention interview)

5.5.1.2 Variation of responses - Bulelani

In Fig. 5.1 Bulelani's responses to the post-instruction questionnaire and post-intervention questionnaire are graphically represented along with the correct answer. Bulelani who was a keen participant and observer of the demonstrations in the class had no difficulty to consider that waves carry energy and the particles in a medium vibrate as waves travel along it. This is indicated by his responses to questions 1 and 2. His responses are the same before and after the interactive computer simulations intervention stage. Moreover, for question 16 Bulelani chose the correct answer after watching the computer simulations. This question aims to find out whether the learner can identify the relative positions of the particles in a wave motion. From this it is evident that the computer simulations helped Bulelani to understand the micro-level mechanics of wave motion.

The response to question 9 changes from A to B after the computer simulations intervention. The simulations helped Bulelani to distinguish between wavelength and amplitude of a wave, but failed to choose the correct answer as he failed to understand the graphical notation indicating the measure of amplitude.

Figure 5.1: Variation of responses - Bulelani



Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correct answer	B	A	A	D	D	F	C	A	D	D	D	B	C	C	B	A
Post-instruction	B	A	B	B	C	T	C	A	A	C	A	B	A	B	B	C
Post-intervention	B	A	B	B	C	T	C	A	B	C	A	A	A	B	B	A

5.5.1.3 Siziwe

Siziwe who considered a wave as water which moved up and down in the sea still considers that water particles move along with the wave. During the post-instruction stage she thought that particles of a medium remain stationary as a wave travels along it. This idea had been changed to 'particles move along with the wave', after watching computer simulations of wave motion. This change is indicated by her responses (Fig. 5.2) to question 2. Her conceptual change was "context dependent and unstable"

Siziwe also like most of the learners who took part in the study thought that she was going to use computers to learn science. During the ripple tank demonstrations, she was the first one who asked," Sir, when are we going to use computers?" But unlike the five students who left the remaining lessons after the first demonstration of computer simulation Siziwe continued attending all the lessons and activities. She was a learner who was not consistent in her decisions.

I: *That means what type of wave is it?*
S: *What type of waves? Its transverse ... Ummm.. longitudinal.* (Post-instruction interview)

Again,
I: *Now what type of wave is represented by that?*
S: *Transverse wave?*
I: *Umm?*
S: *Yeo. Longitudinal wave (answers correctly)* (Post-intervention interview)

She was very outspoken and had no hesitation in admitting that she guessed the answer or she did not understand the question.

I: *Then why did you choose this answer.*
S: *Hahaha.. I did not understand the question.*

However, the interactive computer simulations did not have much effect in bringing about remarkable conceptual changes in Siziwe. Her concept on wave motion remains unchanged: *"Wave motion is the disturbance of water".*

5.5.1.4 Variation of responses – Siziwe

Siziwe's response to question 1 changed from C to D (Fig. 5.2) after the computer simulations intervention. She thought that waves carry water or particles. Both the ripple tank demonstrations and computer simulations failed to give Siziwe the idea that waves carry energy. Question 2 (Appendix B) aims to find out whether learners can determine the relative positions of the particles in a wave motion. For this question, Siziwe chose the correct answer before the computer simulations intervention and the wrong one after watching the simulations. This may create an impression that computer simulations give wrong ideas to the learner. However in the post-instruction interview it was revealed that Siziwe did not understand the word 'stationary'.

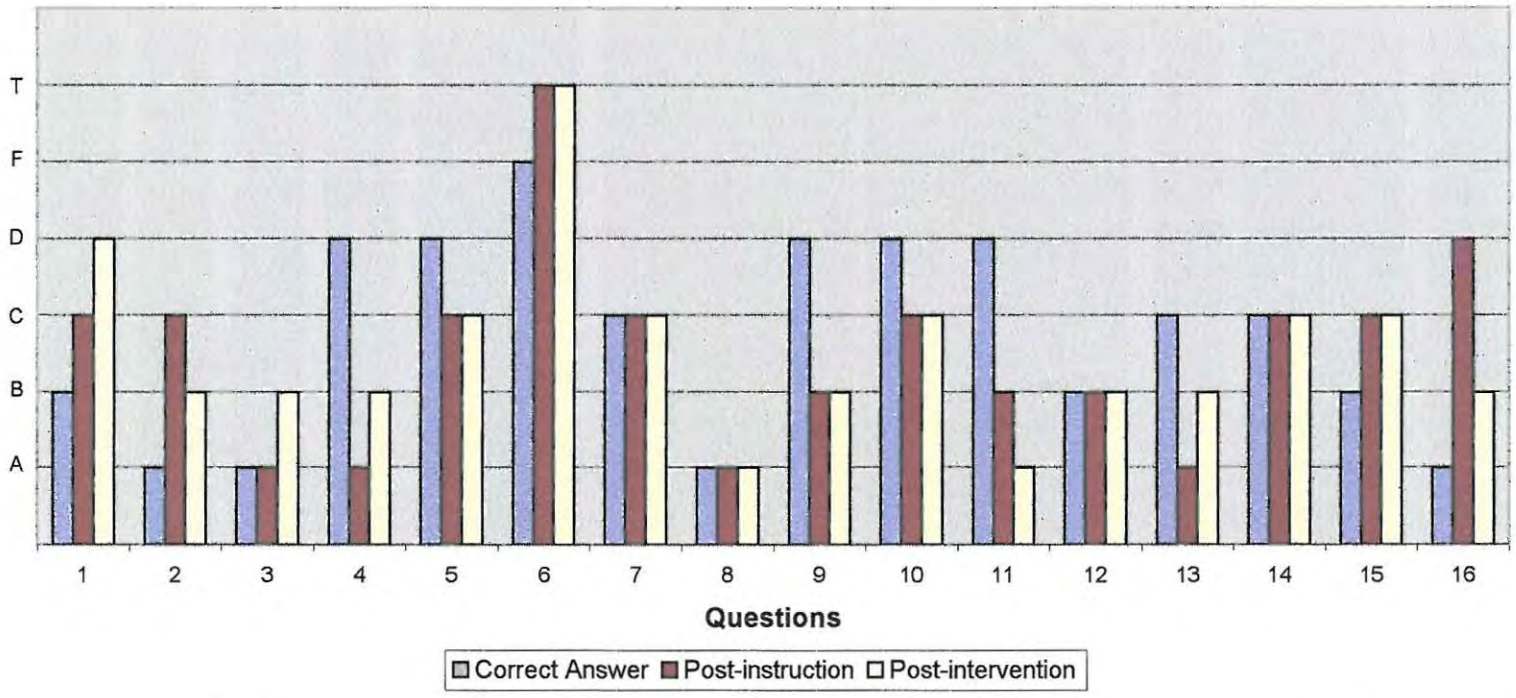
I: *Ok. For the second question, you have answered that the particles remain stationary. Can you tell me why you think so?*
S: *I think it is because I see the waves moving ... in water they don't move.*
I: *What didn't move?*
S: *small things.*
I: *Then what were they doing?*
S: *Moving up and down.*
I: *Ok. Can you say that they remain stationary, when they are moving up and down.*
S: *(No answer)* (Siziwe - Post-instruction interview)

Figure 5.2 shows that for question 13, Siziwe's responses changed from A to B. For answering this question the learners must understand that the wavelength of a wave is the length of a single wave. The total length of three waves is indicated in the diagram (Fig. 3, Appendix B), but not the length of a single wave. Learners must use simple arithmetic to calculate the wavelength. Siziwe could not do this calculation. However, in the post-intervention interview she could identify the wavelength of the wave, but could not calculate it.

I: *Now let us consider question number 13. What is wavelength here?*
S: *(Shows correctly)*
I: *In terms of numbers.*
S: *Here to here.*
I: *But is that given as a choice?*
S: *(Long pause)* (Siziwe – Post-intervention interview)

Structured problems requiring productive thinking were implicitly difficult exercises for Siziwe.

Figure 5.2: Variation of responses - Siziwe



Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correct answer	B	A	A	D	D	F	C	A	D	D	D	B	C	C	B	A
Post-instruction	C	C	A	A	C	T	C	A	B	C	B	B	A	C	D	E
Post-intervention	D	B	B	B	C	T	C	A	B	C	A	B	B	C	D	B

5.5.1.5 Siphokazi

Siphokazi had no idea what a wave was, but she knew what 'amaza' was. She was not familiar with the English terminology 'wave'. But when a clue was given she got the idea what a wave was. She considered wave as 'water moving like snake' and believed that particles in the wave move together with the wave. After attending the lessons she realised that waves carry energy and the particles remain stationary when the wave moves. The concepts of wavelength, amplitude and frequency were well rooted in her mind, but she could not give the right responses to questions involving numerical problems or graphical interpretations. She too like Bulelani and Siziwe was not used to problem solving skills or inductive learning.

