TEACHER SUPPORT FOR THE USE OF MBL IN ACTIVITY-BASED PHYSICS TEACHING IN TANZANIA

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IN ACTIVITY-BASED PHYSICS TEACHING
IN TANZANIA

PROEFSCHRIFT

ter verkrijging van
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Preface

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Frank Tilya

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CHAPTER 1
Introduction

This chapter introduces the study on "Teacher Support for the Use of MBL in Activity-based Physics Teaching in Tanzania" by presenting the contextual information about the study. Section 1.1 introduces the country by describing the geography, economy and educational system of Tanzania. Section 1.2 gives a picture of the problems facing the country's secondary science education. Section 1.3 depicts the reality of introducing computers to the Tanzanian education. Also briefly elucidated are the potential as well as some of the problems of using computers in science education. The Teacher Education Assistance in Mathematics and Science (TEAMS) project, its purpose and relation to the study are summarised in section 1.4. An overview of what the study aims at, and a preview of the dissertation are explained in sections 1.5 and 1.6 respectively.

1.1 TANZANIA: GEOGRAPHY, ECONOMY, AND EDUCATION SYSTEM

1.1.1 Geography

The United Republic of Tanzania is located in the eastern part of the African continent. Tanzania (Tanganyika) shares its borders with eight other countries. Kenya and Uganda are to the north, Rwanda and Burundi to the Northwest, The Democratic Republic of Congo to the west, Zambia and Malawi to the Southwest and Mozambique to the southern part. The Indian Ocean lies to the east of the country, where the islands of Zanzibar, Pemba and Mafia are situated (see figure 1.1). The United Republic of Tanzania includes the islands of Zanzibar, Pemba and Mafia. Zanzibar and Pemba are about 45km off the coast to the Northeast of the mainland part of the country. Tanganyika gained independence from the United Kingdom in 1961. In 1964, Tanganyika joined with Zanzibar, which had been a British protectorate until 1963, and became Tanzania. The country covers an area of 945,087 square km. with a population of 32.8 million (2001 estimates) and population density of 29.9 per square km.
The Tanzanian climate varies from tropical along the coast to temperate in the highlands. The terrain is also variable, with plains along the coast; a central plateau; and highlands in the north and south. The country has extreme elevations with its lowest point being at the Indian Ocean which is 0 m, and the highest point being Mount Kilimanjaro, which is 5895 m above the sea level (MAPS, 2000).

1.1.2 Socio-economic situation

Today a democratically elected government rules Tanzania. The country is divided into 25 administrative regions (20 in the mainland and 5 in Zanzibar), with regions ruled by regional commissioners. Since political power is vested in the central government, the system of government and decision-making is centralised. Currently, the population is estimated to be slightly more than thirty-two million people with an annual growth rate of 2.6%. Close to 46% of the population is less than 15 years of age. Approximately 85% of Tanzanians live in rural areas. The official languages are Kiswahili and English with the latter being the official written language and the medium of instruction used in the secondary schools and higher education (URT, 2002).
The economy is heavily dependent on agriculture, which accounts for 56% of GDP, provides 85% of the country’s exports, and employs 90% of the work force. Topography and climatic conditions, however, limit cultivated crops to only 4% of the land area. Industry accounts for 15% of the GDP and is mainly limited to processing agricultural products and light consumer goods. The economy is currently in transition from a state-controlled system to a market economy. The economic recovery programme announced in mid-1986 has generated notable increases in agricultural production. Financial support for the programme has come largely from bilateral donors. Growth from 1991 to 98 featured a pickup in industrial production and a substantial increase in output of minerals, led by gold. Recent banking reforms have helped to increase private sector growth and investment. The annual economic growth rate was estimated to be 5.2% in 2002 (URT, 2002).

However, Tanzania is going through a difficult time. The economy is deteriorating. Unemployment is increasing through layoffs from former state-owned institutions. There is an ever-increasing flow of children leaving school in favour of finding jobs. Finally, there are increasing signs of social unrest, and the tragic impact of AIDS.

1.1.3 Educational system

The formal educational system in Tanzania is predominantly academic and is hierarchically divided into three different levels, which are primary, secondary, and tertiary. The existing structure (see figure 1.2) of the formal education system is 7-4-2-3+, that is 7 years of primary education, 4 years of secondary education at the Ordinary level, 2 years of secondary education at the Advanced level and a minimum of 3 years of university education. Infants and young children (0-6 years old) are cared for and receive initial education both at home and in few existing day-care centres, kindergartens, nursery-schools and other pre-schools located mostly in urban areas.

Primary education is compulsory in enrolment and attendance, but not enough schools are available to accommodate all children. Only 66% of eligible children are enrolled in schools. Primary education is the main delivery system for basic education of children, outside the family. Its purpose is to prepare every citizen to continue on the unending journey of lifelong education, training and learning processes (URT, 2002).
Primary education was made free immediately after the country's independence, which caused a rapid expansion of primary school education and made it impossible for a number of available teachers to provide specialised assistance to needy children. Private tutoring became more common in the early eighties after affluent parents discovered that primary schools were no longer providing quality education for their children. This trend did not end there. In the nineties private primary schools started mushrooming as well in all urban areas.

Primary education is terminal for the majority of those who leave primary school. At the very end of the seventh year, which is Standard VII, the students sit for a national exam, which in actuality is used for selecting less than 20 percent of those students to pursue secondary education in government sponsored schools. The students who fail this exam have the option of joining a private secondary school, depending on the will of the individual, and the financial status of the family. Around 80 % of those who finish primary school are not selected for secondary or any other form of further education.

![Figure 1.2: Tanzania Educational System](image-url)
Secondary education refers to post-primary formal education offered to persons who have successfully completed seven years of primary education and have met the requisite entry requirements. Secondary education is subdivided into ordinary level (Forms 1 to 4) and advanced level (Forms 5 and 6). Students who complete O-level secondary education can go on to the next stage of A-level secondary education, or they can pursue vocational training, professional training or join the labour market. Those who complete A-level secondary education join either tertiary or higher education and training institutions or join the workforce. Secondary education is no longer completely free. Parents are obligated to contribute some money toward educational costs.

Private secondary schools are part of the education system. In this case parents have to pay for everything involved in education. The students in these schools come from two sources. One source is those who finished primary school but couldn't secure a place in a government school and whose parents are willing to pay for their education. The second group is comprised of students who secured admission in government schools but whose parents are not satisfied with the services and the expected final performance in government schools. The second group is not large but private secondary schools generally outperform government secondary schools in their final exams. There are two types of private secondary schools- a few are relatively well endowed schools, but the majority are quite poor and are often in even worse shape than public schools.

Tertiary and higher education and training encompasses all post O-level secondary education leading towards a certificate, academic diploma, or a degree. All degree courses, which in most cases are undertaken by those who successfully completed A-level, assume a minimum of three years, and lead to a bachelors’ degree. Other post A-level education leads to a diploma after completing two years of training.

In addition, there are vocational and technical schools for those who completed O-level education and for adults. These schools provide young people and adults with the opportunity to acquire skills in production, service, entrepreneurship and small business management. The schools prepare them to create work and employ themselves or access available job opportunities.
The teacher is the most important player in education and training. Teachers are educated at teacher colleges. Most of the colleges offer certificates for primary school teachers who have completed ordinary level secondary education. Some colleges train and teachers who have completed advanced level secondary education and most of these teach O-level secondary schools. Most of the university educated teachers go on to teach in A-level secondary schools, though a few specialise in adult, child and special education. Teacher education focuses on producing teachers who can guide students in their learning experiences and interaction with the content of the curriculum and who can promote student initiatives and readiness for their own learning.

Teaching and learning of science advances with the level of education. In primary school, students are taught general biology, chemistry, and physics in combination. These sciences are not taught in depth at this level and students only learn about the basic concepts of each subject. When a student reaches O-Level, the sciences are separated into biology, chemistry, and physics, which are taught as different courses. Students learn theory and start to do a bit of complex hands-on activity. This trend continues in A-level but the science becomes more complex and students do more practical work.

To facilitate shared learning among teachers, the government has established teacher resource centres (TRCs). These resource centres were established with the aim of enabling teachers to share among themselves, whether it be ideas or other useful teaching resources in a workshop environment or on an individual basis. Each administrative region has at least one TRC to support secondary school teachers and many more for primary school teachers. The centres may be located in a school or other accessible place where many teachers can meet at one time. The management and financing of the TRCs is a bit tricky as many organisations are involved. Some of the TRCs are very active and others are dormant depending on activities, financing and leadership. Among other activities, the TRCs are supposed to be places where in-service training for teachers takes place; a place where resources to be shared are stored, and made accessible and available to all potential users. Some TRCs get support from government institutions such as the University of Dar es Salaam and Teacher Training Colleges, to run in-service training and sometimes provide teaching materials. For example, the University of Dar es Salaam, through donor support, runs in-service training in some TRCs for secondary school science
teachers and sometimes produces support materials to improve teaching and learning of science.

Apart from TRCs, there are other institutions that play an important role in the education sector. The Tanzania Institute of Education (TIE) for example is responsible for many educational activities, the most important of which is curriculum development for both primary and secondary education as well as Teacher Colleges. In addition to curriculum development, the institute produces curriculum materials such as textbooks that accompany the curricula.

Another institution that plays a key role in the educational sector is the National Examination Council of Tanzania (NECTA). The main task of the council is to set examinations that correspond to the curriculum. The council gives all final examinations for primary and secondary schools, as well as Teacher Colleges. The council consists of members of academia from higher learning institutions, schoolteachers and the Ministry of Education and Culture (MoEC). TIE and NECTA are both under the Ministry of Education and Culture, but are operationally independent.

Tanzania's educational system is slowly improving, but it still has its problems. Economically and technologically Tanzania is struggling. Steps being taken to fix these problems include the Education Sector Reform Programme and the government placing a greater emphasis on science education. Cultural aspects of Tanzania must also be considered as variables that influence this country's education. Among these are the status of women, and the variety of ethnic groups. As Tanzania's educational system continues to develop the country's education will progress.

1.2 PROBLEMS WITH SECONDARY SCIENCE EDUCATION IN TANZANIA

1.2.1 Teaching and learning problems

The essence of teaching is to bring about a change in the behaviour, attitude and thinking of the learner. The teaching approach that the teacher adopts in order to bring about this change is very important. The traditional teacher-centred lecture (chalk and talk) approach, which emphasises the transfer of knowledge and skills and rewards memorisation, is the predominant teaching format in Tanzanian
secondary schools as well as in most of the sub-Saharan countries (Chonjo, Osaki, Possi & Mrutu, 1996; de Feiter, Vonk & van den Akker, 1995). In this approach, the teacher talks most of the time, while students take down notes, mainly for the purpose of passing examinations. This method does not allow much room for critical analysis of issues, but rather enables students to return facts to the sender. In this teaching approach, there is very little interaction between the teacher and the students or among the students themselves in the classrooms. Students hardly ask any questions and the teachers rarely provoke students into asking critical questions. Though the approach has obvious pedagogical merits such as being an efficient means of conveying a body of information when there is too little printed material, or the teachers' ability to control the direction of content in the classroom (Blight, 1997), this is not always the reason behind the teachers' choice to lecture. Rather, the decision is quite often a default option chosen in part because it is familiar and in part because it gives the teacher control.

A study done to learn more about the situation of science teaching in Tanzania revealed that most teachers used transmission (chalk and talk) rather than interactive, learner-centred pedagogy. Teachers were seen to be authoritative, dogmatic and inflexible (Chonjo et al., 1996). Their teaching emphasis in lectures was to convey science content, and in some cases technical training for acquiring practical skills. The problem is furthered by the cultural belief system in which teachers are regarded as elders and are to be respected and not challenged by students.

In another study, Osaki (1999) found that in many schools, pupils read teachers' notes instead of textbooks, and hence teachers are the main source of information and knowledge. The students may have textbooks, but choose to rely on teachers' notes. These notes often encourage rote learning in order to pass examinations. The use of the textbook by pupils for reference and homework is not always effective, especially for those in form one and two. Although pupils bring textbooks into class, teachers rarely gave any tasks requiring them to make use of the textbook during the lesson. Some students may read the textbooks regularly but when reviewing for tests and exams they revert to reading the teachers' notes (Osaki, 1999). In the classroom, science is usually presented as a rigid body of facts, theories, and rules to be memorised and practised, rather than a way of thinking about and understanding natural phenomena. Research on students' conceptions of scientific topics has
convincingly demonstrated that students exposed to this approach often end up with only a superficial understanding of scientific concepts. Such approaches are only successful for tasks that demand rote memorization; but have not been shown to be effective for teaching higher-order thinking and problem solving (e.g. Anderson, 1997; Saunders, 1992). The problem is further aggravated by the fact that most teachers still take a very academic approach to practical work and seemed unable to use the local environment familiar to the students in the context of their lives (Knamiller, Osaki & Kuoga, 1995). Knamiller et al. (1995) further noted that schools are hardly able to provide children with the experience to generate and test hypotheses, let alone to recognize variables and manipulate them. There are many reasons for this including the following:

(i) Children are rarely given the opportunity to conceptualise the basic philosophy of the scientific method used by scientists. Instead they study science blindly, out of context, and with one main goal, to pass examinations.

(ii) Children rarely do experiments in school.

(iii) Even if they do experiments, the experiments are often confined to verification of existing theories rather than experiments aimed at testing their own theories and conceptions or challenging commonly held beliefs.

(iv) Most teachers have been taught in a similar manner and are not able to use the scientific method effectively.

(v) There is often a big gap between the scientific method as used by the scientific community and the process that is taught in schools.

Osaki (1999) also found that most teachers lack skills on promotion of student centred teaching and learning procedures. Included among the skills that were found to be lacking are observations, generation and testing of hypotheses through experiments, discussion of experimental results, analysis of data and writing reports of observations and experiments.

The situational analysis study by Chonjo et al. (1996) also revealed that science teaching was in a poor state with regard to necessary inputs in the schools (e.g. books, laboratory supplies, good teachers) and teaching and learning processes (classroom presentations, teacher-pupil relations, management of teaching and learning resources, and professional development and support).
Lack of sufficient resources in addition to poor teaching affected the learning outcomes in terms of student performance in examinations, participation in innovative science activities, and general scientific and technological literacy of graduates. As it stands, something must be done to rescue science education. Osaki (1999) suggested professional development of the teachers as a temporary measure while a more long-term solution is awaited. Professional development was recommended in order to raise teacher awareness and understanding of a variety of professional skills that are still at a low state. Among these are:

- the use of textbooks to promote independent learning;
- the use of learners existing ideas and environmental experiences in teaching;
- effective questioning in classrooms;
- management of student practical work.