I: *Now you know two most important ideas regarding waves in Physics. What are those important ideas, which you have learned?*
S: *They carry particles. They also carry energy.*
I: *So do the particles move along with the wave?*
S: *No.*
I: *Again here, in longitudinal wave does the particle move along with the wave?*
S: *No.*
I: *You are contradicting yourself. Are you not? You said that the waves carry particles and here you say that they just vibrate only. So which is right.*
S: *This one (pointing to a diagram drawn by her showing the vibration of particles)*
I: *Ok. They are not carrying particles. But what do the particles do?*
S: *They vibrate.*
I: *While they vibrate what else do they do?*
S: *They carry energy. (Post-intervention interview)*

Initially, the computer simulations could not convince her that particles do not move with the wave motion. Finally, Siphokazi showed remarkable shift in her conceptualisation of wave motion. According to her wave motion is a disturbance of water and it carries particles and energy. She considers that which bring television pictures also as waves. In her case, I agree with Freyberg and Osborne (1985:83) that frequently new constructions and previously existing ideas in memory will be held simultaneously and over time the status of one view may increase while the other decreases.

5.5.1.6 Variation of responses – Siphokazi

Fig.5.3 shows that Siphokazi selected response C for question 2 (Appendix B) both before and after the computer simulations intervention. It appears that Siphokazi believed that the particles of a medium remain stationary as waves travel along it. Fig.5.3 shows that for question 6 (Appendix B) she considered the statement, "In order for Fani to hear Lungisa, air molecules must move from the lips of Lungisa to the ears of Fani" as true. She ascertained this in the post-instruction interview.

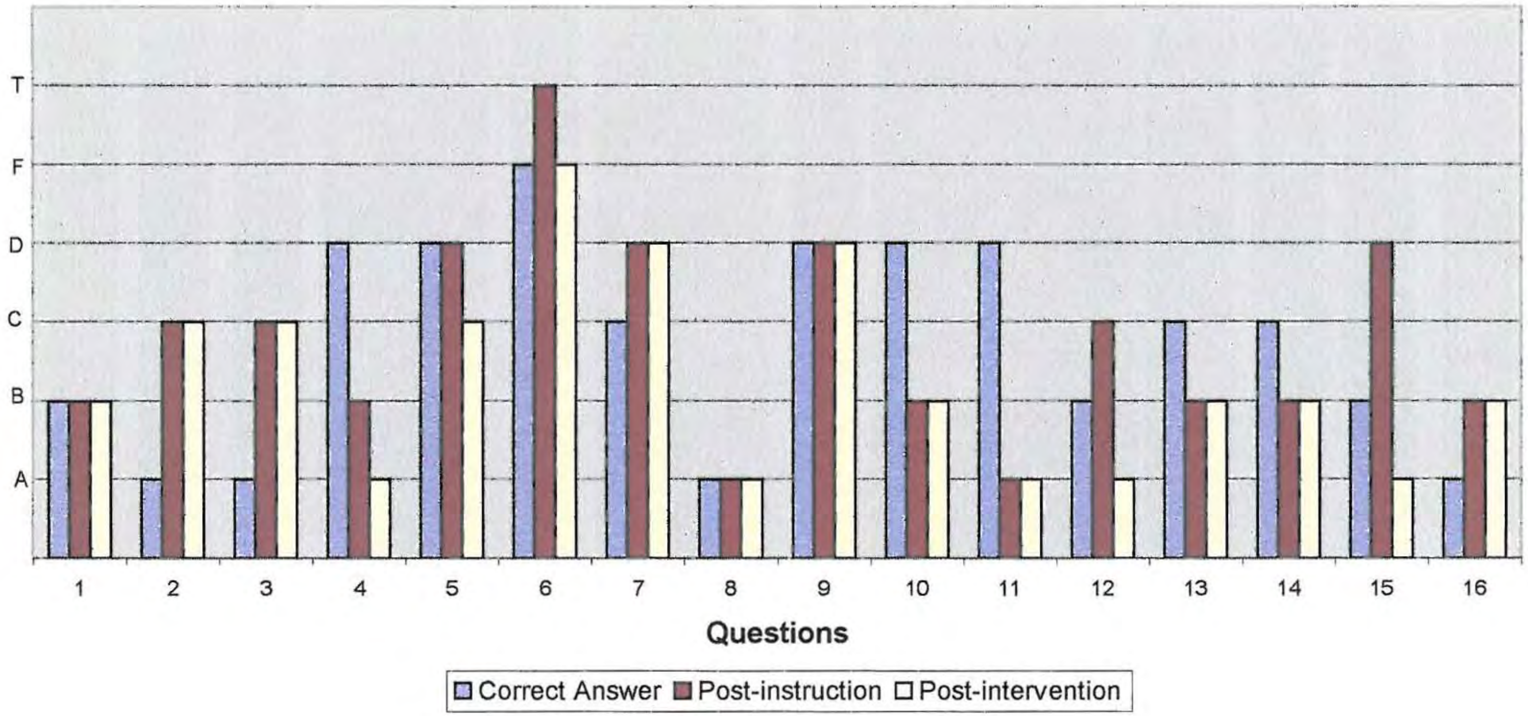
I: *(Reads question number 6). You say that the answer is 'TRUE'. Why do you say so?*
S: *It is because you cannot hear someone if he just say... like if... he must say some word ... sound travels as longitudinal waves. If I told you that I miss you I must see you face to face.*
I: *So you mean that if somebody should hear you, you should see face to face?*
S: *Yes*

(Siphokazi, Post-instruction interview)

However after watching the computer simulations she accepted that the statement in question 6 (Appendix B) was false (Fig.5.3). This shows that the computer simulations helped Siphokazi to realise that particles in a wave motion vibrate. Later in the post-intervention interview she contradicted herself regarding the particle motion in a wave motion and corrected it on further questioning. As in the case of Siziwe, the conceptual change in Siphokazi regarding particle motion in waves was found to be "vacillating between alternative and scientific conceptions from one context to another" during the study (Tao & Gunstone, 1999:859). Their conceptual change was context dependent and unstable.

Both question 9 and 13 (Appendix B) aim to find out the learners' conception of amplitude. Siphokazi answered question 9 correctly both before and after the computer simulations intervention. However, for question 13 she got the wrong answer. This shows that she too like Bulelani, failed to understand the graphical notation indicating the measurement of amplitude.

Figure 5.3: Variation of responses - Siphokazi



Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correct answer	B	A	A	D	D	F	C	A	D	D	D	B	C	C	B	A
Post-instruction	B	C	C	B	D	T	D	A	D	B	A	C	B	B	D	B
Post-intervention	B	C	C	A	C	F	D	A	D	B	A	A	B	B	A	B

5.6 Summary

In general the conceptual changes brought about by interactive computer simulations is summarised below.

Table 5.1: Summary of conceptual changes

Concept	Intuitive notion	Post-instruction	Post-intervention
Energy transmission	Waves are powerful and strong	Waves carry energy	Waves carry energy
Particle motion	Particles move with the wave	Particles do not move with the wave, remain stationary or vibrate	Particles vibrate in a specific direction depending on the kind of waves
Reflection of waves		Could not visualise properly	Could visualise properly
Refraction of waves		Could not be visualise the refraction of waves	Could visualise the refraction of waves, but could not understand the mechanics of it

5.7 A questionnaire to find out the attitude of learners towards learning science

On realising that the learners had difficulty in focussing on relevant observations and arriving at their own conclusions, an additional questionnaire (Appendix C) was designed and administered to explore the familiarity of the learners in laboratory methods and learner-centred teaching strategies.

1. *Are you interested in learning science?*

All the 12 learners who completed the questionnaire conceded that that they are interested in learning science.

2. *Why do you like science?*

It helps me to get a good job	3	25.0%
It is a very interesting subject to learn	4	33.3%
I can go for higher studies in the university	4	33.3%
All of the above	1	8.3%

Two respondents want to know science better.

3. *Have you been to the science laboratory for science lessons before?*

Very often	1	8.3%
Once in a while	1	8.3%
Not at all	10	83.3%

Majority of the learners conceded that they have never been to the science laboratory for science lessons before. The one who responded 'very often' said that he did not read the question carefully. The learner who responded 'once in a while' had attended another school in the past. However, it was not possible for just two learners to attend science lessons in the laboratory while the majority said that they never had been to the laboratory before for science lessons.

4. *Have you done experiments on your own?*

Very often	1	8.3%
Once in a while	4	33.3%
Not at all	7	58.3%

Again, the majority of the learners accepted that they never did experiments on their own. Out of the four who responded 'once in a while', two were learners who had helped with teacher demonstrations and the other two said that they had done simple experiments at home.

5. *Have you seen demonstration of experiments done by your teacher?*

Very often	1	8.3%
Once in a while	3	25.0%
Not at all	8	66.7%

6. *During experiments or demonstrations have you been able to make important observations on your own?*

Very often	0	0
Once in a while	10	83.3%
Not at all	2	16.7%

Here majority of the sample responded that some times they were able to make observations on their own. It was not possible for 83.3% to make observations during experiments or demonstrations while more than 66 % said that they never had seen any demonstration or been to the laboratory for science classes. On questioning the validity of the answers it was found that their responses were in reference to the observations, which they had made during the recent demonstrations done by me.

7. *Have you been encouraged to arrive at your own conclusions from the experiments?*

Very often	1	8.3%
Once in a while	3	25.0%
Not at all	8	66.7%

These responses revealed that the learners were not familiar with either discovery learning or constructivist approach of instruction.

8. *Do you think that experiments help you to understand science better?*

Very often	9	75,0%
Once in a while	3	25.0%
Not at all	0	0%

Majority of the learners believed that experiments or laboratory work would help them to understand science better.

9. How do you learn science?

By doing experiments	5	41.7%
By observing demonstrations by teacher	2	16.7%
By using my textbooks.	2	16.7%
By using notes from teacher	3	25.0%
All of the above	1	8.3%

It was surprising to see that three learners learn by using notes from the teacher. But one among those two uses other methods also. The validity of 41.7% responses saying by doing 'experiments' is doubtful as more than 60% of the respondents earlier said that they had never been to a laboratory for science lessons.

10. How do you like to learn science?

By doing experiments	6	50.0%
By observing demonstrations by teacher	2	16.7%
By using my textbooks.	0	0%
By using notes from the teacher	2	16.7%
All of the above	2	16.7%

It was good sign to see that majority of the learners liked to learn science by doing practical work. Out of the two respondents who preferred notes from the teacher, one had opted for experiments also.

5.7.1 The attitude of learners towards learning science

The data from this questionnaire reveals that the learners possess "intrinsic" motives for learning science. Bruner (1966:174) defines intrinsic motive as one that does not depend on reward that lies outside the activity it impels. So the learners must be eager to learn science. This eagerness must come from the confidence in one's ability to understand the subject (Bruner, 1966). But the eagerness was not demonstrated in the skills of learning science. What could be the reason for that? The answer also hides in the data collected from the questionnaire. The eagerness or will to learn science becomes a problem only under specialised circumstances like those of a school, where a curriculum is set, learners confined, and a particular learning path fixed (Bruner, 1966). Bruner (1966:127) argues that the problem exists not so much in learning itself, but in the fact that what the school imposes often fails to enlist the natural energies that sustain spontaneous learning – curiosity, a desire for competence, aspiration to emulate a model etc. The data obtained from this questionnaire revealed that majority of the learners (83.3%) had never been to a laboratory for science lessons and a considerable number (66.7%) had never seen teacher demonstrations. This showed that the learners are not used to laboratory method or practical work or any learner-centred approaches. But majority of the learners showed their preference to learn science by doing practical work and no one wanted to use textbook as the sole resource for science learning.

5.8 Conclusion

The interactive computer simulations did not do much to change the overall performance of the learners. Generally, the learners were found to be wavering between intuitive notions and scientific conceptions depending on the situation that they were facing. However, the study ascertained that interactive computer simulations proved to be useful in bringing about conceptual changes about the micro level mechanics of wave motion. Computer simulations were a motivating factor in attending the lessons. But once the learners realised that they were not getting the opportunity to use computers on their own they lost interest in the lessons. There were many factors involved in hindering the detection of conceptual change during and after instruction. In addition to the language problem, the lack of explicit experience in problem solving strategies and inductive learning were stumbling blocks in the detection of conceptual changes.

The following excerpt from the post-intervention interview summarises the role of interactive computer simulations in a science class.

I: *What did you see clearly in computer simulation?*
S: *Transverse pulse.*
I: *What did you see clearly in that?*
S: *The movement of particles……. the wave motion.*
Also circular waves… reflected clearly.

(Bulelani, post-intervention interview)

I: *But if I show you a chart with a diagram, is it not enough?*
F: *No.*
I: *Why?*
F: *I don't like that. There you are not going to make them move like a computer*

(Noncedo, post-intervention interview).

CHAPTER 6

RESEARCH FINDINGS

This chapter contains the findings of the study, its limitations, implications of the findings for science education, recommendations for further research and a conclusion.

6.1 Findings

The research was carried out in a natural setting in a previously disadvantaged school with the intention that any findings may be used to inform teachers about the potential use of interactive computer simulations in the instruction and learning of science in the majority of South African schools. The findings are outlined below.

6.1.1 Learners develop intuitive notions

Learners do not come into science classes with an empty mind about what they are going to learn. They bring with them ideas, beliefs and models of natural phenomena, which they have formulated, based on their socio-cultural environment. Not only the natural environment in which the learner lives but also the social environment has an effect in developing intuitive notions about wave motion among learners. For example, the influence of television, in developing intuitive notions of wave motion emerged in the pre-instruction stage.

6.1.2 Conceptual changes through simulations

The study ascertained that interactive computer simulations could bring about conceptual changes to a certain extent in learners. Computer simulations proved to be useful in bringing about conceptual changes about the micro level mechanics of wave motion.

Simulations on wave motion give an experience that produces discord with the intuitive notion that particles move along with the wave. So after using simulations for teaching there was a considerable increase (from 33% to 58%) in the number of learners who believed that particles in wave motion vibrate. In this aspect simulation was found to be useful in producing a positive conceptual change. Again the learners could easily identify the relationship between the direction of travel of the wave or pulse and the direction of particle motion in both types of wave motion. Simulations were useful in demonstrating wave properties like reflection and refraction.

6.1.3 Interactive computer simulations can be used as complementary tools

From this study it emerged that computer simulations are not the answer for all the problems in science teaching, let alone in teaching wave motion. For example, the idea that waves carry energy could not be imparted successfully using the computer simulations that I used. This is in accordance with the claim of Ronen and Eliahu (2000: 25) that simulations should, by no means, replace any activity aimed at experiencing and investigating the real phenomena. Therefore, it is important that learners be given opportunities to experience the real wave motion by means of concrete examples of wave motion through ripple tank experiments although these experiences cannot help the pupils to visualise the particle motion in a wave or the difference in the direction of motion of the particles in the two types of waves. In general, the common demonstrations and teaching experiences facilitated by most science teachers in township schools cannot help learners visualise micro level mechanics of wave motion and momentary situation in a rapidly occurring phenomenon. Theoretical explanations with the help of static models and pictures cannot solve the problems in the conceptualisation of these aspects of wave motion. But interactive computer simulations, which I have downloaded from the Internet, do have the features that are not found in existing teaching tools in most township schools in the Eastern Cape. Interactive computer simulations are animated and the learners can see the micro level mechanics of wave motion. The animation can be stopped to see the instantaneous status of wave motion. Moreover, the simulation can be allowed to take place step-by-step to see the various aspects of interacting waves. Hence these simulations can be used as complementary tools to modify the learners' misconception of wave motion.

6.1.4 Computers can be used as a demonstration tool

It is true that learners must get hands-on experience with computers to benefit from the interactive nature of simulations and similar computer based teaching experiences. It could be argued that it is not possible for a school, which cannot afford basic audio-visual equipment, to buy relatively expensive computers for the learners. Not necessarily. To begin with computers can be used as a demonstration tool in science teaching. The instruction need not necessarily be a teacher mediated one. The teaching strategy can adopt a predict, explore and explain format in which the learners will be asked to predict what will happen if the parameters of a simulation are changed, to explore the changes with the help of the teacher who control the computer and to explain what they have observed. In this way learners can create knowledge of their own and possess the ownership of their knowledge and follow the tenets of constructivism in a way.

6.1.5 Computer simulations can help the learners to focus on the essentials of a concept

Simulation is a visual medium and what it portrays explicitly catches the attention of the learner. Because of that simulations gave learners the idea that waves carried vibration and vibration of particles moved along the medium. It could be argued that the transmission of vibrations transmits energy. However, simulations could not convey the idea that waves carry energy.

6.1.6 Failure of learners to visualise phase difference

Simulations did not produce any effect in changing the learners' ideas regarding the position of the particles after the wave had passed. It was very difficult for the learners to conceptualise the phase of vibration of particles in a wave motion. This supports the view that the concept of wave motion is complex as there is a horizontal as well as vertical component of displacement in it. The inability of the learners to see the difference in the phase of vibration of particles from the simulations could be attributed to the lack of previous experience in laboratory methods of learning.

6.1.7 Mislabelling of concepts

Intuitive notion of a particular concept could be totally different, due to mislabelling, from the actual concept. For example a 'wave' was labelled as a 'cave'.

6.1.8 Conceptualisation of a physical quantity as a mathematical relationship

Learners have a tendency to conceptualise a physical quantity as a mathematical relationship. e.g. Period = 1 /frequency; not as time taken for one complete vibration. This is because learners learn to answer examination questions, especially numerical problems which require a mathematical formula.

6.1.9 Computer simulations and numerical problems

Simulations have no effect on questions involving numerical problems. Standard exercises, which are well defined and narrow in focus, are normally solved with an algorithm using a formula and algebraic manipulation of a number of variables. Structured problems requiring productive thinking are implicitly difficult exercises. The simulations used in this study are not capable of developing higher order problem solving skills in the learners.

6.1.10 Computer – a motivating factor?

The use of a computer in teaching was found to be a motivating factor for the learners. This was reflected in their initial eagerness in the lessons. The learners were somewhat demotivated on finding that they do not get an opportunity to use computers on their own.

6.1.11 Computer simulations and improvement in learner performance

Computer simulations did not produce much improvement in learner performance. Overall, interactive computer simulations raised learners' scores by a mere 0.095 standard deviation (Table 6.1), but the confidence of learners in answering the questions improved, by 1.587 standard deviations (Table 6.2). However, this finding is not a reliable one as other factors might have influenced learners' ability to respond to the tools used to determine their conceptualisation. These are discussed under limiting factors of the study.