Professional development can also be used as an avenue for the promotion of student centred teaching and scientific inquiry skills such as observation, generation and testing of hypotheses through experiments, discussion of experimental results, analysis of data and writing reports of observations and experiments.

### 1.2.2 Recent science curriculum review

Over the years, there have been revisions of the curriculum at the secondary school level dictated by exigencies operating at the time. The most recent revision took place in 1996. This was necessitated by drastic changes in science, technology and the society that called for changes in the curriculum after being stagnant since 1976. The changes were to match the expectations of society to students' competency. The ultimate intention of the new curriculum was to prepare secondary school graduates to be able to adapt and adjust in the rapidly changing world of the competitive job market.

These changes involved all academic subjects, though the changes were more prominent in science than in the other subjects. For the science curriculum, new topics were added to reflect the demand for knowledge on environmental issues and new technological developments. The addition of new topics implied that more content would need to be covered since very few topics were left out of the old curriculum. In addition to the new topics, entirely new subjects on computer literacy and computer science were introduced. The teaching approach mentioned in the curriculum documents was student-centred but this was not reflected in the few exemplary materials accompanying the syllabus.
These changes were on one hand very positive and on the other hand posed difficulties in implementation. All revised secondary school science syllabuses tend to maintain a great deal of content to be covered. They leave very little opportunity for students to understand the process of science, that is, to be able to pose questions, create a list of plausible hypotheses, design successful experiments to test hypotheses, and propose models to explain collected data. The syllabuses are also written as schemes of work, meaning that they suggest a lot of activities, some of which are not within range of the abilities or interests of the classroom teacher. They also suggested very few extra readings for the teachers and pupils. As a result, in order to try and do everything suggested in the syllabus, teachers are forced to cover a lot of content without giving proper attention to actually understanding science through active involvement of students. This affects the quality of teaching as teachers are often forced to rush through topics on the syllabus in order to touch upon everything before the final examination.

Those in charge of developing the curriculum must realize that with the current information explosion, it is impossible to update the science subject matter to an adequate level for life and living in today’s world. It is impossible to predict what knowledge will be most useful in the future, therefore, it is senseless to try to teach it all in advance. Instead, the educational system should try to teach students to love learning so that they will have the skills and motivation to undertake whatever subjects are placed before them. Therefore a more pragmatic change is required in the science curricula in order to equip students with the skills needed for learning in an ever-dynamic world of science and technology. A curriculum review is needed in which content will be reduced and more time will be freed for developing process skills in scientific learning. This conclusion is implied in the study by Duggan and Gott (2002) on the role of science for employees in science-based industries and members of the public interacting with science in their everyday life. They concluded that, there is a need to substantially reduce the conceptual content and more explicitly teach the nature of evidence (procedural understanding) in science.

Complaints from school heads and teachers of these subjects about the overloaded curriculum have not been addressed. This largely contributed to the downside of this implementation. Some professionals, for example Osaki (1999), have voiced their concerns about lack of in-service training to help the
teacher with teaching new topics and improving their teaching approach, these are also yet to be addressed.

1.3 THE INTRODUCTION OF COMPUTERS IN SECONDARY SCHOOLS

One of the new modifications in the curriculum that is of interest to this study, is the introduction of computer literacy and computer science to the secondary school programme of study. This was needed as it became clear that secondary school graduates without computer skills and knowledge could not survive in the existing job market. A high demand for professionals knowledgeable in computer science, software engineering and computer communication engineering, necessitates the preparation of secondary school graduates who can pursue such education at the tertiary level and later in life throughout their careers.

Computers generally play three distinguishable roles in education: the computer as an object for study, the computer as an aspect of a discipline or a profession, and the computer as a medium of instruction (Voogt, 2003). Computers as an object of study refers to the discussion of whether the role of computers in society justifies the introduction of new subjects, such as computer literacy and computer science, in the curriculum. Computers as an aspect of a discipline or a profession is related to necessary curriculum changes due to the impact of computers on jobs. The computer as a medium for teaching and learning, concerns the potential of computers to improve the curriculum process. As an instructional medium, computers are used to aid the delivery of subject matter.

The computer may play an aspect role as well as the object role in the case of Tanzania. The changes in the curriculum are intended to enable students to learn about computers and how to do a bit with computers. The ultimate goal is to enable students to explore, nurture and increase their ability to use computers confidently for obtaining and processing information.

The computer literacy part of the syllabus is to be completed in the first two years of secondary education, covering most of the computer literacy course essentials. General handling of computers and mastering of household software
such as word-processors and spreadsheets is expected. After two years of secondary education, students are expected to be able to handle and operate the computer confidently. Simple computer programming is introduced as part of computer science in the last two years of the first four years of secondary education. More detailed coverage of computer science is to be done in the second stage of secondary education, which is another two years. The computer science syllabus equips the students with knowledge that enables them to design and write a workable computer program for simple tasks.

Though the idea sounds plausible, little was done in terms of planning that will facilitate the implementation of computer literacy and computer science in public schools. The essential support structure to sustain the anticipated changes has never existed in schools and is still not there. Trained teachers and basic resources such as computer hardware and software are not yet available in schools. Teachers who can run computer literacy courses were either self-taught or got private tuition somewhere else. Teachers with whom the schools could begin working were a few physics and mathematics teachers who learned a bit of computer programming while studying at universities. In other words, the majority of teachers were and still are themselves computer illiterate (Kafanabo, 1999; Tilya, 1997).

As a step to prepare schools for this change, the Ministry of Education asked heads of public schools to allocate and prepare a room to be a computer lab. Public schools all over the country have labs ready but only few schools have received the computers that were promised by the government. Some schools have computers that were donated by various organisations but in most cases they are older modelsthat are not fast enough to handle current software (Kafanabo, 1999; Tilya, 1997). Presently, there is not a single government school that is seriously implementing the new computer related syllabus. A few teachers use computers, but mostly just for word processing and in some cases to process examinations (Esselaar, Hesselmark, James & Miller, 2001).

The situation is a bit different in private schools, where the number of computers in a school depends very much on how rich the school is. To attract students, schools have trained or hired qualified teachers who can partly implement the new syllabus. The implementation is partial, as schools are not obliged to complete the syllabus, which is not examinable at the end of the
school year. These schools implement the computer literacy part of the syllabus and spend the rest of the time teaching students whatever the school think is useful for the future growth of the students (Tilya, 1997).

As the matter stands no official statement has been issued by the government as to what to do next. Also, no other more recent research has been carried out on how the schools are coping with implementation. Officially, the computer syllabus looks as though it is compulsory for all secondary schools, but in practice that is yet to happen. Consequently, this part of curriculum change is not officially examined at the end of secondary school. This is not in line with the current education policy document, which claims to promote "computer studies in order to promote technological and scientific development" (MoEC, 1995, p.52).

The few computers that have been put into schools are also under-utilised because of a lack of proper vision, planning, and leadership from national level down to the individual school level. Despite the fact that at the national level, it is beyond the reach of schools, much more can be done at the school and classroom level by the schools themselves. At the school level, a framework relating to policy and availability of resources, support of teachers, organisation of computer-related resources, and leadership to support and stimulate computer use is necessary. At the classroom level, the organisation of learning experiences in which the computer could be used, supported by characteristics of computer-related resources such as hardware and instructional design resources, is essential. All these changes can happen but cannot be imposed on schools. It is only by intervening through involving teachers in activities that demonstrates the benefits of computers to their teaching practices, that will influence their attitude towards computers in education. Success in the integration of computer literacy and computer science in the school curriculum depends very much on proper planning and focused effort in implementation.

It also must be clear that, the goals and purposes, and the content of the computer course have implications for the curriculum as a whole. Studies have shown that the success rate is low if computer literacy is separated from other subjects. Teachers hardly change their practices, and that hampers the possibility of harnessing the potential of computers in teaching and learning (Voogt, 2003). Complete integration of a computer literacy course into the existing subjects will make the course more meaningful for both teachers and students.
The decision makers from schools to the national level need to be aware that, though computers are advocated in science education; there is little evidence that they increase students' ability to learn science. The lack of pedagogical consideration of issues pertaining to learning science with computers during classroom implementation is mentioned as one of the hindrances. Thomas (2001) proposed guidelines for orienting computer use in high school science classrooms, which may reduce the obstacles that currently exist to taking advantages of the potential of computers for science education. These guidelines are the following:

- pedagogy should be strongly informed by appropriate theoretical orientation;
- the importance of models in science should be acknowledged in pedagogy and in software development;
- development of students' meta-cognition during instruction involving computers should be focused upon;
- teacher and student beliefs and epistemologies should be reorganised as key factors in educational change involving computer implementation.

Theoretically, Thomas' ideas are very good but to put them into practice at a large scale is difficult as it involves co-ordinated actions from different actors, which is not easy to synchronise. Finding teachers who are aware and willing to put all of that together while taking into consideration the pressure placed upon them to cover the curriculum materials within a given period is rare. This does not prevent schools and the nation from thinking big and starting small with a few schools or a few subjects in schools. In each case a few teachers who are willing and courageous enough to start this process, can be involved.

For example, they could start small with a few physics topics where promising technologies for teaching and learning science are advocated such as microcomputer-based laboratories (MBL), which the author of this work also intends to incorporate into the study. Voogt (2003) noted that the MBL promotes inquiry-based learning, encourages students to interpret graphic data, promotes understanding of difficult science concepts, improves collaboration among students, motivates students and fosters concentration. This technology can promote active construction of physics knowledge, in addition to fostering collaborative learning.
This approach of integration of computers in the science curriculum can be successful and MBL in particular has the potential to help students acquire mastery of difficult science (Physics) concepts and vital laboratory skills. MBL as used in this research intends mainly to:

- help A-level students acquire an understanding of science (physics) concepts;
- provide A-level students with a direct experience of the physical world using MBL tools for real-time data collection, display and analysis;
- enhance traditional laboratory skills;
- reinforce topics covered in lectures and readings using a combination of conceptual activities and quantitative experiments.

MBL is just one example of many promising technologies that the Ministry of Education in Tanzania can consider in introducing and integrating computers in the science curriculum. The choice of technology and the strategy for implementation should be backed by research findings in the teaching and learning of science with technology.

1.4 TEAMS PROJECT AND ITS CONNECTION TO THE STUDY

From the early 1990s onward, the government of Tanzania has strengthened her desire to improve science education which dwindled in the 1980s. Foreign financial agencies and western governments financially supported the efforts and there are currently a number of science education projects in operation. In that spirit the government forged a link with The Netherlands government, through collaboration of the Free University of Amsterdam and the University of Twente on the Dutch side and the University of Dar es Salaam as a counterpart on the Tanzanian side. The collaboration was realised in the form of a project. This project is called Teacher Education Assistance in Mathematics and Science (TEAMS). The project involves curriculum restructuring of undergraduate science education courses, in-service education and development of teaching materials, as well as promotion of girls' enrolment into science and mathematics education. For undergraduates courses, only future A-level science and mathematics teachers benefits from TEAMS. The support for pre-service teacher education and in-service education in science and mathematics is intended, among other things, to improve the teaching skills of teachers. TEAMS also engages in research and development of teaching and learning materials, and in capacity building by training science education researchers and leaders.
for the future. The problem of science education in Tanzania is a very big one and the TEAMS project can only assist in reducing its size.

The TEAMS project is a result of the study on the situational analysis of science education in secondary schools (Chonjo et al., 1996). The study report revealed shortcomings of current science education in the country and also pointed out the reasons that the Tanzanian science education failed to produce the expected scientifically literate citizens. From the findings, the need to strengthen pre-service science education was pointed out. Also important was the need to intervene in teaching methods in schools through in-service training in science education. TEAMS has been involved in a number of activities to address the issues raised. Some of them require research input. It is in that spirit that the author of this work was motivated to do research on an intervention in teaching that could eventually benefit students in schools by helping them to better understand physics concepts, while at the same time helping the teachers to reshape their teaching methods toward a more student-centred approach.

As is clear from previous sections, the study will try to introduce a shift from teacher-centred to a student-centred approach of teaching. This is not an easy task. It requires fundamental changes in the teacher's complex decision-making and way of doing things. It requires different lesson-plans and lesson design. It also requires a new mindset for both teachers and students, as their respective responsibilities are a bit different from the traditional teacher-centred approach. These changes in attitude and practices are difficult, and without retraining of practising teachers, impossible. With the help of the TEAMS project, this study endeavours to investigate the characteristics of an intervention scenario that can contribute to the change process and if implemented, will eventually improve teaching and learning of physics at high schools in Tanzania.

1.5 AIM OF THE STUDY AND RESEARCH APPROACH

1.5.1 Aim of the study

The preceding sections have described the major problems that science education in Tanzania is facing. There is no single solution or quick fix as it is a complex problem that requires a multifaceted solution. This study primarily focuses on developing effective teacher support for A-level secondary physics teachers, which plays a role in the integration of computers in the physics curriculum. The support plays a primary role in promoting the learning and
understanding of physics, which will eventually improve the performance of students in the final exam.

In this support, microcomputer-based laboratories (MBL) are used as a tool to facilitate activity-based teaching and learning in physics classrooms. The study also examined ways in which practising teachers could be helped to use MBL in teaching physics. This led us to formulate research questions that guided the study. The main research question was:

*What are characteristics of an in-service arrangement that facilitates the implementation of MBL-supported lesson activities in physics education?*

To come up with characteristics of in-service education that create teacher learning and can influence teachers' practices, three sub-questions guided the process:

i. What are characteristics of an in-service strategy that contributes to the preparation of teachers in the implementation and use of MBL technology in an activity-based physics classroom?

ii. How should MBL-supported lessons materials be structured to assist teachers in the implementation of activity-based learning in the Tanzanian context?

iii. What is the impact of an in-service arrangement on MBL-supported lessons in classroom teaching, student motivation and physics learning?

Each of these questions plays a role in answering the main question of the study.

The teacher support proposed is in three forms. First, is to equip teachers with essential knowledge and skills, crucial for the development of a computer assisted activity-based approach to teaching science in a student-centred learning environment. We will also introduce a few aspects of student learning problems of which teachers should be aware. Second, is to help teachers to improve their classroom practices. As portrayed in the earlier sections, a fairly good number of teachers lack effective classroom interaction skills. However, teachers as any other human being, are hesitant to change due to the uncertainty involved in predicting the outcome of the change. The study embarks on the development of exemplary teacher and student materials, which are to be used in professional training to encourage the change process.