	POST-INSTRUCTIONSCORE		POST-INTERVENTION SCORE
	1		2
	2		2
	2		3
	3		3
	3		3
	4		4
	4		4
	4		4
	4		5
	4		6
	5		6
	6		6
TOTAL	42		48
SD	1.381698559		1.477097892
DIFFERENCE		**0.095399**	

Table 6.1: Marks scored

	POST-INSTRUCTIONSCORE		POST-INTERVENTION SCORE
1	47		57
2	58		65
3	54		61
4	32		43
5	40		44
6	37		53
7	46		66
8	52		62
9	56		43
10	41		46
11	58		68
12	48		42
TOTAL	569		650
SD	8.56481527		10.15187697
DIFFERENCE		**1.587062**	

Table 6.2: Confidence rating

6.2 Limiting factors of the study

- One of the weaknesses of the study was the difficulty of finding the conceptual changes through questionnaires and classroom observation as the learners' responses and behaviour were influenced by inadequate experience of a learner-centred approach of teaching. The general questionnaire, which was administered at the end of the intervention, revealed that the learners were not familiar with practical activities or learner-centred teaching.

- The difficulty in expressing ideas in English can make it difficult to detect conceptualisation. Most learners were not conversant with English and hence they had difficulty to comprehend the questions as well as to write definitions or descriptions of a term or concept. Learners might have developed the right concept in their mind, but could not express it due to language problem. Therefore this study concurs with Clerk and Rutherford that "language confusion can be mistaken for misconception" (2000: 703). However as all the learners were not interviewed it was not certain whether all of them had language difficulties. Therefore no attempt was made to adjust the scores of the learners before and after the computer simulation intervention. This was one of the weaknesses of the study which should be attended to in future studies of this nature.

- Again, the descriptive questions in the questionnaire yielded wrong answers while questions with diagrams on the same concept produced more accurate evidence of learners' conceptualisation of wave motion.

- Structured problems requiring productive thinking and logical reasoning are implicitly difficult exercises for the learners. It appeared that the learners were not explicitly exposed to this type of problem analysis.

- As discussed in chapter 5, paragraph 5.5 (6) the inability to understand graphical notations may also be considered as misconception. Hence learners who have difficulty in analysing graphical notations also may not respond to conceptual change strategies.

- Characteristics of learners who use the technology can affect its effectiveness. Learners who are not familiar with instructional technology may be pre-occupied with equipment and apparatus rather than the use of it to make reasonable observations. Rather than concentrating on the important aspects of the simulation, the learners were focussing on the actions taken by the demonstrator with the computer. Computer and the data projector were found to attract the attention of the learners more effectively than the actual simulations. So in many instances the learners were told what to observe.

6.3 Implications of the findings on science education

- Many changes need to be effected in science education in township schools. Teaching styles and methods are to be reviewed. The predominance of textbook or 'chalk and talk' method of teaching in schools must be challenged. Problem solving skills must be developed in the learners and inductive learning must be encouraged. More and more practical work must be ensured.

- Educationists need to be kept abreast of the technological changes and their impact on education. The rapid development of ICT can offer new opportunities and resources for the exploitation of the emerging technology in enhancing the teaching of the sciences and we should exploit these technologies in the training and education of our teachers in both Pre-service Training (PRESET) and In-service Training (INSET). Individual teachers must develop new pedagogical skills and capabilities needed to employ computer-based resources in teaching. They must develop the skills to use the Internet as well as to evaluate and select wisely those computer programs that are suitable for science teaching in their classroom environment.

6.4 Recommendations for further research

Information and Communication Technology (ICT) is capable of providing more active and learner centred education for learners, encouraging teachers to serve as facilitators of learning rather than deliverers of knowledge. More research in South African contexts needs to be done on how to inform and encourage educators about the impact of Information and Communication Technology on teaching and learning. I conclude this report by recommending the following areas for future research.

- The usefulness of computer simulations in other secondary school science concepts.
- The efficacy of using computer simulations as a demonstration tool in other subject areas.
- The efficacy of using computer simulations as a demonstration tool in a guided learning environment.
- A comparison of the effectiveness of Information and Communication Technology among low achieving learners and high achieving learners and/ or learners in disadvantaged schools and learners in model C schools.

- A comprehensive evaluation of interactive computer simulations currently available from the Internet and which are suitable for secondary school science teaching.
- An evaluation of the methods of using Information and Communication Technology in a cost effective way in our schools.
- An analysis of the improvement of learners' self-confidence through the use of ICT.
- An investigation on the motivating factor of computer use in science education: Is the motivating factor genuine or a temporary fascination of a novel instructional medium?
- An investigation on the problems of distraction while using computer simulations.
- An analysis of the confusion in interpreting examination questions containing graphical notations and symbols.

6.5 Conclusion

The study ascertained that interactive computer simulations proved to be useful in bringing about conceptual changes about the micro level mechanics of wave motion. As one of the science teachers in the school said, "the simulations clearly show the movement of particles in the two types of wave motion". This statement was further supported by a group of science and mathematics teachers who were participating in a workshop on the use of computers in education. I had an opportunity to use the same interactive computer simulations that were used in this study for this workshop. All the teachers who used the simulations were impressed by the interactive features of the simulations and agreed that they could be effective in bringing about conceptualisation of wave motion in the learners. I too believe in the capabilities of these simulations in bringing about significant conceptual changes about wave motion in the learners if they are used as complementary tools with the existing tools of wave demonstration.

I hope that this study offers at least one answer to the decision makers who object to the use of Information and Communication Technology (ICT) for teaching and learning in our schools. ICT can be used as demonstration tools to bring about profound conceptual changes in areas of science education where conventional methods of teaching are not adequate.

REFERENCES

Abrahams, E. & Rotchford, K. (2000). *A comparative investigation into the reasons given by financially privileged and underprivileged learners for not registering for science subjects at tertiary level.* In SAARMSE Conference 2000 proceedings: eighth Annual Conference. Port Elizabeth: University of Port Elizabeth.

Alessi, S.M. & Trollip, S.R. (1991). *Computer-based instruction – Methods and development.* (2nd ed.). New Jersey: Prentice Hall.

Ausubel, D.P., Novak, J.D. & Hanesian, H. (1968). *Educational Psychology: A Cognitive View.* (2nd ed.). New York: Holt, Rinehart and Winston.

Barber, S. (1996). *Our students finish bottom of the class in Maths and Science: Shock report on SA schools.* Sunday Times.

Best, J.W. & Kahn, J.V. (1999). *Research in Education.* (7th ed.). New Delhi: Prentice Hall of India.

Blaschke, K., Kissingen, G. B. & Heuer, D. (2000). *Learning Physics with multimedia and experimental-supported workshop instruction.*
Available online: http://gandalf.ipn.uni-kiel.de/projekte/esera/book/allf.htm [2000 July 06].

Boardman, A.D., Cooper, G.S., James, B.W., Keeler, G.J. & Swage, J. (1988). *Software Development for Undergraduates in Physics.* In Kibby, M.R. & Mayes, J. T. (eds.). Computers and Education: An International Journal, 12(1), 29-35. New York: Pergamon Press.

Brink, B. du P. & Jones, R.C. (1985). Physical Science: Standard 8. Ndabeni: Juta.

Bruner, J.S. (1966). *Toward a Theory of Instruction.* London: Belknap/Harvard.

C2005 Review Committee. (2000). *Report of the C2005 Review Committee.* [Online]. Available at: http://www.polity.org.za/govdocs/reports/education/curric2005exec.html. [2000 December 10].

Cantrell, D.C. (1993). *Alternative Paradigms in Environmental Educational Research: The Interpretive Perspective.* In Mrazek, R. (ed.). Alternative Paradigms in Environmental Educational Research. Lethbridge: NAAEE.

Chuang, C. (2000). *The Efficacy of computer-simulated Courseware in Teaching Selected Technological Concepts.* Proceedings of Natural Science Council, Republic of China (D), 10 (2), 51-60.

Clerk, D. & Rutherford, M. (2000). *Language as a confounding variable in the diagnosis of misconceptions.* International Journal of Science Education, 22 (7), 703-717.

Cockburn, P. (1997). *Building a Brighter Future: Curriculum 2005*. Pretoria: Department of Education.

Cohen, L. & Manion, L. (1994). *Research Methods in Education*. (4^{th} ed.). Lndon: Routledge.

Collis, B. & Meeuwsen, E. (1999). *Learning to Learn on a WWW-based Environment*. In French, D., Hale, C.; Johnson, C. & Farr, G. (eds.). *Internet [based] Learning: An Introduction and Framework for Higher Education and Business*. London: Kogan Page Ltd.

de Jong, T., Martin, E., Zamarro, J., Esquembre , F., Swaak, J.& van Joolingen, W.R. (1999). *The Integration of Computer Simulation and Learning Support: An Example from the Physics Domain of Collisions*. Journal of Research in Science Teaching, 36 (5), 597-615.

de Jong, T., van Joolingen, W., Scott, D., De Hoog, R., Lapied, L. & Valent, R. (1994). SMISLE: System for Multimedia Integrated Simulation Learning Environments. In de Jong, T. & Sarti, L. (Eds.). *Design and Production of Multimedia and Simulation –based Learning Material*. Netherlands: Kluwer Academic Publishers.

Denzin, N.K. & Lincoln Y.S. (ed). (1994). *Handbook of Qualitative Research*. California: Sage Publications.

Department of Education. (1997). Norms and Standards for Educators. Pretoria: Department of Education.

Dolby, R.G.A. (1996). *Uncertain Knowledge: An image of science for a changing world.* New York: Cambridge University Press.

Eastern Cape: Department of Education and Culture. (1996). *Physical Science Syllabus: Higher Grade (Standards 8, 9 and 10).*

Edison, S. & Simmons, P.E. (1998). *Microcomputer Simulation Graphic and Alphanumeric Modes: Examining Students' Process Skills and Conceptual Understanding.* Journal of Computers in Mathematics and Science Teaching, 17 (1), 21-61.

Fone, J. (1995). *From the traditional to the democratic classroom.* In McKay, V. A. (Ed.). *Sociology of Educating.* Isando: Lexicon Publishers.

Fraser, J.B. (2000). *Environments for Learning Science and Mathematics.* In SAARMSE Conference 2000 proceedings: eighth Annual Conference. Port Elizabeth: University of Port Elizabeth.

FRD News (1996). *Newsletter of the Foundation for Research Development*, Pretoria. October.

French, D. (1999). *Preparing for Internet-based Learning.* In French, D., Hale, C., Johnson, C. & Farr, G. (eds.). *Internet [based] Learning: An Introduction and Framework for Higher Education and Business.* London: Kogan Page Ltd.

Freyburg, P. & Osborne, R. (1985). *Learning in Science: The implications of children's science.* London: Heinemann.

Government Gazette. Volume 357. No. 16312. Cape Town 1995.

Greene, J.C. (1994). *Qualitative Program Evaluation: Practice and Promise*. In Denzin, N.K. & Lincoln Y.S. (ed). *Handbook of Qualitative Research.* California: Sage Publications.

Hargrave, C.P. & Kenton, J.M. (1999). *Preinstructional Simulations: Implications for Science Classroom Teaching.* Journal of Computers in Mathematics and Science Teaching, 18(4), 47-57.

Hashweh, M. (1988). *Descriptive Studies of Students' Conception in Science. Journal of Research in Science Teaching*, 25 (2), 121-134.

Jonassen, D. (1994). *Thinking technology*. Educational Technology, 34(4), 34-37.

Kalkanis, G. & Sarris, M.M. (1998). *An Educational MONTE CARLO Simulation/ Animation Program for the cosmic Rays Muons and a Protoype Computer-Driven Hardware Display.* Journal of Computers in Mathematics and Science Teaching, 18(1) 61-80.

Kamii, C. (1974). *Pedagogical Principles Derived from Piaget's Theory: Relevance for Educational Practice*. In Golby, M., Greenwald, J. & West, R. (eds). *Curriculum Design.* London: Croom Helm.

Khoo, G.S. & Koh, T.S. (1998). *Using visualisation and simulation tools in Tertiary science education.* Journal of Computers in Mathematics and Science Teaching, 17(1), 5-20.

Kuiper, J. (1998). *Science Education: A Course Manual.* Grahamstown: Rhodes University.

Kuiper, J. (1994). *Student ideas of science concepts: alternative frameworks?* International Journal of Science Education, 16(3), 279-292.

Lunetta, V. & Hofstein, A. (1991). *Simulations and laboratory practical activity.* In Woolnough, B. (Ed.). *Practical Science: The role and reality of practical work in school science.* Philadelphia: Open University Press.

Leedy, P.D. (1992). *Practical research: Planning and Design.* New Jersey: Prentice Hall.

Meighan, R. (1981). *A Sociology of Educating.* (2nd Ed.). London: CassellEducation.

Murphy, E. (1997). Characteristics of Constructive Learning and Teaching. [Online]. Available: http://www.stemnet.nf.ca/~elmurphy/emurphy/cle3.html. [2000, December 10].

Olson, J. (1988). *Schoolworlds/ Microworlds: Computers and the culture of the classroom.* New York: Pergamon Press.

Pena, C.M. & Alessi, S.M. (1999). *Promoting Qualitative Understanding of Physics. Journal of Computers in Mathematics and Science Teaching*, 18(4), 439-457.

Physical Science Syllabus. (1996). Eastern Cape: Department of Education.

Pretorius, C. (2000). *Apply Maths and Science Basics*. In Sunday Times, December17, 2000.

Rogan, J. & Nel, E. *The Rainbow Biology Project*. In SAARMSE Conference 2000 proceedings: eighth Annual Conference. Port Elizabeth: University of Port Elizabeth.

Rogers, E.M. & Wenham, E. J. (1978). *Revised Nuffield Physics: Teachers' Guide- Year 3*. London: Longman Group Limited.

Ronen, M. & Eliahu, M. (2000). *Simulation – a bridge between theory and reality: the case of electric circuits*. Journal of Computer Assisted Learning, 16, 14-26.

Sanger, M.F. & Greenbowe, J.F. (2000). *Addressing student misconceptions concerning electron flow in aqueous solutions with instruction including computer animations and conceptual change strategies*. International Journal of Science Education, 22(5), 521-537.

Schwier, R.A. & Misanchuk, E.R. (1993). *Interactive Multimedia Instruction*. New Jersey: Educational Technology Publications.

SEDL. (1996). *The Practice Implications of Constructivism*. SED Letter 9 (3). [Online]. Available: http://www.sedl.org/pubs/sedletter/v09n03/practice.html. [2000, November 16].

Sewell, B.T. & Burger, B. (1995). *Can Computer Based Education Save Science Education in South Africa*. [Online]. Available: http://www.uct.ac.za/depts/emu/cbe/projects/talk/saarmse1.htm [2000, November 20].

Sirestarajah, R.K. (2000: 526). *Science teaching using low cost equipment.* In SAARMSE Conference 2000 proceedings: eighth Annual Conference. Port Elizabeth: University of Port Elizabeth.

Squires, D. & McDougall, A. (1994). Choosing and Using Educational Software – A Teachers' Guide. London: The Falmer Press.

Tait, K. (1994). Discourse: The Design and Production of Simulation-based Learning Environments. In De Jong, T and Sarti, L. (eds.), *Design and Production of Multimedia and Simulation –based Learning Material.* Netherlands: Kluwer Academic Publishers.

Tao, P. & Gunstone, R. F. (1999). *The process of Conceptual Change in Force and Moton during Computer-Supported Physics Instruction.* Journal of Research in Science Teaching, 36(7), 859-882.

Task Team on Education Management Development. (1996). *Changing Management to Manage Change in Education.* South Africa: Department of Education.

The Virtual Laboratory. (1999). [Online]. Available: http://physicsweb.org/TIPTOP/VLAB/ [2000, July 02].

USAID Education Strategic Team (SO2). (2000). *Scope of Work: Eastern Cape Department of Education Information Technology Initiative.*

Van Maanen, J. (1983). *Reclaiming Qualitative Methods for Organizational Research: A preface.* In Van Maanen, J. (ed.). Qualitative Methodology. London: Sage Publications.

Windschitl, M. & Andre, T. (1998). *Using Computer Simulations to Enhance Conceptual Change: The Roles of Constructivist Instruction and Student Epistemological Beliefs.* Journal of Research in Science Teaching, 35(2), 145-160.

Woolnough, B.E. (1991). Practical Science as a Holistic Activity. In Woolnough, B. E. (Ed.). *Practical Science: The role and reality of practical work in school science.* Philadelphia: Open University Press.

APPENDIX A

PRE-INSTRUCTION QUESTIONNAIRE

Name of Learner: ....

In the following pages you will find a questionnaire to determine what you know about wave motion.

This is not a test or examination. Please read the questions carefully before answering the questions.

Thank you for your time and co-operation.

SUNNY JACOB

PART 1

1. Have you heard of the word 'wave'?

YES	

NO	

2. Where did you come across the word 'wave'?

....

....

3. What is your first thought regarding 'waves'?

....

4. Have you seen waves?

YES	

NO	

5. Where do you see waves?

....

6. Draw a diagram showing the waves.

PART 2 (Reference is made to the waves in the sea and pools)

For the next item in the questionnaire put a ✓ mark against the statement/s that are correct.

7. Suppose you drop a plastic ball into the sea waves. What happens to the ball next?

The ball will be pushed towards the shore ☐

The ball will be pushed out into the sea ☐

The ball will remain where it is dropped. ☐

8. Draw a diagram, showing the motion of the ball using arrows to indicate direction.

9. How can you produce waves in a small pool of water?

....

....

For the next item in the questionnaire put a ✓ mark against the statement/s that are correct.

10. Suppose you drop a plastic ball into the waves in a pool. What happens to the ball next?

The ball will be pushed towards the side of the pool ☐

The ball will be pushed towards the middle of the pool ☐

The ball will remain where it is dropped. ☐

11. Draw a diagram showing the motion of the ball in the waves.

12. Describe wave motion in your own words.

....

....

APPENDIX B

POST-INSTRUCTION/ POST-INTERVENTION QUESTIONNAIRE

Name of Learner: ....

In the following pages you will find a questionnaire to determine what you have learned from the classroom exercises on wave motion.

This is not a test or examination. Please read the questions carefully before answering the questions. Indicate your confidence in choosing the answer by using the confidence rating scale, which is given below each question.

Thank you for your time and co-operation.

SUNNY JACOB

For items 1 –16 in this questionnaire circle the most correct answer from the responses given. Indicate your confidence level in answering the item by using the scale

Very Confident	Fairly confident	Not very confident	Guessing

1. What do waves carry?

   A. vibrations
   B. energy
   C. particles
   D. water

Very Confident	Fairly confident	Not very confident	Guessing

2. What happens to the particles of a medium as the waves travel along it?
   A. vibrate
   B. move along with the wave
   C. remain stationary

Very Confident	Fairly confident	Not very confident	Guessing

3. Zandile sends a pulse from left to right along a rope. How does the position of a point on the rope, before the pulse comes, compare to the position after the pulse has passed?