The third aspect is to enable teachers to make use of the computers that are available in their schools in a more positive and effective way by learning how to teach physics with the computer as a tool in carrying out lab work. Teachers
acquire the skills necessary to use the computers as well as designing lesson materials that students can use to improve their learning and understanding.

The nature of the study requires us to adapt a number of new educational ideas that were developed and tested in different contexts to a Tanzanian context. To ensure success, the study must employ well thought out measures to reflect the differences in context. In order to achieve the goals, our research trajectory must veer from the traditional approach. This approach that taken is called development research and is explored further in the next section.

1.5.2 Research approach

Traditionally, research is viewed as a means of discovering or producing new knowledge, and development as the translation of knowledge into a useful form. Consequently, research traditionally precedes development and this is considered as a necessity in product innovation. Richey and Nelson (1996) described development research in education as the production of knowledge with the aim of improving the process of design, development and evaluation of educational products.

This view may not always be true, especially when dealing with the unpredictable events of social nature, as there may exist no direct relationship between research and development practice. Van den Akker (2002) argued that traditional research approaches (e.g. surveys and experiments) generate descriptive knowledge that hardly provides prescriptive solutions to the variety of design and development problems in education, where the context is very dynamic, clouded with uncertainties. In these situations, the answers provided by research to the uncertainties are often too narrow to be meaningful, too superficial to be instrumental or too artificial to be relevant.

One context where traditional research approaches hardly work is in curriculum reform endeavours, which involve multiplayer levels of responsibilities and decisions with diverse needs and different problems to be addressed. The problems are often ill defined in broad contexts.

In all these cases, evolutionary (iterative or cyclic) approaches are required to solve the problems, with integrated research activities to feed the process. The research activities will require a development research approach. This research
approach will reduce the uncertainties in designing and developing educational interventions. Through development research, the gap between theory and practice can be lessened.

From a curriculum perspective, van den Akker and Plomp (1993) gave a functional definition of development research by specifying two main purposes:

i. supporting the development of prototypical products; and
ii. generating methodological directions for the design and evaluation of such products.

From this definition, development research contributes to two main aspects: product improvement and knowledge growth. Product improvement aims at making a high quality product, and knowledge growth is reflected in design principles. Those principles do not guarantee success, but they are intended to select and apply the most appropriate knowledge for specific design and development tasks.

This study intends to (i) produce a valid and practical teacher in-service scenario aimed at sound implementation of computers in science education (ii) generate methodological guidelines for design, evaluation and implementation of such innovation in schools. However, there are many unknown factors that may interfere with and hinder positive results if research findings from another context are directly applied to the problem at hand in the Tanzanian context. For example, there is ambiguity in current teacher knowledge and skills in relation to the development of the in-service programme. For this reason, the study progressed through cyclic design and evaluation stages, before any trial implementation in schools. On this basis, the approach is characterised as development research.

1.6 PREVIEW

The development research activities and findings of the 'Teacher Support for the Use of MBL in activity-based Physics Teaching in Tanzania' study are presented in the subsequent chapters. In chapter 2, a theoretical framework is presented. First, current teaching and learning theories are explored as a stepping-stone toward establishing a rationale for employing an activity-based learning
Introduction

approach in the study. Afterward, the microcomputer-based laboratory (MBL) is discussed and reasons for adopting it in science education are established. The chapter further scrutinises ways in which MBL-based activities in the form of lab work can play a role in implementing activity-based science learning. The chapter concludes with a recounting of the trajectory that the teacher-learning process may take in order to prepare effective teachers, who can adapt an activity-based learning approach into their teaching. *Chapter 3* discusses prototyping of professional learning and lesson materials according to the developmental research. It explains the characteristic cyclic research process inherent in development research. During the cyclic process the design and development phase is followed by a formative evaluation phase, in which prototypes of both professional training and lesson materials are developed in an iterative manner. *Chapter 4* discusses the evaluation of the effects of professional training and the lesson materials on teacher. *Chapter 5* goes on to discuss the outcome of the effects on teachers learning. *Chapter 6* centres holds reflections on the study as whole, conclusions that can be drawn with regard to the research questions, and the implications of the findings. Recommendations for future endeavours bring the book to an end.
CHAPTER 2
Theoretical framework

This chapter aims at developing a theoretical framework upon which the study is built. It commences with a thorough discussion of current theories of learning and their implication on teaching in section 2.1 before considering the significance of activity-based learning in section 2.2. Then, the role of practical work in secondary education as a form of activity-based learning is discussed in section 2.3, including current trends to promote learning with laboratory work, and how to blend the new trends into a curriculum that is based on current models of instruction. Sections 2.4 through 2.6 explore the potential of ICT (incorporating microcomputer-based laboratories) for science learning and how ICT may facilitate the implementation of activity-based learning. Teacher beliefs on teaching and learning and how they influence change in curriculum reform are reviewed in sections 2.7 and 2.8, and finally the importance of teacher support materials is explored at the end of the chapter.

2.1 CURRENT APPROACHES TO SCIENCE TEACHING AND LEARNING

Until quite recently, understanding the mind and the thinking and learning that the mind makes possible has remained an elusive quest, in part because of a lack of powerful research tools. But over the last twenty years the situation has changed. Cognitive scientists, and researchers in the field of cognitive science have made great strides in understanding the processes of thinking and learning, on the neural processes that occur during thought and learning, and on the development of competence. This research has important implications for education, as a new theory of learning comes into focus that leads to very different approaches in the design of curriculum, teaching, and assessment. With regard to science learning, the major research focus is on how learners acquire knowledge and on the difficulties learners experience during science education. Naturally, these advances in learning are very suggestive about the ingredients that should be present in effective science instruction. The advances
also have far reaching implications for teaching with respect to how to embody or express intended knowledge to learners in ways that makes it possible for learners to gain the intended knowledge. Perhaps the best synthesis of research on learning is contained in a recent report by Bransford et al. (1999) to the US National Research Council titled *How people learn: Brain, mind, experience and schools*. The report goes beyond synthesis and provides examples on how learning research can be applied in teaching. Blumenfeld et al. (1998) reported in their review of teaching for understanding, that in the last two decades the approaches to teaching and learning have evolved from models that stress information transmission to ones that emphasise student transformation of knowledge. The progression noted was a shift from emphasis on teacher directed, well structured, organised delivery of information to emphasis on the role of the individual learners in constructing understanding and the influence of the social environment on such construction.

Blumenfeld *et al.* (1998) argued that in the student transformation model of learning, the cognitive processes 'mediate' between the instructional events organised by teachers and the eventual learning that the student achieves. This purports that learning takes place not only because of what a teacher does during lesson presentation, but because of the cognitive processes that a student uses and the level of cognitive development of the student. During teaching in this model, careful attention is paid to the knowledge, skills, attitudes, and the beliefs that student brings to the educational setting. The teachers' role shifts from being an authority to being a mentor or facilitator. The teacher helps to create an environment and selects areas of inquiry for students to engage in while investigating, solving problems, and exploring ideas using technological tools as aids. The teacher scaffolds learning by modelling cognitive processes, coaching, providing feedback and breaking down tasks. Teaching emphasises discourse and collaboration so that students learn from each other and from those with greater expertise. This mode of teaching and learning is still in the process of evolving, and is based on a constructivist theory of teaching and learning.

With constructivism, learning is founded on the premise that, by actively reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generates our own 'rules' and 'mental models,' which we use to make sense of our experiences. Learning in a constructivist view, is simply the process of adjusting our mental models to accommodate new
experiences. From Bransford et al. (1999), reflections on constructivism as an epistemology of learning can be summarised as:

- Knowledge is constructed, not transmitted.
- Prior knowledge impacts the learning process.
- Initial understanding is local, not global.
- Building useful knowledge structures requires effortful and purposeful activity.

Constructivism is used to indicate a theory of communication in teaching, in addition to being used as a philosophy and an epistemology. Simply stated, when you send a message by saying something or providing information, if you have no knowledge of the receiver, then you have no idea what message was received, and you cannot unmistakably interpret the response. Thus, simply presenting material, giving students problems, and accepting answers back is not a refined enough process of communication for efficient learning. Consequently, for pedagogic purposes, the tenets of constructivism can be rephrased as follows (Bransford et al., 1999):

- Students come into our classrooms with an established world-view, formed by years of prior experience and learning.
- Even as it evolves, a student's world-view filters all experiences and affects their interpretation of observations.
- Students are emotionally attached to their world-views and will not give them up easily.
- Challenging, revising, and restructuring one's world-view requires a great deal of effort.

Constructivism, though established as a theory of learning, teaching, education, cognition, personal knowledge, scientific knowledge, and as a worldview in science education, is not without critics. Matthews (2002) compiled disapprovals raised by many opposed to the theory. The criticism is directed mainly to the so-called radical constructivism, which challenges the notion of an external reality; and asserts that no amount of stimuli, experience, or thinking is sufficient to prove the existence of an external agent. But contrary to that, science presumes such an external reality and seeks to describe its nature and behaviour. Science also presumes that the external reality is well behaved and capable of being explained.
The critics also raise many questions on the practicality of the theory in the science classroom. They claim that constructivism does not have a well-elaborated method of teaching science to the entire body of a school that can be followed by all teachers as the traditional information transmission model can. Critics ask, as Matthews (2002, p. 129) put it, "if knowledge cannot be imparted, and if knowledge must be a matter of personal construction, then how can children come to knowledge of complex conceptual schemes that have taken the best minds hundreds of years to build up?" Matthews goes on to say that science educators want to know how to teach a body of scientific knowledge that is largely abstract (e.g. force, gene), knowledge that is removed from experience (e.g. cellular processes or astronomic events), that has no connection with prior conception (e.g. ideas of viruses, evolution or electromagnetic radiation), that is alien to common-sense, and in conflict with everyday experience, expectations and concepts.

On the other hand, the critics agree that constructivism has done a service to science education by alerting teachers to the function of prior learning and extant concepts in the process of learning new concepts. It has also been helpful by showing that understanding is a goal of science instruction, by fostering pupils engagement in lessons and other such progress matters. Also, constructivism made educators aware of human dimensions in science and the place of convention in scientific theory.

On the other hand, Bransford et al. (1999) describe contemporary learning principles as a compromise between traditional and a constructivist views of teaching and learning. In some cases as Bransford et al. put it, books and lectures can be wonderfully efficient modes of transmitting new information, stimulating the imagination, and whetting students' critical talents. They further argue that lectures should not elicit from students their preconceptions and existing level of understanding. Well thought out science experiments can be a powerful way to establish emergent knowledge, but they alone do not evoke the underlying conceptual understanding that aids generalisation. Therefore there is no universal, best teaching practice. The teacher must instead use a combination of practices where appropriate.

Bransford et al. (1999) furnish a broader overview on learners and learning and on teachers and teaching. On learners and learning they concluded that:
Theoretical framework

i. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and the information that they are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.

ii. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

iii. A 'metacognitive' approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

The implications of their conclusions on teaching suggest that:

i. Teachers must actively elicit students' pre-existing understanding to provide a foundation on which formal understanding of the subject matter is built or provide the opportunity to challenge the initial understanding.

ii. Some subject matter must be taught in depth, providing many examples relevant to the concept being focused on and also providing a firm foundation of factual knowledge.

iii. The teaching of metacognitive skills should be integrated into the curriculum.

The researchers affirm that when this is incorporated in science teaching, students' achievement improves.

Currently, the trends in science education research and teaching practice are toward a teaching approach that advocates inquiry learning. Inquiry learning refers to the active processes by which students are engaged as they pursue increased understanding of science (National Research Council, 1996). With this approach, students gain active knowledge full of deeper conceptual understanding and enhance the application and transfer of knowledge to new and unique situations. The success enjoyed by inquiry as an instructional method is attributed to its potential to help students comprehend meanings of scientific ideas and grasp abstract concepts. Further, it is ascribed to the application of those ideas, the supporting strategies for scientific thinking and problem solving, building scientific understanding, supporting the idea of learning as a social activity and students' enjoyment of hands-on exposure to scientific ideas (Bransford et al., 1999; Hofstein, Nahum & Shore, 2001).
However, changing from traditional teaching methods to an authentic inquiry-oriented approach is difficult to enact, in any of its many forms. In the following section, we will discuss an inquiry-based learning approach rendered in a student-centred learning environment.

### 2.2 Activity-based learning

#### 2.2.1 What is activity-based learning?

The term activity-based is usually used interchangeably and synonymously with hands-on or learning-by-doing in the literature (e.g. Prawat, 2000; Woolnough, 1991). We adopt the same stance in this study. John Dewey is viewed by many educational philosophers as the initiator and promoter of activity-based learning (Prawat, 2000) in the early part of 20th century. Dewey was advocating this approach in learning pertaining to children. The key to the activity-based approach, according to Dewey, is the learner's engagement in situations that appeal to their curiosity and interest. The importance of activity-based learning in science education is likely to continue to be held in high esteem by science educators who hold the view that knowledge is constructed not imparted.

With time, the emphasis on children has changed and sway toward adults as more educators employ hands-on experience as an approach to teaching and learning. Evidence that supports this view is abundant in the literature. From the early 70s to the late 80s, activity-based learning was considered suitable more for younger learners than for older students. Recently that view has shifted as more and more areas in education, science, technology and commerce are using activity-based learning as a means of motivating and engaging adult learners to fully participate in the learning process.

Activity-based or hands-on learning is defined in a variety of ways expressing relatively similar meanings. Lumpe and Oliver (1991, p.345) defined activity-based science as: "any science lab activity that allows the pupil to handle, manipulate or observe a scientific process". It can be differentiated from lectures and demonstrations by the central criterion that students interact with materials to make observations, but the approach involves more than mere activity. The assumption is that direct experiences with natural phenomena will provoke
curiosity and thinking, so, "a recent new twist has been added, and the topic is called Hands-on/Minds-on science".

Lumpe and Oliver went on to say that hands-on learning can be thought of as comprising three different dimensions: the inquiry dimension, the structure dimension, and the experimental dimension. In inquiry learning, the student uses activities to make 'discoveries.' The structure dimension refers to the amount of guidance given to the student. Prescribed activities do not increase a student's problem-solving abilities. The third dimension is the experimental dimension that involves the aspect of proving a discovery, usually through the use of a controlled experiment.

Geller and Dios (1998) view activity-based/hands-on learning as any activity oriented toward instructional techniques/methods that enhance learning and comprehension, with an emphasis on learning by doing.

As we have seen in the activity-based approach to learning, learners are active participants with the goal being to bring them into the process of their education. Activity-based learning takes students beyond the role of passive listener and note taker and allows them to take some direction and initiative during the class. It engages them in in-depth investigations with objects, materials, phenomena, and ideas and allows them to draw meaning and understanding from those experiences. It has the potential to enable students to become critical thinkers, to apply both what they have learned and the process of learning to various life situations. Science activity-based learning can then be any educational experience that actively involves students in manipulating objects or ideas to gain knowledge or understanding. In this study activity-based learning is considered to be any student-centred, experiential approach to science education that focuses on science inquiry in a cooperative, problem solving learning environment.

2.2.2 Characteristics of activity-based learning

Many publications have demonstrated that if students are actively engaged in learning, their performance is significantly better than that of students taught in the traditional way (e.g. Hakes, 1998; Redish, Saul & Steinberg, 1997). What are the characteristics of such activities? McDermott, Shaffer and Constantinou (2000) noted that science instruction for young and adult students is known to
be more effective when concrete experience establishes the basis for the construction of scientific concepts, especially when they encounter a new topic or a different treatment of a familiar topic. Laws (1997) adopted a learning sequence distilled from cognitive psychology and educational research, in which students predicted the outcomes of the activity before observation. Students also explained the reasons for their predictions. Students then reflected on the outcomes of the observations before were encouraged to apply the learned ideas to new contexts. This enabled the students to check how well the learning was transferred to new problems and settings. Linn and Hsi (2000) emphasised the importance students being able to integrate new and old knowledge and transfer it into a context different from the learning environment as it helps students to develop competence and prepares them for flexible adaptation to new problems and settings. Tinker (1992) indicated that students work collaboratively in these activities as they solve problems. Beichner (1995) argued that, when the activities involved using computer technology, thorough software integration into the instruction is a must, as it enables teachers to supply a variety of ways for students to become involved with content, essentially establishing an environment for learning. The more hands-on experience and mentally engaging tasks presented to students, the better they grasp the material. The findings of these researchers indicate that, the interactive qualities of well-designed hands-on activities persuade the student to experience the phenomena directly, and to experiment in a relaxed way with the effects of self-chosen variations in procedure. That approach can lead to discovering what fails as well as what succeeds, and can be an important part of the experiences on which formal science learning is based.

The researchers emphasise the view that hands-on learning embraces social and enjoyment aspects. The students’ habit of both giving and taking suggestions and of collaboratively combining efforts is an essential aspect of much real science, both academic and industrial. Enjoyment, as used, combines the delight of discovery with satisfaction of gaining some significant knowledge and experience (sometimes quite unexpectedly), and taking pleasure in the accomplishment itself rather than earning a grade.

### 2.2.3 Forms of activity-based learning

There are many teaching approaches elaborated in the literature in which learning is centred on the learning activity. In these forms students are actively
involved in constructing (or organising) and using their knowledge. Such forms may take a different format. For example, it may involve a process of learning through experience, with self-direction and collaboration as the foundation, or it may challenge students to select, identify and defend their choices of concepts and principles for use in a given context, as well as describing the relationship between concepts. Hands-on learning can be any inquiry-based learning activity that engage students in doing something, whether it being lab work, a demonstration or anything else that helps students acquire a more fundamental understanding of the nature of science. Activities that promote active mental engagement of students in the process of learning science are referred to as activity-based. These could be questions that guide students through necessary concepts and that help the students to apply them in real-world situations or provide practice in understanding various interpretations (e.g. formulas, graphs, verbal descriptions, etc.). In all cases students' work collaboratively.

Also, student learning is evaluated to discover misconceptions among students, and to determine the effectiveness of the instruction. The students' assessment aligns with curricular aims, instructional practices, and performance tasks.

The ultimate goal of any form of activity-based learning is to aid in developing the critical thinking skills necessary to increase scientific literacy and motivate them to learn more. This is accomplished through the mastery of concepts, investigative skills and mathematical modelling techniques. The form of activity-based learning adopted in this study is experimentation.

2.2.4 Perceived benefits of activity-based learning

There are many benefits that researchers and educators adduce to activity-based learning to justify the approach to science education. Stohr-Hunt (1996) compiled these benefits. They include increased learning, communication skills, independent thinking and decision-making based on direct evidence and experience; perception of creativity, better science process skills in creativity, logic development, increased learning and achievement in science content. Thornton and Sokoloff (1990) claim that activity-based learning can result in a better understanding of science. McGervey (1995, 96) observes that hands-on activities are a means to fostering student participation in physics class and can be used to illustrate basic concepts that are often overlooked. Carlton (2000) argued that hands-on activities could be used to overcome misconception.
Tinker (1992) asserts, "it supports deep, interdisciplinary, collaborative study, it puts students in charge of their own learning, and makes learning relevant and interesting (p. 35)". And Bruder (1993) noted that it is capable of motivating students to continue with informal science education as part of their life long learning process. While Triadafilidis (1996) noted that educational experiences can be used as a way of enhancing motivation and provoking thought among students.

To conclude this section, activity-based learning will play an important role in this study. Properly used, it has the potential to promote inquiry skills which are essential in learning science, and can also motivate students to enjoy learning science. When the approach is used in the form of experiments, scientific process skills will be promoted in addition to the learning of scientific concepts. The approach has the potential to enhance students' constructive learning, conceptual understanding, and understanding of the nature of science. It can promote collaboration, and interactivity between students and teachers and among students. These are some of the virtues the study would like to incorporate into schools.

2.3 SCIENCE LAB EXPERIMENTS AND ACTIVITY-BASED LEARNING

According to Woolnough (1991) the terms practical work, lab work, experiments or hands-on activities are all synonyms referring to the performance of experiments or practical exercises with science apparatus, in a laboratory setting. In addition, practical work includes any activity that involves the basic ingredients of science and would be useful for all students.

There are many arguments to support the use of practical work in science curricula (Arce & Betancourt, 1997). Experiments are considered effective in improving students understanding of science as it allows students to change the abstract to concrete, helping them to internalise and understand concepts. Students are lead to a deeper sense of understanding by applying the concepts in new situations, which makes them think about the true meaning of the lab.

Hodson (1996) argues that another benefit that may be attributed to lab work is the acquisition of skills, which can be classified as content-free or craft. Hodson
explains content-free skills as generalised and transferable skills, which are therefore of value to all students. These skills include things like decision-making and problem-solving abilities, skills that can be utilised in any aspect of society. Hodson stresses that craft skills are science specific skills that are deemed essential for future scientists and technicians. These are inquiry skills such as hypothesising, predicting, identifying and controlling variables, processing and interpreting data; and technological problem-solving skills such as developing a plan, testing a design, troubleshooting and evaluating.

Hodson also attributes the development of scientific attitudes to experimentation and by this he refers to student understanding of the approaches and attitudes toward information, ideas and procedures essential to the science practitioner. However, there is very little literature linking the development of such attitudes with practical work in science education.

Practical work is also understood to generate motivation, curiosity, enthusiasm, and confidence in learning science (Arce & Betancourt, 1997) especially when students design their own experiments, as they find the work challenging and rewarding.

Despite the advantages and wide acceptance in industrialised countries of practical activities in school science, a number of researchers have questioned the effectiveness of these activities for lack of sufficient evidence supporting the supposed benefits. While writing to explore the link between laboratory and learning, White (1996, p.768) concluded, "there is insufficient evidence that laboratories promote better understanding of methods of science and abstraction processes, make information memorable, reveal links between topics, and motivate". Even more recently, Watson and colleagues came to the conclusion that students were often 'unaware of the educational aims of investigational lessons' and that there was a 'mismatch between teachers' aims for an investigation and things students considered that they learn during the investigation' (Watson, Goldsworthy & Wood-Robinson, 1998, p.20). Some studies have even concluded that the fundamental concern of many students while in laboratory is completion of task, and that this concern can overwhelm any serious learning possibilities (Berry, Mulhall, Loughran & Gunstone, 1999). The criticism arises from the fact that lab tasks often have low cognitive demands and provide a context that precludes reflective thought.
Regardless of much negative publicity of practical activities, there are many research studies discussing proposals to improve laboratory activities or to create new types of laboratory activities rather than analysing the current practices with regard to laboratory activities. The new trend is to try to make laboratory work an active learning environment, where collaboration and discussion are pivotal, and students are offered opportunities to better direct their enquiries (Dvir & Chen, 1998). This approach can develop student understanding about the way scientific facts are established. Researchers hold it to be very successful from both a cognitive and an affective perspective (Hart et al., 2000). Research suggests a number of ways to conform to the new trend. Gil-Perez and Carrascosa-Alis (1994) proposed a problem-solving approach in science teaching (including lab work), that is, teachers should "organise learning as the treatment of a problematic situation that pupils can identify as worth thinking about" (p. 307). Others have advocated open-inquiry as a means of making learning tasks more 'authentic', that is, making the students better surrogates for the activities of research scientists (Roth, 1995). Mestre (1994) proposed structured inquiry labs as they require less from students who are inexperienced in scientific inquiry. Some research findings went further to suggest that hands-on or activity-based experiences, blended with discussions are efficient ways of overcoming misconceptions (Carlton, 2000).

There are a number of good examples where experiments played a major role in learning and understanding of science (e.g. Laws, 1997; McDermott et al., 2000; Redish et al., 1997; Thornton, 1996; Thornton & Sokoloff, 1990). In all cases the experiments are inquiry-based and part of hands-on science learning. In some cases they were well thought-out and planned, problem driven, hands-on activities that required students to observe and experiment. They stimulated students' innate curiosity about nature and encouraged them to carry-on despite obstacles. They also required the student's reflection in order to make sense of activities. Lab work can help students: confront their preconceptions of how the world works, experience what real scientists do, learn how to use and operate equipment and practice problem solving skills (Lazarowitz & Tamir, 1994). Therefore the experiments, promote active learning that catalyses critical thinking. They support inquiry and problem solving, which enhances construction of scientific knowledge, the development of the scientific attitudes of the students and the transfer of knowledge to different contexts.
Thornton (1997) affirmed that students need powerful, easy to use, scientific tools to collect physical data and display them in a fashion that is manipulative and easy to think about and remember in order to make lab work engaging and effective for developing scientific intuition. Such tools he urges will enable students to concentrate on the scientific ideas, and eliminate the drudgery associated with data collection and display. Modern computer technology (ICT in particular) has the potential to support Thornton's claims and can help to make science understandable and attractive.

The role of the teachers is fundamental to the success of any lab work endeavour. Teachers must have a special approach to science and must use special instructional skills involving pre and post activity discussions. They must also have a positive attitude and special management skills to work with groups of students, under time constraints within a lab setting (Woolnough, 1994).

To conclude this section, we would argue that only through practical work can students build experience about the natural phenomena that science seeks to understand and explain. However, current laboratory work has trivialised the experiences and leaves students with the view that finding out about the natural world is simply a matter of executing an experiment. Few practical activities are needed in the curriculum to help students understand how difficult it is to secure knowledge about the natural world. Such activities help students to understand that lab work is about devising and planning the experiment. Therefore it requires imagination, creativity, technique, persistence, collaboration, disappointments, difficulty, success and failure. Lab work is also about asking questions about what to measure, solving problems, about how to measure it and evaluating the outcome. Lab investigation can lead to a greater understanding of existing evidence. Students, by actively participating in a well thought out activity-based lab activity, can learn both science concepts and science process skills and eventually master science inquiry skills.

### 2.4 The Potential of ICT for Activity-Based Science Teaching and Learning

From the discussion presented in the previous sections, we can draw a number of useful conclusions pertaining to why activity-based learning is important to
science education. Activity-based learning orients students toward an active mode of learning that facilitates the construction of knowledge. Student knowledge construction is fostered by an inquiry-based method of teaching. The method of inquiry used may include setting up a problem, formulating a hypothesis, creating a research design and testing results, all of which is done by the students. Student cognition is developed through participation in motivated goal directed activities.

This form of learning involves doing something, and can assist students in learning science concepts as they experience real world situations. Activity-based learning can aid in the creation of a learning environment where students work cooperatively and collaboratively, interacting in many ways including discussion. The added advantage to this approach is its inherent ability to stimulate students' critical thinking and develop their problem-solving skills. As students perceive the advantages of engaging in activities that have relevance to their world, their affinity for science increases. Students may even be inspired to pursue scientific studies even career.

ICT has the potential to support science education through experiences gained by actively engaging students in laboratory experiments. ICT can be used as a tool by teachers to structure the learning process such that students actively construct knowledge while engaged in hands-on activity. ICT has the potential to be exploited for learning new content, experimenting and investigating or to aid in applying knowledge to different contexts. To do this certain didactical principles must be observed. When students work individually or collaboratively in exploratory activities (a) they predict the outcomes of scientific experiments (b) reconcile experimental results with predictions (c) reflect on the results of group experiments and (d) integrate everyday and laboratory investigations (Laws, 1997; Linn & Hsi, 2000).

The use of ICT in education is broad and includes word-processing, spreadsheets and most recently the internet. Databases, simulations and microcomputer-based laboratories are seen as typical examples of applications useful in hands-on scientific study (Knezek et al., 2000). ICT applications that are specific to physics learning and support the hands-on learning approach can be characterised as tutorials, simulations and modelling systems, and microcomputer-based laboratories (Voogt, 1996a). Tutorials can be used for learning new educational
(physics) content and with it, instructions can be individualised. The new content is interactive and in most cases consists of multimedia.

Simulations on the other hand are representations of reality. The reality simulated could be natural, man-made or imaginary. By manipulating variables of the representations and studying the effects, students can gain a better understanding of the complex system represented by the variables. Simulations can aid visualisation of abstract ideas. Driver and Scanlon (1988) and Linn and Hsi (2000) contend that simulations aid in students in explicit reasoning and in visualising the consequences of their thinking. The visualisation can occur in individual or group settings.

Generally, models are an idealisation of physical reality. Students can use modelling systems as powerful tools to predict the consequences of complex theoretical assumptions. Through modelling, students are offered the opportunity to ‘play with ideas and eventually improve their ability to solve realistic physics problems (De Beurs & Ellermeijer, 1996).

Microcomputer-based laboratories, which will be discussed in the coming section, is generally used to enhance experimental data gathering processes, which then reveal patterns, and relationships demanding explanations. The explanations enable models to be created that lead to a greater understanding of the phenomena being studied by students. Modelling tools can be used to complement measurements, observations and evidence gathered by microcomputer-based laboratories.