   A. the same
   B. above
   C. below

Very Confident	Fairly confident	Not very confident	Guessing

4. A transverse wave is transporting energy from east to west. The particles of the medium will move

A. east to west only
B. both eastward and westward
C. north to south only
D. both northward and southward

Very Confident	Fairly confident	Not very confident	Guessing

5. A wave is transporting energy from left to right. The particles of the medium are moving back and forth in a leftward and rightward direction. This type of wave is known as a

   A. mechanical
   B. electromagnetic
   C. transverse
   D. longitudinal

Very Confident	Fairly confident	Not very confident	Guessing

6. TRUE or FALSE? In order for Fani to hear Lungisa, air molecules must move from the lips of Lungisa to the ears of Fani. (*Hint: Sound travels as longitudinal waves)*

TRUE ☐ FALSE ☐

Very Confident	Fairly confident	Not very confident	Guessing

7. In order for a medium to be able to support a wave, the particles in the wave must be

   A. frictionless. B. isolated from one another.

   C. able to interact. D. very light.

Very Confident	Fairly confident	Not very confident	Guessing

Consider the diagram in figure 1 in order to answer questions 8-9.

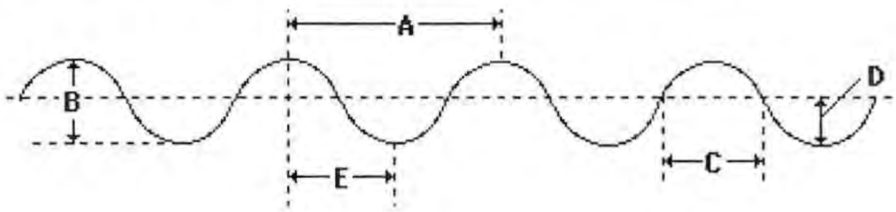


Figure 1

8. The wavelength of the wave in the diagram above is given by letter ______.

Very Confident	Fairly confident	Not very confident	Guessing

9. The amplitude of the wave in the diagram above is given by letter _____.

Very Confident	Fairly confident	Not very confident	Guessing

10. Indicate the interval that represents one full wavelength.

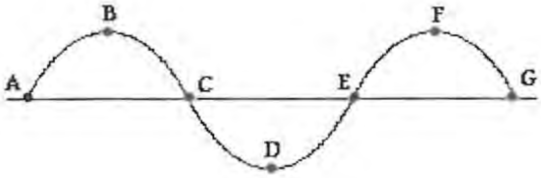


Fig. 2

A. a to c
B. b to d
C. a to g
D. c to g

Very Confident | Fairly confident | Not very confident | Guessing

11. A tennis coach paces back and forth along the sideline 10 times in 2 minutes. The frequency of her pacing is ________.

A. 5,0Hz B. 0,20Hz C. 0,12Hz D. 0,083Hz

Very Confident | Fairly confident | Not very confident | Guessing

12. As the frequency of a wave increases, the period of the wave __________.

A. increases
B. decreases
C. remains the same

Very Confident | Fairly confident | Not very confident | Guessing

The diagram in Fig. 3 represents the pattern of waves with a frequency of 30 Hz travelling from left to right. Answer questions 13 to 15 by referring to Fig.3.

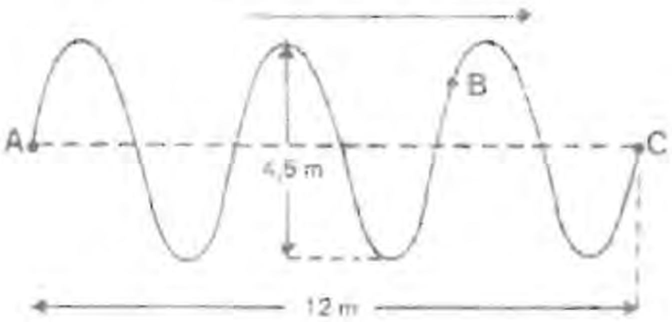


Fig. 3

13. What is the wavelength of the waves?
    A. 12m B. 4,5m C. 4m D. 30m

    Very Confident | Fairly confident | Not very confident | Guessing

14. What is the amplitude of the wave motion?
    A. 12m B. 4,5m C. 2,25m D. 6m

    Very Confident | Fairly confident | Not very confident | Guessing

15. In which direction is point B about to move?

    A. upward B. downward C. to the left D. to the right

    Very Confident | Fairly confident | Not very confident | Guessing

16. The diagrams A –E in Fig. 4 show an instantaneous photograph of a transverse wave on water in a ripple tank. The wave is travelling from left to right. The arrows on the diagram are intended to indicate the direction of motion of the water at the instant the photograph was taken. Which one of the diagram is correct?

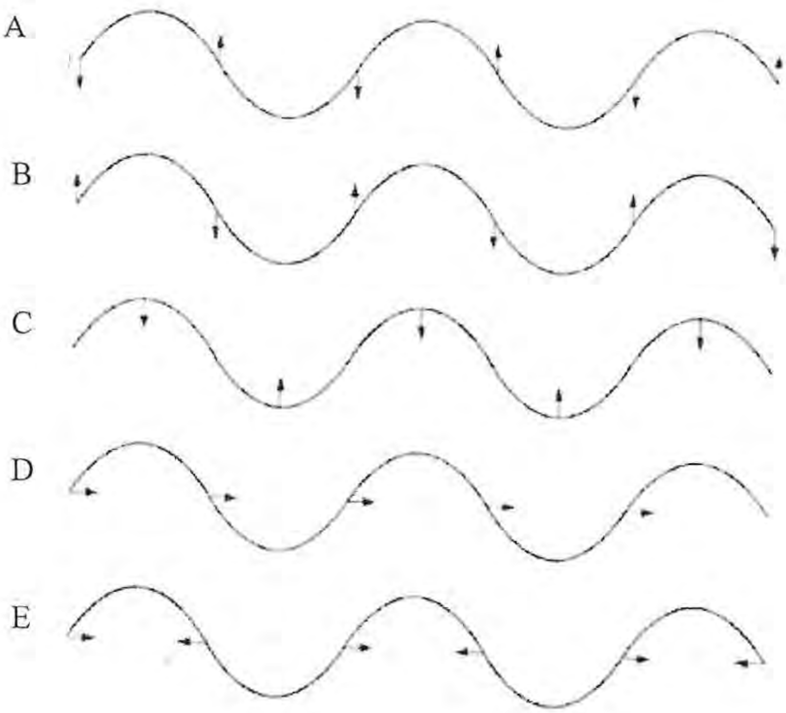


Fig. 4

Very Confident	Fairly confident	Not very confident	Guessing

17. Draw a diagram showing a wave motion.

18. How does 'wave motion' in science compare with wave motion at a beach?

....

....

19. What causes wave motion?

....

....

20. Describe wave motion in your own words.

....

....

....

APPENDIX C

A QUESTIONNAIRE TO FIND OUT THE ATTITUDE OF LEARNERS TOWARDS LEARNING SCIENCE

Name of Learner: ....

In the following pages you will find a questionnaire to find out your attitude towards learning science.

This is not a test or examination. Please read the questions carefully before answering them.

Thank you for your time and co-operation.

SUNNY JACOB

APPENDIX C

1. Are you interested in learning science?

YES	

NO	

If your answer to question 1 is 'NO' proceed to question 2. If your answer to question 1 is 'YES' proceed to question 3.

2. Why don't you like learning science?

I do not understand science	
It is not an interesting subject to learn	
There is no use in learning science	
All of the above	

Any other reasons:

....

....

3. Why do you like science?

It helps me to get a good job	
It is a very interesting subject to learn	
I can go for higher studies in the university	
All of the above	

Any other reasons:

....

....

4. Have you been to the science laboratory for science lessons before?

Very often		Once in a while	
Not at all			

5. Have you done experiments on your own?

Very often		Once in a while	
Not at all			

APPENDIX C

6. Have you seen demonstration of experiments done by your teacher?

Very often		Once in a while	
Not at all			

7. During experiments or demonstrations have you been able to make important observations on your own?

Always		Some times	
Not at all			

8. Have you been encouraged to arrive at your own conclusions from the experiments?

Always		Some times	
Not at all			

9. Do you think that experiments help you to understand science better?

Always		Some times	
Not at all			

10. How do you learn science? (Tick whichever is applicable)

By doing experiments	
By observing demonstrations by teacher	
By using my textbooks.	
By using notes from teacher	
All of the above	

11. How do you like to learn science? (Tick whichever is applicable)

By doing experiments	
By observing demonstrations by teacher	
By using my textbooks.	
By using notes from the teacher	
All of the above	

VIBRATIONS

1. Define vibration

....

....

2. Using the sketch, and the letters A, B and C describe
   i. one complete vibration of the pendulum.
   ii. amplitude of the pendulum

(i) ....

....

(ii) ....

....

3. **To find out the time taken by one complete vibration**

Trial	Time for 10 vibrations
1	
2	
3	
4	
5	
Total	
Average	

Time for one vibration = ...

This is called the .... of the pendulum

4. Calculate the number of vibrations per second.

Time for 1 vibration = ...

Number of vibrations per second = ...

This is called the **frequency** of vibration.