2.5 WHAT IS A MICROCOMPUTER-BASED LABORATORY (MBL)

Microcomputer-based laboratories (MBL) is a term coined by Tinker and his collaborators back in 1983, and the idea has been in use for nearly 20 years in science education (Tinker & Papert, 1989). MBL constitute a modern approach to teaching science in a laboratory, with students conducting experiments in which data are acquired and transmitted directly to a computer.

The idea is simple; the computer is used as a laboratory instrument and is turned into a powerful tool for quantifying the physical world. This is
accomplished by adding some sensors to it and take advantage of the computer's facility for processing the output of the sensors. This allows students to discover the rich possibilities for measuring a variety of phenomena in a novel and indirect way.

The computer can then help students to measure, record, and graph quantities such as force, light, position, pressure, temperature, heart rate, speed, acceleration, brain waves, muscle signals, response time, and many other phenomena. These measurements may be saved, further analysed in diverse ways, or printed out. With MBL it is easy for students to run experiments and see data presented as a bar graph, line graph, or histogram, individually or together. MBL provide the possibility of displaying graphs concurrently with the observed phenomenon, in addition to storing the data for further analysis. The students are not automated out of the experimental process, rather they are given powerful tools that help them to gain a 'feel' for the data: data become almost tangible as their links to sensory experience are clarified.

In brief, Microcomputer-based Laboratories, or MBL, refers to any laboratory where a microcomputer gathers and displays data directly from the environment. MBL is not a simulation, but a flexible and unified tool for measurement and analysis. The complexity and sophistication of such a tool varies widely.

MBL technological developments are generally in the area of better hardware and software. For hardware there are improvements in quality of input/output electronics and more new sensors and actuators are available. The software development is evolving in many facets. The software has new subprograms for better data collection, data processing (smoothing, filtering, spreadsheets, etc.), data representation (various graphical representations) and data analysis (mathematical operations). The software now has extension subprograms for controlling laboratory experiments, system dynamic modelling and data capturing from video representations of physical, chemical and biological phenomena in real-life situations. The user interface in most cases is compatible with a standard Windows™ interface.

MBL offers the potential to turn the focus of teaching laboratories away from trivial mechanical processes, like copying down temperatures from a thermometer or graphing data, to the more creative aspects of science: analysis,
hypothesis, and experiment. Since the computer can be instructed to draw a
graph, the student can concentrate on thinking about, rather than manipulating,
the data. The very ease with which the gathering and processing of data can be
done encourages exploration.

There is abundant literature regarding the possible applications of MBL
technology as illustrated across physics, chemistry and biology education (e.g.
Adamson et al., 1997; McRobbie & Thomas, 1998; Trumper & Gelbman, 2000;
Wild & Bateman, 1995) and the list continues to grow. Others such as Balacheff
and Kaput (1996) argued that MBL has applications in mathematics education
as well.

The literature also provides a number of learning benefits derived from MBL
technology. These include improving student ability to produce and interpret
graphs (Burton, 1997; Mokros & Tinker, 1987; Trumper, 1997); real-time data
collection that makes it possible to repeat experiments, to measure different
variables at the same time, to use a short or a long time range to analyse and
represent data graphically, which makes it possible to spend less time on data
collection and more time in data analysis and interpretation (Voogt, 1996b).
MBL facilitates group work interactions because of its ability to contribute
information during group discussion (Kelly & Crawford, 1996). Linn and Hsi
(2000) in their Computer as a Learning Partner project found that MBL is more
effective if complemented with simulations, because in complementary
arrangements various visualisations are possible for different types of students.
Some studies have reported positive learning outcomes (e.g. Friedler, Nachmias
& Linn, 1990; Nakhleh & Krajcik, 1994; Redish, 1997) and in some cases students
have rated highly in courses involving MBL (Beichner et al. 1995; Bennet &
Brennan, 1996). Furthermore, MBLs provide students with one of the tools of
the scientist and allow students to engage in activities that resemble those in
active scientific laboratories (Weller, 1996).

2.6 MBL AS A TOOL TO FACILITATE ACTIVITY-BASED LEARNING

As we have seen in the previous section, the potential for MBL to enhance
learning lies in its ability to overcome barriers to learning which includes
removing delays in processing results, observation of phenomena in multiple
representations, and the capability of multiple simultaneous measurements. As the computer does most of the technical work, it is proposed that the student is better able to think, solve problems and employ higher order thinking skills. Further, it is purported that continuous interaction with the experimental data should aid in the identification of alternate conceptions and conceptual change.

MBL serves as a catalyst for change toward activity-based science education as it can facilitate student contributions to scientific understanding, through participating in the process of understanding scientific phenomena. MBL can play a role to make students more responsible for their own learning, rather than absorbing information, and can be helped to sort out experiences, reconcile alternative explanations and integrate diverse observations (Linn & Hsi, 2000).

There is sufficient evidence that hands-on activities conducted in a learner-centred environment is the common attribute of successful science laboratory activities (Laws, 1997; Redish et al., 1997). Newton (1997) maintains that to enable students to concentrate on the scientific ideas that they are investigating, tools such as MBL should be employed to eliminate the drudgery associated with data collection and display, and activities should be structured to encourage an inquiry approach to science.

There are number of good examples where MBLs were used to engage students actively in learning. Thornton and Sokoloff (1990) and Redish et al. (1997) offer a few examples where they conjecture that the MBL activities they have designed were effective in learning physics because of the following characteristics:

- students focus on the physical world;
- immediate feedback is available;
- collaboration is encouraged;
- powerful tools reduce unnecessary drudgery;
- students understand the specific and familiar before moving on to the more general and abstract;
- students are actively engaged in exploring and constructing their own understanding.

In another example, Thornton (1996) designed an interactive demonstration that engaged students actively by employing a prediction-discussion-observation sequence. In the demonstration: the teacher describes the activity, then asks the
students to record individual predictions. The teacher then asks the class to engage in small group discussions, followed by asking each student to sketch a final prediction. Finally, the teacher carries out the demonstration with MBL, asks a few students to describe the results and discuss them in the context of the demonstration. The teacher concludes with a discussion of analogous physical situations that produce a similar physical result but different context.

MBL software also has features that require both hands-on science and minds-on science experiences in order to benefit from them. The MBL modelling software features can generate data based on theoretical (mathematical) models and these data can then be compared to observed data. With this feature, students learn more when they commit themselves to a prediction prior to making an observation; if the prediction is right they are elated, if not, they are ready to try to understand why. MBL software can also enable students to extract data from digital video images of real-world events, which provides an intrinsically motivating environment, and can be used to nurture development of more advanced reasoning. When video data is augmented with sensor data, it enhances the gathered information, which, when correctly interpreted, can help students to build a more robust understanding of the phenomena under investigation.

MBL embedded in a curriculum that fosters student collaboration, makes it easier for students to take advantage of learning from peers. Linn and Hsi (2000) contend that students understand new scientific perspectives better when they hear them in the words of their peers than when they hear them from scientists or read them from textbooks. Peers may connect an idea to a personal problem, present the idea using more familiar vocabulary or motivate students to make new connections. MBL in combination with simulation and/or modelling can be designed to help students get new ideas from each other through prediction, observation and discussion.

Students can also discuss the MBL based activities and use the discussion to connect laboratory experiments to naturally occurring problems involving the scientific principles under investigation.

Linn and Hsi (2000) summarised the evidence by arguing that MBL provides visual experiences and encourages visual thinking through graphs of real-time
data collection to animate trends in experiments. The MBL experiments in which students watch data appearing on a graph while conducting an experiment helped students to connect experimental findings to their real world source. The graphs help students visualise the process behind the mathematics required for scientific phenomena to be understood. The MBL software enables students to make predictions and later compare the predictions with the outcome of their experiments. Additionally, all of the information is stored quickly and easily. Students are enabled to spend a considerable amount of time writing their comments and reflecting on their experimental outcomes.

For teachers, MBL is a tool that helps them asks questions, as a form of scaffolding or to facilitate communication. Teachers may ask students to make predictions, explain their graphs, describe concepts in their experiments, and talk about their conclusions. Or the teacher may give students everyday examples and ask them how they relate to the principles they have derived from their experiments. MBL tends to hold students on task and keep them thinking.

Though MBL research reports on instruction are impressive, the success will never have a large impact in science education if it is not thoughtfully integrated into the curriculum. Nakhleh (1994) in a review of MBL literature emphasised that across the studies, the following two points were evident: "(a) MBL is motivating and satisfying at a variety of educational levels (b) the effectiveness of MBL is greatly enhanced by appropriate instruction and thoughtful design of curriculum" (p. 379). This argument is further strengthened by the success of the computer as lab partner, in which MBL was thoughtfully integrated into the curriculum (Linn & Hsi, 2000).

This line of thinking is in agreement with a contemporary view in science education that advocates turning from the content-based curriculum to a more process oriented curriculum. In other words a move away from the voluminous transmission of information and attendant laboratory exercises stressing the replication of proven concepts toward a greater focus on skills of analysis, questioning, synthesis and problem solving via laboratory experience. Its pedagogy encourages changing from a teacher-oriented presentational style to a participatory style involving the negotiation of meaning (constructivism) wherein teachers surrender a large degree of situational control, and rather
become facilitators. MBL technology and methods can provide a route to this style of interaction by encouraging student control, centered upon the experimental relationships under study rather than instructor and textbook direction (Linn & Hsi, 2000).

### 2.7 Teacher Learning as a Process

Teachers are key to enhanced learning in schools. For teachers to teach in a new and unfamiliar way requires a re-education that may transform their knowledge and skills pertaining to subject matter, epistemology, their conception of how knowledge is constructed, and their views about science. The research evidence that exists, mostly in the form of case studies, provides important information about teachers as they attempt to change their practices. This information asserts that what is known about student learning applies to teachers as well, that is: (a) what learners know influences their learning (b) learners construct new knowledge (c) knowledge is constructed through a process of change (d) knowledge and knowing have a social nature, and (e) knowledge construction is influenced by context.

The role of experienced teachers' cognition in influencing new learning is well described by van Driel, et al. (2001). They describe this knowledge as practical knowledge, which consists of an integrated set of knowledge, conceptions, beliefs and values that teachers develop in the context of the teaching situation, and is mainly the result of their teaching experience. This knowledge is critically important, as it is a determinant of how a teacher teaches and how their views change. Putman and Borko (1998) in their review argued that this knowledge and beliefs are important influences on or determinants of change, serving as critical filters for what and how teachers learn. Like students, practising teachers can make sense of new instructional practices or ideas only through the lenses of what they already know and believe. Both Putman and Borko and van Driel et al. advise us to make teachers' knowledge and beliefs about teaching and learning the target of change if teachers are to be successful in moving toward new instructional practices.

It is also known that for experienced teachers, much of their knowledge has become routine and automatic. Automation or fluency is essential for coping with the managerial and cognitive complexity that is inherent in guiding the
activities of a classroom full of students. However, routine knowledge can impede teachers' efforts to reflect on their own practices, to see thinking in new ways or to learn new instructional approaches (Borko & Putman, 1996; van Driel et al., 2001).

Putman and Borko (1998), in an effort to emphasise the importance of a good command of subject matter, argued that teachers with a richer understanding of subject matter tend to emphasise conceptual, problem-solving and inquiry aspects of their subjects, where as less knowledgeable teachers tend to emphasise facts and procedures. Putman and Borko further established that when teachers were teaching topics they knew well they were more likely to provide students with the opportunity to raise questions about science and focus on central ideas and the links among them.

Teachers also require knowledge and skills specific to teaching particular subject matter (Shulman, 1987) or pedagogical content knowledge (PCK) as it is generally known. It is only when teachers have acquired a deeply principled conceptual knowledge of the content that they can develop pedagogical content knowledge (van Driel et al., 2001). The researchers concluded that PCK is dependent on teaching experience.

The view that teachers are active constructors of knowledge implies that their knowledge and beliefs are critically important to professional development. Their existing knowledge and beliefs influence how they learn new pedagogical ideas and practices. Therefore, staff development can be successful in facilitating meaningful change in the experienced teachers' instructional practices, if it explicitly addresses teachers' pre-existing knowledge and beliefs and supports the teacher in examining and changing them. The new knowledge should focus on changing teachers' beliefs about teaching and learning by providing opportunities for teachers to learn themselves in a setting where the construction of meaning is encouraged and valued. The practising teacher then reflects on those experiences to rethink his assumptions about subject matter, teaching and learning, and to design new instructional sequences for their classrooms (Smith & Neal, 1991). These findings suggest that both subject matter knowledge and pedagogical knowledge are important for proficient teaching. This is because knowledge domains have unique methods of inquiry associated with them and are thus essential in teacher learning. These two kinds
of knowledge should be the target of change in any effort to help teachers change their practices.

Knowledge construction from the viewpoint of a constructivist social perspective is also important. What we accept as knowledge and how we think are the product of interactions between groups of people over time and the ways in which these groups have come to order their experiences and make sense of their worlds. It is through sustained interaction that individuals come to share common ways of thinking and express ideas (Vygotsky, 1978). In this social constructivist view of learning, other persons play the role of model and supporter for learning. Individuals learn by observing the interaction with more knowledgeable members of the culture, appropriating for themselves new ways of thinking. Individuals can construct personal meaning only in the context of the ideas, conceptual tools, and modes of thought provided by the social environment and discourse communities. Individuals can 'transmit' these conceptual tools and modes of thought only to the extent that they can make personal sense of them (Putman & Borko, 1998).

The view of knowledge as socially constructed also has implications for the learning experiences of teachers. One key implication is the importance of establishing new discourse communities in which teachers can participate as they work to change their teaching practices.

Putman and Borko (1998) insist on the importance of establishing new kinds of discourse communities (which may include researchers) in which teachers engage in active learning, inquiry, reflection, and reasoning about teaching practices. Just as students need to learn new ways of reasoning, communicating, and thinking, and acquire dispositions of inquiry through their participation in classroom discourse communities, practising teachers need to construct their complex new roles and ways of thinking about their teaching practices within the context of a supportive learning community. Practising teachers need opportunities to learn to be critical and reflective about their teaching. They also need discourse communities in which to learn and practice these skills and dispositions.

The context in which learning takes place also plays an important role in knowledge integration and transfer (Linn and Elyon, 2000). Theories of situated
cognition assume that knowledge is inseparable from the context and activities in which it develops. The physical and social context in which an activity takes place is an internal part of the activity. In turn, the activity is an integral part of the learning that takes place within the context (Brown, Collins & Duguid, 1989a).

From the situated cognition perspective, knowledge transfer is made possible to the extent that knowledge is grounded in multiple contexts (Brown, et al., 1989b). The perspective of situated cognition implies that learners should learn valued knowledge, skills, and dispositions as they occur in meaningful contexts, and that what is learned should be connected to situations of use. Brown et al. (1989a) insist that this perspective suggests the importance of authentic activities in classroom, that is, activities that are similar to what actual practitioners do; or activities that foster the kinds of thinking and problem-solving skills that are important in outside of the learning environment. Putman and Borko (2000) argue that teacher knowledge is also situated within the context of the classroom and teaching. Thus, professional knowledge is developed in context, stored together with characteristic features of classrooms and activities within which it is developed, and accessed for use in similar situations. Professional development experiences situated in a variety of contexts are potentially valuable tools for helping teachers to change their instructional knowledge, beliefs, and practices (Putman and Borko, 1998/2000). Putman and Borko suggest that educators, when designing experiences intended for promoting new ways of teaching, must determine the kind of knowledge, skills and understanding that will enable teachers to teach in a new way, identify experiences likely to foster this education, and then determine the appropriate contexts in which to situate these experiences. Putman and Borko (2000) suggested three approaches to staff development that can be used to situate the learning experiences of practising teachers. One could be conducting activities at school sites, with a large component taking place in individual teachers' classrooms. Another is to have teachers bring experiences from their classroom to staff development activities. And the last is to have a staff development activity out of school for a number of days where theoretical and research-based ideas are introduced followed by ongoing support for a specific period of time.
To recap, in order to carry out any professional development activity in an effective way, we need to bear in mind the following:

- Teachers are learners and the principles of learning and transfer for student learners apply to them as well.
- To teach properly, teachers need expertise in both subject matter and teaching.
- Teachers need to acquire an understanding of theories of knowledge (epistemologies) that guide the subject matter they are specialised in and of pedagogy as an intellectual discipline that reflects theories of learning.
- Teachers need knowledge and skills that support their classroom and professional environment to be able to reflect and develop their own model of learning and teaching.

2.8 EFFECTIVE PROFESSIONAL DEVELOPMENT FOR TEACHERS OF SCIENCE

Much is already known and written about effective professional development for teachers in science and mathematics (e.g. Birman, Desimone, Porter & Garet, 2000; Garet, Porter, Desimone, Birman & Yoon, 2001; Loucks-Horsley, Hewson, Love, Stiles, 1998) as it plays an essential role in successful education reform. Professional development is essential because it serves as the bridge between where practising teachers are now and where they will need to be in order to meet the new challenges of guiding students toward achieving higher standards of learning and development. But every bridge requires careful design that considers its purpose, who will use it, the conditions that exist at its anchor points (beginning, midway, and end), and the resources required to construct it. Similarly, every professional development initiative requires a careful and unique design to best meet the needs of the teachers and the students to be served. In this section we shall discuss what constitutes such an initiative.

The professional development programs or initiatives that were effective in bringing about changes in teachers' behaviour and their thinking were found to have certain characteristics common to all. Garet et al. (2001) and Birman et al. (2000) identify six key features of effective professional development. They claimed that there are three core structural features that set the context for professional development and that have positive effects on teacher knowledge and skills and changes in classroom practices. These attributes were: that the
activities should focus on developing the teachers' content knowledge and on how students learn particular content; they should grant opportunities for active learning; and they should encourage coherent professional development experiences. It is primarily through these core characteristics that the following three structural characteristics significantly affect teacher learning, these are: the form of activities (e.g. workshops vs. study groups); the collective participation of teachers from the same school, grade or subject; and the duration of the activity. These attributes were a supplement to the list of Loucks-Horsley et al. (1998) which included fostering collegiality and collaboration, promoting experimentation and risk taking, involving participants in decision making about aspects of professional development and supplying appropriate rewards and incentives to participants.

Research, theory, and the wisdom of experienced, practicing professional developers suggest principles of effective professional development, which Loucks-Horsley et al. (1998) summarise into five parts:

1. **Professional development experiences must have students and their education at the core.**

   Science education that will yield high achievement for all students, requires a different perspective on the content students should learn and the teaching strategies that should be used by their teachers. To meet this challenge, all professional development resources, including teacher time, must be focused on rigorous content and the best ways to reach all students.

2. **Excellent science teachers have a very special and unique kind of knowledge that must be developed through their professional learning experiences.**

   Pedagogical content knowledge (Shulman, 1987) entails knowing how to teach specific science concepts and principles to young people at different developmental levels. This kind of knowledge and skill is the unique territory of teachers and distinguishes what they know from what scientists know. Knowledge of science content, although critical, is not enough, just as knowledge of general pedagogy is not enough. The goal of developing pedagogical content knowledge must be the focus of professional development opportunities for teachers.

3. **Principles that guide the improvement of student learning should also guide professional learning for teachers.**

   Learning principles are the same for children and adults; therefore, professional developers must follow the methods that they prescribe because people tend to teach in the ways in which they have learned.
Engaging in active learning, focusing on fewer ideas more deeply, and learning collaboratively are all principles that must characterize learning for teachers if they in turn are to apply these to helping their students learn.

4. The content of professional learning must come from both inside and outside the learner and from both research and practice.

Professional development opportunities must honour the knowledge of the practising teacher as well as draw on research and other sources of expertise outside schools and classrooms. Artful professional development design effectively combines theory and practice.

5. Professional development must both align with and support system-based changes that promote student learning.

Professional development has long suffered because of its separation from other critical elements of the education system, with the result that new ideas and strategies are not implemented. Although professional development is not a cure-all, it can support changes in such areas as examinations, assessments, and curricula, creating the culture and capacity for continuous improvement that is so critical to educators facing current and future challenges.

With these principles as a foundation, designers of effective professional development of science teachers need to proceed carefully and consider a number of different elements. Loucks-Horsley et al. (1998) proposed a design framework that organises the elements in ways that suggest how to design a new program. The elements constitute a four step cycle that includes goals, planning, implementation and reflection. In addition to the four central steps of the cycle, the design framework also considers four inputs important to the design process that designers of professional development need to draw upon:

1. The existing base of knowledge and beliefs about learning, teaching, the nature of science, professional development, and the process of change.
2. An analysis of the context in which the teachers teach and their students learn.
3. Attention to a set of critical issues that will help them to be successful or foil their attempts if neglected.
4. A range of strategies (15) for professional learning that can be used individually or jointly in different ways at different times to maximize various learning goals.
Knowledge and skills about learners and learning, teachers and teaching, the nature of science, professional development and the change process, are all essential. Some of the knowledge base was discussed in the preceding section. But, also of importance is knowledge of the change process. As Fullan (1991) indicated, extensive knowledge about how effective change occurs in an education setting needs to guide professional developers. Change is said to occur if there is evidence of change in teachers' ways of acting (demonstrated by new skills, behaviour, activities, etc.) and thinking (through acquiring new beliefs, ideas, understanding, etc.). Therefore, the relationship between thoughts and action is important in professional development (Loucks-Horsley et al., 1998). Guskey (1986) claims that a change in teachers' attitudes often results when teachers use new practices and see their students benefiting. On the other hand, Loucks-Horsley et al. (1998) argue that change is a mutual interactive process, whether ideas and attitudes or action and behaviour, change in one brings about and then reinforces change in the other. They further argue that fundamental change occurs over time, through active engagement with new ideas, understandings and new life experience. Change can be said to occur only when beliefs are restructured through new understanding and experimentation with new behaviours.

The context elements involve students, teachers, practices, educational policies, resources, organisational culture and structures, and other important factors. Therefore a thorough examination of the factors in the context that participants bring to the program also assists in design.

There are also critical issues that designers of professional development must consider to avoid failure. These may not all require attention at the onset but should be considered as the initiative or program unfolds. These issues include such things as finding time for professional development, scaling up resources, ensuring equity, and building professional culture, to mention just few.

The last element to consider is what strategies or approaches to adopt. Every professional development plan uses a variety of strategies in combination with one another to form a unique design. For example, in this study a workshop strategy amalgamated with exemplary lesson materials is used in combination with a technology strategy. Each strategy is one piece of the puzzle. How strategies fit together depends on the other elements of the design framework. The challenge is to assemble the combination of learning activities that best
The theoretical framework meets specific goals and context. A well-chosen array of experiences will promote teachers' opportunities for growth in many different areas of knowledge and skill, and in a wide variety of contexts.

2.9 MBL DESIGN AND TEACHER LEARNING

Integration of MBL technology into the traditional curriculum as lab equipment to simplify data gathering and analysis processes will have very little impact on students' ways of constructing scientific knowledge. Also, because it is much easier to process data with MBL, some students may actually end up worse off as they may lose even the skills to construct graphs. Teachers who will integrate (to make pedagogical and curricular changes to include MBL) the MBL technology in their curriculum need to be well versed in activity-based learning approaches to be beneficial to the students.

The major challenge is to orient teachers to learn how to teach with technology in ways that accommodate constructivist ideas about learning, and to learn how to create conditions for students to do science such that students get the opportunity to, at least partly, formulate their own theories and to build and validate their own models of whatever scientific idea they are learning. The new teacher knowledge requires a shift from the traditional approach to the current didactical approaches that emphasise:

- More active learning by starting from concrete situations and by stimulating classroom discussion, practical work and personal student investigations.
- More effective and motivating learning by treating content in a real-life context.

Teachers also need to have knowledge of good practices that lead to successful MBL learning, general laboratory skills and techniques related to MBL technology. They also need to have some basic knowledge of the system (hardware and software) before they can use MBL in the classroom.

Studies done elsewhere on computer integration into curricula are crucial to avoiding the mistakes others have made and defining the best practices. In a review of factors that influence teacher use of ICT, Mumtaz (2000) cited access to resources, quality of software and hardware, ease of use, incentives to
change, support and collegiality in schools, school and national policies on ICT, commitment to professional learning, and background in formal computer training to be the key ingredients to success. Others are important factors include sufficient time to learn, correct vision and rationale, technical and administrative support, and effective in-service training, which are seen by Wetzel (2002) as the essence to overcome contextual barriers to effective use of ICT by teachers.

These factors ought to be accompanied by a change in teachers' beliefs about teaching and learning with ICT. Teachers first need to realise and be convinced of the importance of ICT and its potential in teaching and learning, to become dissatisfied with the existing conditions, and view change as intelligible, plausible and useful for new situations. Hakkarainen., Muukonen, Lipponen, Ilomäki, Rahikainen and Lehtinen (2001) found that teachers who actively use ICT emphasise the importance of information technology for supporting a research-like process of inquiry, collaborative learning and the learner's active engagement in the knowledge-forming processes. The research also furnishes the researchers with evidence that there is a high degree of correlation between teachers' pedagogical principles that emphasis active construction of knowledge and self-reported pedagogical practices.

Bitner and Bitner (2002) established eight areas of consideration for teachers to successfully integrate technology into the curriculum. The areas of consideration are: fear of change, training in basics, personal use, teaching models, learning base, climate, motivation and support. The researchers found that teachers have fears, anxieties and concerns about changes involved in using technology for teaching and learning as it involves changes in classroom practices and use of often unfamiliar technology. Training that addresses these fears and helps them by various means to overcome them and realise the benefits of ICT in teaching is fundamental. Once the fears have been overcome, in-service training must provide teachers with a basic knowledge of computer use. Teachers are more confident using a technology they can handle in classroom. Training should not overlook the fact that teachers will use a technology when they understand the personal benefits of using such technology. Teachers also need teaching models for using technology in the classroom as well as conceptualisation on how the use of certain software facilitates teaching and learning. If learning is not the driving force behind using technology in school, it
will not work. Therefore, learning must be organised around the technology enabling teachers to use it to enhance students' learning and eventual understanding. In the teacher learning process, a climate must be created for teachers to experiment without fear of failure. Teachers need support and motivation in case of failure both during and after the training.

From the literature it is clear that any training to integrate ICT into the curriculum should focus less on technical skills and more on knowledge and skills related to application of ICT within a professional context. As the study intends to orient teachers toward more of a scientific inquiry teaching approach, with the MBL technology exploited as a tool, the knowledge and skills the teachers need to be trained for may embrace the following:

1. Exposure to student-centred (environment that pays careful attention to knowledge, skills, attitudes and beliefs that students bring to the educational setting) classroom teaching experiences. Through experience, training facilitators practise what they preach, and by doing so can learn more.

2. Exposure to practical ways of integrating MBL into the physics classroom, such as, by designing MBL lessons and micro-teaching them during the training sessions.

3. Support for teachers with exemplary lesson materials that are relevant to the running of these types of classes.

4. Help for teachers in acquiring management skills and new assessment techniques that focus on the understanding needed in order to operate a non-traditional type of classroom; e.g. how to work with few computers in a large class and still be productive. Formative assessment needs to be embedded in instruction as it can improve teaching and learning in science and learners can gain insight into their learning and their understanding (e.g. Treagust, Jacobowitz, Gallagher & Parker, 2001) Ensuring sufficient computer basics skills of teachers should be the starting point.

2.10 TEACHER LEARNING AND EXEMPLARY LESSON MATERIALS

Curriculum change as for teacher change is a difficult and complex process. Many studies of attempts at innovative curriculum changes have reported a lack of sustained impact on the classroom practice. Nonetheless, de Feiter et al.
Chapter 2

(1998) claim that successful implementation in southern Africa can be accomplished through the provision for intensive support settings. They recommend, among other things, the use of well-tried exemplary materials. Teachers, like others learners, need support in the form of materials to facilitate the change process. Curriculum materials designed to address teacher learning as well as student learning, are seen as one potential vehicle to support learning on a large scale (Ball & Cohen, 1996).


- clearer understanding of how to translate curriculum ideas into lesson practice;
- stimulation and reflection on one's own role with the eventual possibility of adjusting one's own attitude toward innovation;
- concrete foothold for execution of lessons that resemble the original intentions of the designers.

Voogt (1993) designed and evaluated materials to support teachers in the use of courseware in an inquiry-base science curriculum based on the same principles as van den Akker (1988). Voogt reported that teachers using teacher support materials kept their lesson approaches closer to the intentions of the designers of the curriculum. However, Voogt reported that teachers who used student materials to prepare lessons instead of teacher materials, performed considerably more poorly and were less active in supporting students.