5. To find out the mathematical relationship between frequency and period

Frequency of vibration	Period of vibration
5 Hz	Time for 1 vibration =
10Hz	
20Hz	
30Hz	

Period = ...

6. What is meant by amplitude of a pendulum?

....

....

7. Define period of vibration

....

....

8. Define frequency of vibration

....

....

9. What is the mathematical relationship between frequency and period

....

Pulses and waves

Answer the following questions (1 to 3) based on the classroom demonstration 1.

1. In what direction does the pulse travel?

....

2. Describe what happens at point B.

....

3. What can you conclude about the **displacement** of a point in the spring and **the direction of propagation** of the pulse in this demonstration?

....
....
....

Such a pulse is called .... pulse.

4. The dotted line given below represents a rope in its rest position.
   (a) Draw a transverse pulse between A and C, which originates from a disturbance at A.
   (b) Indicate on your sketch:
      i. The amplitude (maximum displacement)
      ii. Direction of propagation
      iii. A point X on the rope moving away from the rest position
      iv. A point y on the rope moving towards the rest position

A -- C

The questions 5 to 7 are based on demonstration 2.

5. In what direction does the pulse travel?

....

6. Describe what happens at point B.

....

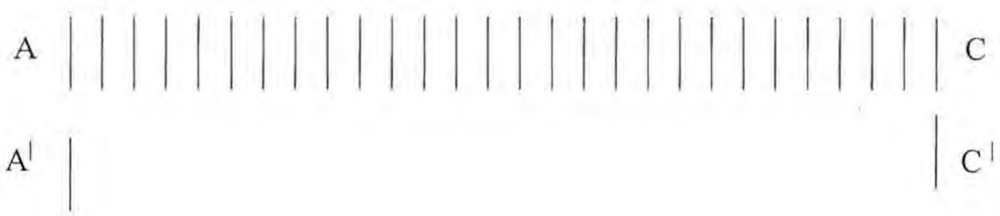
7. What can you conclude about the displacement of a point in the medium and the direction of propagation of a pulse in this demonstration?

....

....

Such a pulse is called .... pulse.

8. AC represents the coils of a slinky spring at rest. Show in $A^{|}C^{|}$ where the coils would be if a longitudinal pulse were travelling from $A^{|}$ to $C^{|}$



9. Define transverse pulse

....

....

10. Define longitudinal pulse

....

....

APPENDIX D

RIPPLE TANK OBSERVATIONS

Demonstration 1: Reflection

Complete the following diagrams (fig.1 and Fig.2) and answer the questions after observations have been made using ripple tank.

1.1 Reflection of circular waves by a straight barrier

(a) Indicate on the diagram
   i. Reflected waves
   ii. Apparent "source" of reflected waves

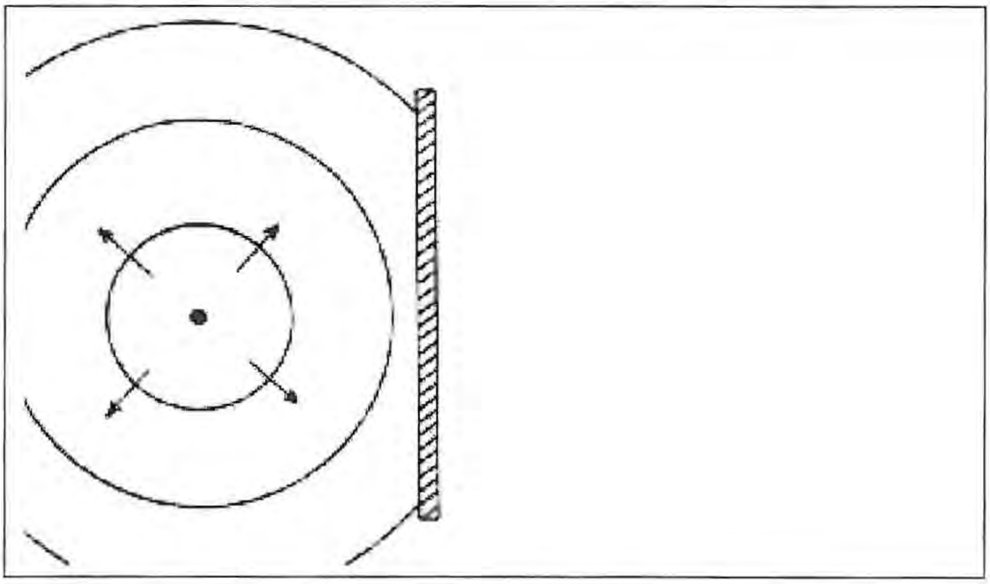


Fig.1

Where is the apparent "source" in relation to the real source of the waves? Describe the position exactly.

....

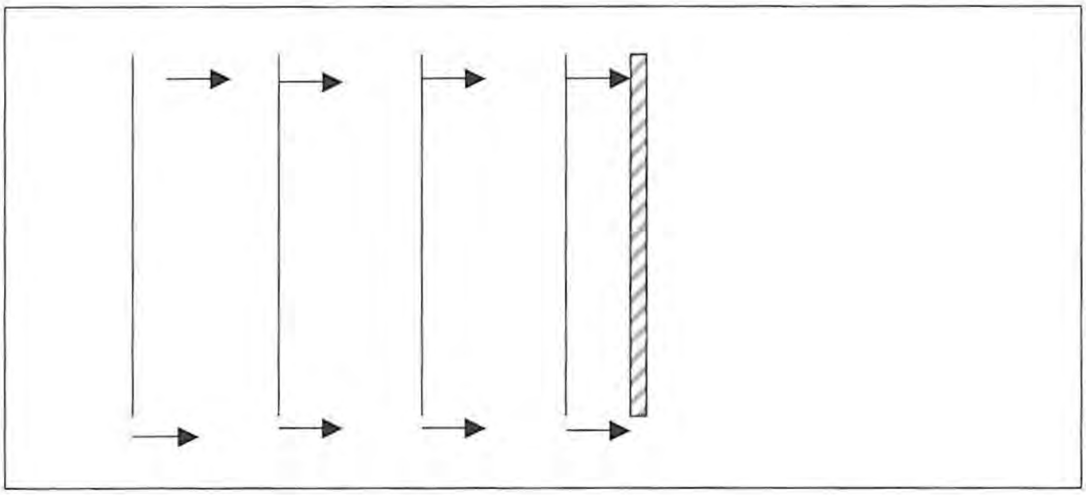
....

APPENDIX D

1.2 Reflection of waves by a straight barrier

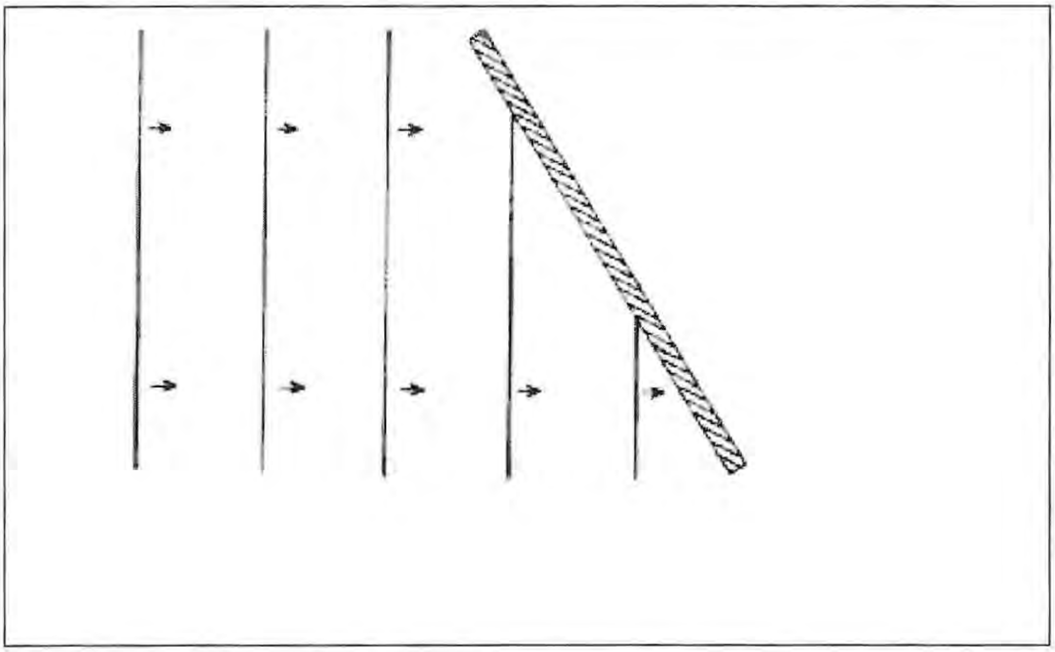
A. Barrier parallel to oncoming wavefronts

Draw the reflected waves on the following diagram



B. Barrier at an angle to the oncoming waves

Draw the reflected waves on the diagram

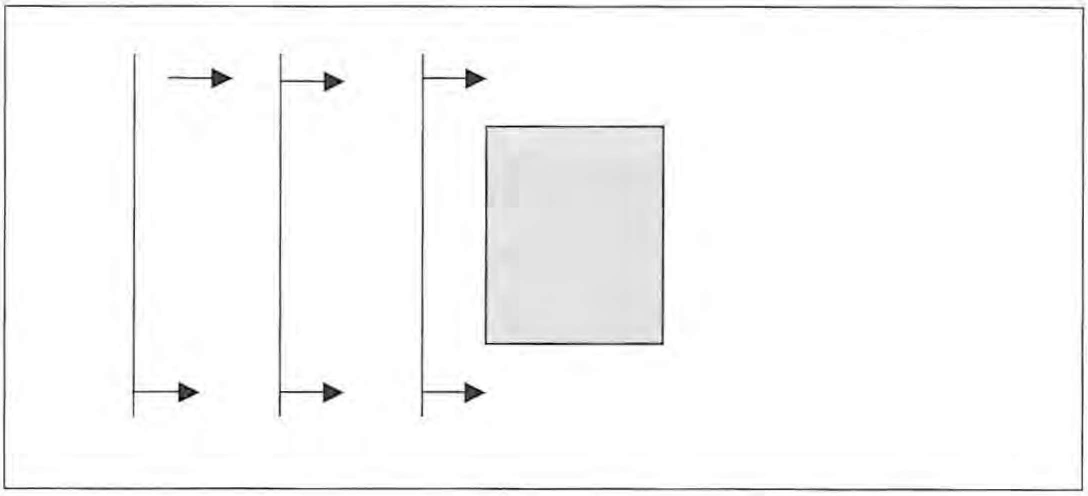


APPENDIX D

Demonstration 2: REFRACTION

A glass plate is placed in the ripple tank so that the water over it is shallower than that surrounding it.