However, Remillard (1999) in review of some research findings observed conflicting information. Some researchers claimed through observation that some teachers do not use the curriculum materials as the authors intended. Remillard reported teachers' struggle to understand the materials, noting a clash of their beliefs about the curriculum materials and the ideals represented in the materials. Remillard also reported that teachers consistently adhered to the topics in the materials, but departed from many accompanying teaching suggestions, particularly those not found on the student's page. The researcher added that teachers used student exercises in the texts considerably more than review sections, teacher directives, enrichment and additional practices.
Remillard (1999) reported findings suggesting that teachers' knowledge of and views about the curriculum materials, their perception of text, their perception of external pressure, and their ideas about the purpose of school and nature of learning all influence the teachers' materials decisions. Remillard observed that curriculum developers usually focus on providing activities for students by speaking through teachers. However, students encountering a new curriculum are mediated by a variety of teachers' decisions, which are based on the interplay between the teachers' reading of the materials and the students' performance, and their beliefs about teaching and learning of particular subject matter.

Though there is no clear-cut view on this issue, some effort has been made by a number of researchers to focus on the characteristics of such materials. Ball and Cohen (1996) argue that development of such materials can put teacher learning at the center of the effort to bring about educational change. Ottevanger (2001) developed teacher support materials for science teachers based on principles formulated by van den Akker (1988). Van den Akker identifies four key areas that the material should address: lesson preparation, subject content, pedagogy and learning effects. As the materials are to be implemented, a large amount of specific information and direction of the teachers' role in the execution must be included. Wormstead et al. (2002) reported on research about the design of support materials for science teachers. The materials were supposed to enable a better understanding of scientific concepts and methods, and to ensure that these concepts and methods are presented to students in ways that are motivating and engaging. They identify and recommend a set of design criteria for such material, which are generally similar to van den Akker, including classroom management practices for inquiry-oriented learning.

Schneider and Krajcik (2002) designed teacher support materials that address teacher learning as well as students learning. The materials included information explaining content and pedagogy, as well as specific information about strategies, representations, and students' ideas (i.e. pedagogical content knowledge abbr. PCK) embedded within lessons. The lessons incorporated five design principles, which include (a) addressing each area of knowledge necessary for exemplary practices; (b) facilitate teacher learning by interconnecting the content of support to lessons for students; (c) linking different knowledge areas within lessons; (d) making knowledge accessible to teachers including useful short scenario and; (e) addressing immediate needs
for understanding as the teacher plans lessons. Though the materials were tried on a very small scale, researchers found that the teacher used and learned from the lessons, and concluded that PCK may be a useful construct for designing educative curriculum materials.

Ottevanger (2001), building on previous research (van den Akker, 1988; Voogt, 1993) incorporated procedural specifications as central to the design of the materials. Those procedural specifications addressed essential areas of the lessons to focus teachers on 'how to do something' in order to illustrate specific change. Materials designed that way proved to produce results more in line with intentions.

Clegg and Osaki (1998) in their observation recommended that teacher guides include lesson plans with diagnostic tests to assist teachers with monitoring student learning and in modifying the daily lessons accordingly, as well as suggestions on classroom management practices and activities for classroom use.

Exemplary materials are important as they illustrate to teachers what and how good teaching materials that accompany good classroom practices look like. Development of such materials is essential in helping teachers bring about instructional change in the classroom as long as classroom practices are taken into account.

Exemplary materials used in this study refer to materials that can assist teachers both in designing new lesson plans and in implementing curriculum reform in their classroom.

2.11 IMPLICATIONS FOR THIS STUDY

2.11.1 Design considerations

This chapter has explored different views in different topics from a variety of literature, which portray a picture of what the study requires and draw from it a framework that could be a platform for designing teacher support materials and students' lesson materials for teaching and learning physics lab work. Based on the review of relevant literature provided by this chapter, discussion now turns to the specific implications for the design and implementation of
activity-based lesson materials for learning in an MBL-supported environment. The topics covered include current learning and teaching theory, activity-based learning, lab work, the potential of ICT for activity-based learning, MBL, MBL as a tool for activity-based learning, teacher learning, effective staff development, MBL design and teacher learning, and development of exemplary lesson materials.

A discussion in section 2.1 about the current view on learning and its implication on teaching has resulted in some interesting conclusions. First, students are actively involved in their learning process, through the use of learning activities that require active mental involvement in which students' prior knowledge is taken into account. Second, the learning processes should be guided by teacher and/or learning activities toward the intended learning outcome. Third, the learning activities should be designed such that interaction among students or with teachers is fostered. Finally, students have to be willing to learn in this new way.

These findings have implications for classroom activities with the potential to promote that kind of learning. Activity-based learning was seen as the best candidate and was discussed in depth. Of the many forms of activity-based learning that can be implemented, lab work was considered the most appropriate for the study as it has potential to help students learn about the nature of science, science process skills, and facilitates the understanding of concepts. However, research confirmed that traditional lab work is not an effective learning activity to many student due distractions provided by a variety of sources during lab sessions. MBL was observed to be the solution to traditional lab work problems and can be effective if well integrated in the curriculum.

Students who are to learn in a new way need teachers who are knowledgeable, skilled and share the beliefs that promote this new way of learning. Additionally, those teachers need support in the form of lesson materials to guide them in this new way of teaching. Consequently, some sections of this chapter discussed the teachers learning process in a professional learning environment, and how materials to support their new teaching should be designed.
Some guiding principles are vital to shaping the process of designing, developing and implementing the exemplary lesson materials and the learning anticipated. Such learning instructions have to serve two purposes, to engage learners actively in the learning process and to help teachers integrate computers into physics laboratory lessons. These guiding principles encompass the following:

i. To bring about a meaningful learning, MBL-supported learning activities must be designed according to sound learning theories and pedagogy.
   a. Design and development of student activities should take into account students' prior knowledge. Consequently, teachers' guide material must focus on providing guidance tasks and activities that can reveal student thinking.
   b. Learning materials should have frequent formative assessments, which will help students make their thinking visible to themselves, to their peers, and to teachers. Such assessments grant feedback to students that can guide modification and refinement of their thinking.
   c. Collaborative processes, through which increased knowledge and understanding are fostered, should be embedded in the teaching and learning.

ii. The learning materials should have an in-depth coverage of topics in which the predict-observe-explain sequence is adopted for each lesson.

iii. Minimum guidance should be provided to students on what to do, what to look for, etc. in the activities, to allow them to think independently.

iv. Teacher materials have to cover appropriate content, with guidelines on how to, exemplary questions, and PCK information useful for teaching a topic.

v. The design of the in-service education and its implementation strategy must ensure promotion of teachers' opportunities for growth. This pertains to many different areas of knowledge and the skills essential to activity-based learning with a computer, and in a variety of classroom learning environments. This includes initiating teaching approaches that exploit attributes of the MBL technology.

2.11.2 Some thoughts about innovation adaptation

Part of the motivation behind this study to explore the characteristics of preparation and support to teachers in using MBL-supported materials, which can influence classroom practices in the Tanzanian context, is the fact that little
has been done in this area. While many studies have examined classroom problems of teaching and learning science (e.g. Osaki, 1999, Chonjo et al. 1996), teacher education (e.g. Trowse, Kent, Osaki & Kirua, 2002) and science education curriculum reforms (e.g. Ogunniyi, 1996) in this context, few, if any have looked at preparation and support for MBL-supported exemplary lesson materials for science teaching. Research in other settings has confirmed the notion that the arena of computer-based learning and teaching contains great potential to contribute to science education improvement.

Despite the known potential of ICT in science learning and teaching, some insights through exploration are needed to find out how it translates to a different setting. The success of transplantation of ideas depends on accurate working knowledge of the target setting and a careful analysis of whether a particular innovation would be appropriate there. This is well illustrated by de Feiter et al. (1998) on the adaptation of curriculum ideas developed somewhere else to a Southern African context. Based on their experiences, they cited ideas, some of which are worth considering, in the later stages of the study. These ideas are the following:

- It is worthwhile to invest a great deal of time into developing teacher support materials with appropriate guidelines.
- Staff development needs to be organised locally to ensure regular teachers' participation.
- Coordination between school leadership and staff development programs is essential.

Based on the information discussed in this chapter, some conclusions can be drawn about what sort of intervention may be needed, what kind of lesson materials are essential in that intervention, and in which mode such intervention should be carried out. Taking into consideration the contextual information described in chapter one, a skeleton structure of the intervention becomes clear. The intervention may be incomplete without some of the following elements that are essential if teachers are expected to introduce science inquiry, with the help of MBL technology, into their teaching. These elements are:

- mastery of computer basics and MBL philosophy;
- knowledge about misconceptions and how they affect learning and understanding;
- techniques and strategies for a student-centred teaching approach;
knowledge necessary to design lab lessons emphasising conceptual understanding rather than measurements and that correlate the conceptual understanding to real life experiences;
• classroom management skills for MBL-based class and
• establishment of collegiality that can evolve into a physics-teacher network.

In the coming chapters these implications will be elaborated further.
CHAPTER 3
Prototyping of in-service and lesson materials

This chapter focuses on the design and development of evolutionary prototypes of the in-service programs and exemplary lesson materials. The early prototypes of both the programs and exemplary lesson materials were evaluated and the results of the evaluation were used to improve the quality of the latter versions. A development research approach guided the progression of the evolutionary trial products. In section 3.2 a more elaborate discussion on development research as it applies to this study is engaged. Sections 3.3 and 3.4 focuses on design principles of lesson materials and in-service programs respectively and eventually formulate design specifications. Section 3.5 concerns the development of both teachers and student lesson materials. Finally, the chapter discusses different phases of in-service programs and how the materials were introduced and integrated into the programs in section 3.6.

3.1 INTRODUCTION

The literature review in chapter 2 generated information out of which important guidelines necessary for this chapter was synthesised. However, most of the researches (and corresponding findings) as presented in the previous chapters were done in contexts quite different to where this study took place. Therefore, it is impossible to determine beforehand the extent to which these findings apply to the Tanzanian context. The contextual differences prevent a direct application of research findings from one context in the other. The difference necessitates repeated experimentation with findings from one context to the other in small scale before large-scale application is sanctioned. In each of these repeated experimentations, appropriate adjustment (successive approximation) is made in the context until a right kind of results is achieved. A development research approach seemed to be a plausible approach in this case. Development research introduced earlier in chapter one, manifest in the phases of analysis, design and development, and formative evaluation. In the previous
chapters the context analysis and review of the literature were presented. This chapter focuses on design and development and formative evaluation of both lesson materials and in-service program adopting development research approach.

On various occasions we make use of a specific curriculum framework. Curriculum is a complex multi-dimensional concept, made up of myriads of elements that may be viewed in multiple perspectives with varying degrees of versatility existing in various representations related to the educational system. The representations are manifestations of curriculum ideas bound together. These representations as formulated by Goodlad and colleagues (1979), and then adapted by van den Akker (1988) include:

- **Ideal** curriculum – as it lives in the mind of the designer (designer's intentions).
- **Formal** curriculum – the written form of curriculum documents.
- **Perceived** curriculum- as the teacher or other users interpret (perceive) the curriculum.
- **Operational** curriculum – how the curriculum reveals itself in the classroom as carried out.
- **Experienced** curriculum – how the curriculum is experienced by students in classroom.
- **Learned** curriculum – as the curriculum is disclosed through learning outcomes (achievement).

Later in this book we will use somewhat broader concepts, such as 'intended' (a combination of ideal and formal) 'implemented' (combination of perceived and operational), and 'attained' (experiential and learned). This range of representation illustrates curriculum evolution, and this evolutionary representation will recur more and more in this chapter and occasionally in the rest of the study.

### 3.2 Development Research

As we have already seen in chapter one, development research is based on the assumption that both theory and practice play an important role in developing and testing adequate solutions to learning and teaching problems. It helps to improve educational practices and at the same time yield scientific output. This research approach is chosen for the study for a number of reasons.
The study intends to propose solutions to the research questions and the solution must fit the local situation. The local situation embraces cultural and contextual factors. These factors are non-uniform for two places with the same problem, they change from place to place. It is very rare for two places with similar problems to require exactly the same solution, because cultural and contextual differences may obligate the solution to be adopted slightly differently. Similarly, solutions for educational problems in the western world may not produce similar results if adapted directly to a similar problem in Tanzania. To realise a practical solution to the problem, we need a formative research approach in which a design based on validated model that is then tested and revised during the practice is used. Such evolutionary intervention yields greater opportunities for coping effectively with contextual and cultural factors and increases the practical relevance of the solution to the local situation. Development research approach is the more obvious choice as it speaks to the potential conflict (cultural and contextual) and can provide successful approximation of interventions in interaction with practitioners.

Thinking from implementation perspective, collaboration between teachers and the researcher (designer) in the design and development of both lesson materials and in-service program is necessary. Such collaboration gives teachers a sense of ownership of the innovation and increases the chance of proper implementation on one hand, but also on the other hand provide the designer with firsthand information of the context, as the teachers understand it. The input from teachers, not only help the designer better understand the context in which it will be used, but also consolidate the understanding of teachers' needs. Development research advances this kind of collaboration to make the solution viable to practising teachers.

Thirdly, the lesson materials designed and developed should fit into the current running curriculum. If the materials are de-linked from the curriculum, teachers will not be interested in adopting them in their teaching. This implies that the design approaches, in which prototypes are developed in collaboration with users, can optimise the link between the existing curriculum and new curriculum materials. With such curriculum materials in place, authenticity can be established.

Finally, the development research approach brings in new insight about the context, proposed solution and better educational product. This is because,

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1 Prototype is used as preliminary version of lesson materials made before full version is developed.
design and development efforts of the curriculum materials and in-service programs are evolutionary in character. Of importance is evolutionary development for both curriculum material prototypes and staff-development programs. The prototypes are developed by the designer, field-tested and evaluated by the user continuously during the development and evaluation process, in a cyclic manner. In each cycle, the evaluation yields some insight that can help to improve or optimise the prototype, thereby contributing new knowledge as a result.

In the design, development and initial implementation phases of the lesson materials and the in-service program, the application of development research approach is evident. Different phases of prototypes, which were to be evaluated, had to be created in a cyclic process until reasonable and acceptable exemplary lesson materials were achieved. The design and development phases evolved around three evolutionary cyclic developments of both lesson material prototypes and in-service programs. Figure 3.1 below shows a graphical representation of the design of the materials and staff development.