A. Place the plate parallel to the oncoming wavesfronts



Compare the waves travelling through deep water with those crossing the glass plate and answer the following questions.

Does the frequency of the wave change?

YES		NO	

Does the wavelength of the wave change?

YES		NO	

Does the speed of the waves change?

YES		NO	

Explain your answer in terms of the relationship $v = f\lambda$

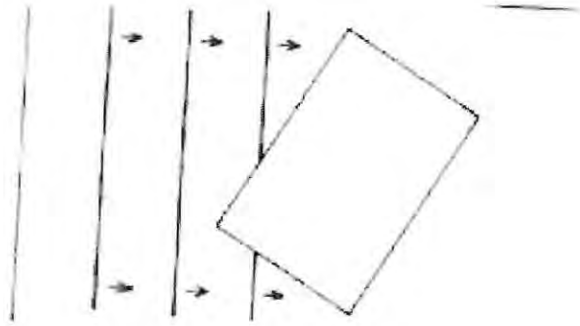
....

....

....

APPENDIX D

B. The glass plate is placed obliquely to the oncoming waves



What is the name given to the phenomenon you observe?

....

....

APPENDIX D

SIMULATIONS OF WAVES

1. When the length of the pendulum increases, its period ……………..(increases/ decreases)

2. When the length of the pendulum decreases its period ……………..(increases/ decreases)

3. What is called the amplitude of the pendulum?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

4. What is a pulse?

…………………………………………………………………………………………………

5. How is a pulse formed?

…………………………………………………………………………………………………

(After demo. 1)

6. Using lines with arrowheads show the direction of travel of the pulse and the direction of motion of the particles of the medium

----

This is called a ……………………………………pulse

(After demo. 2)

APPENDIX D

7. Using lines with arrowheads show the direction of travel of the pulse and the direction of motion of the particles of the medium

----

This is called a ....pulse

8. The dotted line given below represents a rope in its rest position.
   (a) Draw a transverse pulse between A and C, which originates from a disturbance at A.
   (b) Indicate on your sketch:
      i. Direction of propagation
      ii. A point X on the rope moving away from the rest position
      iii. A point y on the rope moving towards the rest position

A --

C

9. What are waves in terms of pulses?

....

10. How are waves formed?

....

11. What do particles in a medium do as a wave travels along it?

....

12. What is the amplitude of a wave?

....

APPENDIX D

13. Draw a diagram showing the wave motion in demo 3 and name the type of wave formed.

14. Draw a diagram showing the wave motion in demo 4 and name the type of wave formed.

15. What is called the wavelength of a wave?

....

16. What is called the frequency of a wave?

....

17. The dotted line given below represents a rope in its rest position.

(c) Draw a transverse wave between A and C, which originates from a disturbance at A.

(d) Indicate on your sketch:

i. Direction of propagation
ii. A point X on the rope moving up away from the rest position
iii. A point y on the rope moving down towards the rest position
iv. A point z on the rope moving down away from the rest position
v. The maximum amplitude of the wave

A -- C

APPENDIX D

18. What are called crests of a wave?

....

19. What are troughs?

....

20. What is called the amplitude of a wave?

....

21. What is the wavelength of a wave?

....

For questions 22 and 23 fill in the blanks

22. The crests of a transverse wave can be compared to the ....of a longitudinal wave.

23. The troughs of a transverse wave can be compared to the.................of a longitudinal wave.

For questions 24 to 27 circle the most correct answer

24. If the wavelength is kept the same and we increase the frequency of a wave, the speed of the wave ....

A. increases B. decreases C. remains the same

25. If the wavelength is kept the same and we decrease the frequency of a wave, the speed of the wave ....

A. increases B. decreases C. remains the same

APPENDIX D

26. Keeping the velocity the same, if we increase the wavelength of a wave its frequency ....

    A. increases   B. decreases   C. remains the same

27. Keeping the velocity the same, if we decrease the wavelength of a wave its frequency ....

    A. increases   B. decreases   C. remains the same

28. What does the term wave mean? Briefly describe.

....

....

....

....

....

APPENDIX E

EXTRACT OF SYLLABUS

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
2.1 Waves	Time allocation 3 weeks (10%)	
2.1.1 Vibrations The concept of regular repetitive motion and the terms frequency and period. 2.1.2 Pulses The transmission of a single transverse and a single longitudinal pulse along a spiral spring. The transmission of a succession of pulses along a spiral spring.	This serves as an introduction to wave motion.	2.1.1 Demonstrate regular repetitive motion with the aid of a pendulum. Determine period and frequency [D] 2.1.2 Demonstrate the transmission of (a) a single transverse pulse (b) a single longitudinal wave on a spiral spring [D]
2.1.3 Transverse Waves The formation of a transverse wave. The graphical representation of a transverse wave. The terms wavelength, amplitude and speed of the waves. The relationship between, speed, wavelength and frequency: $v = f\lambda$	The concept of transverse wave should be developed. Simple calculations involving $v = f\lambda$	2.1.3 Demonstrate the transmission of (a) a succession of transverse pulses (b) a succession of longitudinal pulses along a spiral spring
2.1.4 Longitudinal Waves The transmission of a succession of longitudinal pulses along a spring. The representation of a longitudinal wave motion as compressions and rarefactions.	This leads to the concept of longitudinal wave motion. The relationship $v = f\lambda$ is also applicable to longitudinal waves.	
2.1.5 The propagation, reflection, refraction and interference of waves	Illustrate concepts using water in a ripple tank or other suitable apparatus	The propagation, reflection, refraction and interference of water waves using suitable apparatus (e.g. a ripple tank) [D]

DEMONSTRATIONS MENU

DEMO 1: PENDULUM
http://www.cath-mem.org/physics/java/pend1/index.html

DEMO 2: PULSES & WAVES
http://www.cath-mem.org/physics/Wave.htm

DEMO 3: TRANSVERSE PULSE & WAVE
http://members.nbci.com/surendranath/Twave/Twave01.html

DEMO 4: LONGITUDINAL PULSE AND WAVE
http://members.nbci.com/Surendranath/Lwave/Lwave01.html

DEMO 5: TRANSVERSE WAVE & LONGITUDINAL WAVE
http://wigner.byu.edu/WaveTrans/WaveTrans.htm

DEMO 6: LONGITUDINAL & TRANSVERSE WAVES TOGETHER (COMPRESSIONS& RAREFACTIONS)
http://member.aol.com/nicholashl/waves/movingwaves.html

DEMO 7: WAVE PARTS
http://id.mind.net/~zona/mstm/physics/waves/partsOfAWave/waveParts.htm - pictu

DEMO 8: WAVE PROPERTIES
http://id.mind.net/~zona/mstm/physics/waves/introduction/introductionWaves.html

DEMO 9: CIRCULAR WAVES
http://member.aol.com/nicholashl/waves/circularwaves.html

DEMO 10: REFLECTION: CIRCULAR WAVES
http://member.aol.com/nicholashl/waves/circular_reflection.html

DEMO 11: REFLECTION: PLAIN WAVEFRONTS
http://member.aol.com/nicholashl/waves/reflection1.html

DEMO 12: REFRACTION
http://member.aol.com/nicholashl/waves/refract1.html

APPENDIX G LEARNERS WHO PARTICIPATED IN THE RESEARCH STUDY

NO	**SURNAME**	**NAME**
1	BACELA	ASANDA
2	BOOI	BULELANI
3	DUKASHE	DOTWA
4	KONDO	NOKUTHEMBELA
5	MAZLENI	LUNGISA
6	MDABASE	KHANYISA
7	MFULANA	WENDY
8	MHLAKAZA	KHAYALETHU
9	MNGOMA	LINDIWE
10	MNGXASO	ZANDILE
11	MNGXE	LUSANDA
12	MNYANDA	THNDUXOLO
13	MONDI	SIZIWE
14	MQIKELA	BONGO
15	NBANE	SIPHOKAZI
16	NONCEDO	FANI
17	ZIYABULELA	LIMBA