**Figure 3.1** Design and evaluation of the in-service scenario

### 3.3 DESIGN SPECIFICATIONS FOR MBL-BASED LESSONS

#### 3.3.1 A brief introduction to instructional design

This section discusses the instructional design process of the materials needed for this study. Instructional design is a systematic approach to planning and
producing effective instructional materials. Through it, the general principles of learning and instruction are translated into elaborate and detailed plans for instructional materials and learning (Reigeluth, 1999). The designer, whose main goal is to make learning easier, quicker and more enjoyable, has to consider a number of elements during the instructional design process. These essential considerations are summarised and simplified in an instructional model, which is a visualized representations of an instructional design process, showing the main elements or phases, and their relationships. Currently there are number of instructional models developed over the period of forty years, which can guide the designer in realising the purpose of instruction, which is to help someone learn. These instructional design models have the ambition to provide a link between learning theories and the practice of building instructional systems. Traditional models are shaped around the core elements of the instructional design process. These elements are analysis, design, development, evaluation, implementation and revision (Gustafson & Branch, 1997), and are related as illustrated in figure 3.2.

The first step of the traditional instructional model is analysis of specific inputs related to the educational problem the instruction intends to solve, such as learners' characteristics, and learning environment or context in order to determine the educational needs. In this phase the current situation is examined and the desired output is established.

The design phase take the information from the analysis phase and use that as the basis for developing educational goals. The educational goals describe what the situation will be upon completion of successful educational experiences. Educational objectives are written based upon these goals and a consideration of the target learners. In this study the learning goals had to consider the overall aims of the lesson materials in terms of providing support to teachers and learning to students. Also had to consider learner-oriented goals and objectives associated with activities and events that incorporate MBL technology to enhance the learning of physics.
The design describes *what* is to be accomplished; the development phase describes *how* to accomplish this. The development phase is where goals are expounded to instructions. The first step is to identify what factors are likely to promote effective instruction. Then consider various options for providing the instruction consistent with these important instructional factors. These options for instructional delivery include different instructional methods and different media for delivering the instruction. The next step is to select the most appropriate strategy from among the options.

Implementation traditionally (in a series of linear instructional design steps) has been seen more as a phase after development. However appreciation has grown for integration of the implementation perspective through the entire instructional design process (van den Akker, 1994).

Evaluation plays a major role in instructional system design by providing information to determine whether the learners are acquiring the desired knowledge, skills and attitudes, indicating specific weaknesses for individual students, determining the effectiveness of the instruction, determining how well the total instructional system is working and providing a means for identifying necessary revisions. The data collected in the evaluation form the basis for many crucial decisions. Evaluation does not have to wait till development
Prototyping of in-service and lesson materials

Revision is based on comparison/contrast of evaluation findings and the original intentions of the design in any phase of the design process.

3.3.2 MBL-supported lesson materials design

As we have seen in chapter one, lab activities in Tanzania do not help students to understand how nature works through recognizing patterns in nature and predicting them by doing science. The activities leave students with the impression that there is a recipe out there that can be followed to discover nature and does not motivate students to like lab work. This view is reinforced because (a) student are given step-by-step instructions focused on doing the lab task as efficiently as possible; (b) the lab instructor (in most cases, teachers) spends a considerable amount of the lab time helping students get their apparatus working so they can get the work done; (c) the lab instructions have all the necessary information, so the students do not need to use the textbook or recall the lecture; (d) the labs do not solve any problem and even if there is any, the problems are not seen as challenging; and (e) there is no reference to the labs in the lectures or on tests. This kind of lab work does not benefit students very much cognitively. Instead it encourage students' attitude towards laboratory works to be, "take-the data-and-run".

However, the kind of lab work that this study aspires is activity-based, supported by MBL technology. It is clear from chapter two that, the use of MBL enables real-time and accurate measurements, and can be used to actively engage students in learning and motivate them as well. In a constructivist perspective that students learn best through active engagement in their own studies in an environment that encourages them to actively examine, reconstruct and communicate their own knowledge and understandings. Integration of MBL into the physics curriculum, which is currently very much traditional, will require restructuring of the learning environment to create a more efficient and meaningful learning environment. Students have to engage mentally and physically, communicate findings through class discussion, writing in lab guides, or informal student conversation in small groups. Teachers have to be facilitators of the learning process.
The implications of the content analysis and literature review warrants an intervention that includes situating instruction in a context, facilitating learners to share ideas and information, and encourage students to explore questions in order to develop in-depth understanding of science content and processes. This calls for help to students in these key areas, students' motivation to concentrate on the activities; learn how to learn for understanding scientific concepts and principles, problem-solving that encourage transfer, and acquisition of science process skills. Based on the literature review in chapter 2 and the need to improve lab work in secondary education in Tanzania, the following guiding principle are proposed to facilitate the design of the instruction:

- **Problem-Solving**: Inasmuch as we have seen in chapter two, problem solving is one of the characteristics of activity-based learning. The design of all activities is geared towards solving a particular problem using scientific principles. This is encouraged because, students who acquire scientific knowledge in situations which it will likely be used are more likely to retain what they have learned, and apply that knowledge appropriately (Benoit, 1998; Myers, Botti, & Pompea, 1997). Such approach motivates students to search for underlying principles and concepts for solving the problem at hand. This approach helps students to see usefulness of learning through application.

- **Life Application**: Also emphasises in activity-based learning is students' ability to apply the learned knowledge. The lesson activities ensure students can relate learned principles to everyday life experiences. Students learn information better in the format in which it will be used and are more internally motivated to solve the problem because of its realness (Myers et al, 1997). Real-world application of classroom learning facilitates conceptual understanding of science. Problems and experiments that relate the basic physics principles to the real world are encouraged. For example, students can be asked to use equations of motion, Newton's laws, work and energy principles and conservation of momentum in two dimensions, to analyse an automotive accident report.

- **Knowledge integration and transfer**: This refers to process of making sense of science, such as linking and connecting new and existing ideas; and being able to apply understanding learned in one situation to a problem or issue encountered in another situation (Linn & Hsi, 2000). The lessons and teaching should assist students translate learning into a lasting impact. The lessons should encourage students to practice making decisions based on the
physics presented say in a lecture or in the other parts of the class. The activities should demand from students several things: connect new knowledge to old; recognise what they know and understand - and what they do not; learn concepts thoroughly so they can explain and 'teach' in their own language.

- **Hands-on Experimentation**: From a constructivist viewpoint, individuals construct knowledge of scientific phenomena for themselves. That knowledge (meaning) or understanding is not simply transferred and received but is built within the individual students through their interactions with the natural world. Instructional models that incorporate hands-on investigative activities appear to best address developmental needs of students. The 'hands-on' experience may also contribute to overcoming misconceptions about physical phenomena.

- **No theory specification**: No detailed discussion of the principles explored by the lab activity; or any algebra to be used in the lab activities. This is to emphasise that the laboratory is an integral part of the entire lesson. The theory is available in the textbook and the preparation section for each activity gives direction on which sections of the text are to be read.

- **Minimal Lab Instruction**: The activities do not have step-by-step recipe kind of instructions telling the students what to do. Instead, students are guided through in first making predictions, then in performing the experiment and making observation, finally comparing the predictions and observations, and try to reconcile the differences if there are any. Students are asked to explain meanings of the graphs they create, describe the principle(s) in their experiments and talk about their conclusions to assist the reconciliation (Linn & Hsi, 2000). Such freedom allows students to make choices. In some cases they will make incorrect choices (cliché, we learn from our mistakes) that will allow the teacher to teach the needs of the particular students.

- **Collaborative learning**: The activities force students to work in groups of three or four. Heller and Hollabaugh (1992), have found that groups of three work a little better than pairs or groups of four. Students working in groups discuss what their thoughts are — practice 'talking physics'. Such discussions tend to bring their physics alternative conception to the surface so they can deal with them. Working in the same group in both laboratory and discussion sections allows students to become more familiar with each other so that they feel comfortable enough to discuss their physics difficulties. Research has shown that student' achievement is enhanced when they work
together in a co-operative learning environment (Schacter & Fagnano, 1999). Use of co-operative group learning fosters the development of learning communities in the classroom that reduces the high competitiveness and isolation of typical science course (Schacter & Fagnano, 1999).

These principles call for a different didactical approach that gives students a guided freedom to explore nature. Such approach will entail teaching that require students to work collaboratively in small groups, teacher determining the activities in the lessons, the lesson activities have elements which integrate learning and real life, and learning is by doing. These principles were also used as basis for distilling design specifications for the students' exemplary lesson materials, of which the lesson structure described below was developed.

- **Introduction:** A brief introduction gives a general overview of the problem to be solved. It may include some definitions of concepts, tell students the specific concepts, principles, and other ideas that will be raised and addressed during the activity. If the problem to solve requires a series of experiments, the introduction may include a brief overview to clarify why those experiments and so on.

- **Objectives:** Objectives of the lab work are clearly stated at the beginning so that student is aware what will be achieved at the end of the lesson.

- **Preparation:** Reference readings, chapters or sections of certain textbook where students can gather prior knowledge, mathematical skills and any necessary prerequisite are mentioned in this section.

- **Problem Statement:** The statement describes why doing the lab problem? How the problem is related to the real world? It describes a possible situation that raises the problem students are about to solve. This emphasizes the application of physics in solving real-world problems.

- **Equipment:** To make a prediction about what students expect to happen, they need to have a general understanding of the apparatus they will use before they begin. This section contains a brief description of the apparatus and the kind of measurements students can make to solve the laboratory problem. The details should become clear to students as they use the equipment.

- **Prediction:** One purpose of the lab is to help students clarify their conceptions of the physical world by testing the predictions of their personal theory against what really happens. For this reason, students have to always predict what will happen before collecting and analysing the data. Their predictions have to be completed and written in their lab journal before they come to lab.
- Method Questions: Method questions are a series of questions intended to help students solve the experimental problem. They either help students make the prediction or help them to plan how to analyse data. Method Questions should be answered and written in students’ lab journal before they come to lab.

- Exploration: Students take some time to carefully explore the experimental plan. In this section students practice with the apparatus before they make time consuming measurements. Students carefully observe the behaviour of the physical system, before they begin making measurements. Students also need to explore the range over which the apparatus is reliable. Most apparatus has a range in which its operation is simple and straightforward. This is its range of reliability. Outside of that range, complicated corrections need to be applied. Students should record their observations in their lab journal. If a student observes that the apparatus does not function properly for the range of quantities she/he was considering measuring, they can modify the experimental plan before they have wasted time taking an invalid set of measurements. The result of the exploration should be a plan for doing the measurements that student need. Students record measurement plan in the journal.

- Measurements: After students have predicted the result of the measurement and have explored how the apparatus behaves, they are ready to make careful measurements. To avoid wasting time and effort, students make the minimal measurements necessary to convince themselves and others that they have solved the laboratory problem.

- Analysis: Most interesting quantities are those derived from analysing the data, not the direct measurements themselves. Besides, students' predictions may be qualitatively correct but quantitatively very wrong. For students to discover (realize) this they must process the data. Students are advised always to complete data processing (analysis) before they take the next set of data. If something is going wrong, they shouldn't waste time taking a lot of useless data. After analysing the first data, they may need to modify the measurement plan and re-do the measurements. If they do, they should record the changes in plan in their journal.

- Conclusions: After have analysed the data, students are ready to answer the experimental problem. They state the result in the most general terms supported by analysis, but must compare the results to prediction.
Reflection: After finishing collecting, processing, analysing and drawing conclusions from the data, students re-examine their answers to look for patterns. They are also asked to generalize, abstract, and relate concepts to the situations they have studied.

Exercise: These exercises are to help students think deeply about the activity and in some cases the exercise may involve students applying the learned concept to a different context, to facilitate knowledge transfer. The idea is also to try to make the questions relevant to life of students as much as possible and hard enough to require group work.

In contrast, teacher support materials compliment student material, with the same structure but with extra suggestive information to guide teachers on how to effectively implement the materials in classroom. The support materials were designed as a teacher guide to the student lessons. The teacher materials have to provide teachers with procedural specifications on how to prepare such activities, how to guide students to carry the lesson out and how to draw conclusions from the activities. This important requirement was maintained in the design phase of the materials. The teacher support materials evolved simultaneously with lesson materials, from one prototype generation to another.

Each time a new prototype of the curriculum materials was designed (later developed and initially implemented), the quality aspects were given highest priority. Quality is a concept that means different things to different people depending on criteria and distinguishing characteristics used to define it. In this study three aspects of quality were identified and defined. The quality aspect of validity, practicality and effectiveness, which are central to this study, were carefully defined (cf. McKenney, 2001).

Validity refers to lesson materials that contain state-of-the art knowledge, which is relevant to student learning, and has components that assure internal consistency (e.g. in subject matter, skills, attitudes, pedagogy and assessment), in an integrated and logical way. In this study, such knowledge relates to curriculum materials developed as well as contemporary thinking on how students learn and its implications on effective teaching. The design phase could only take care of subject matter, but latter phases of development and initial implementation furnished the rest needed for validity of the curriculum materials.
Practicality implies usability of the materials by teachers to execute lessons in a logical and coherent manner without many constraints. Further illumination of the aspect has been inspired by Doyle and Ponder (1977), who highlight three dimensions of practicality, i.e. instrumentality, congruence and cost. Instrumentality (depicting real-world contingencies) relates to clarity and procedural specifications for implementing change. Congruence (a match between proposed and prevailing conditions) refers to the degree of proposed change fits the prevailing conditions. And the notion of cost (ratio between amount of return and amount of investment) refers to time and effort the teacher invests in order to gain return of implementing the change. The usability of materials is credited if the three dimensions are satisfied.

Effectiveness of the materials can be viewed in three ways. Firstly, the extent to which teacher can transform the materials into lessons which are in accordance with developers' intentions (similarity between ideal and operational curriculum). Secondly, it looks on how students experience the lessons (congruence between ideal and experienced curriculum). Thirdly is the extent to which ideal curriculum translate into student achievements (attained curriculum). This study however will not consider student achievement, so it might be more appropriate to talk about impact potential of the lesson materials for the link of the ideal and attained curriculum.

### 3.4 Design of In-Service Workshops

Staff development possesses a useful 'craft knowledge' that guides the field. This craft knowledge includes ways to organize, structure, and deliver staff development programs. Loucks-Horsley et al. (1998) indicated that, goal setting; planning, implementation and reflection are the four major steps necessary to any effective staff development program. The first step is to define the purpose or goal of the staff development program. The purpose of the staff development program in general is to support professional development experiences for teachers that will enhance classroom teaching and, ultimately, improve student learning. Specifically in this study, the main goal of the in-service programs was to prepare teachers to teach MBL-supported physics in an activity-based learning environment.
To actualise the goal, other inputs that could shape the design process, were considered by the designer in the decision-making process. These inputs comprise deciding how knowledge and beliefs of the teachers influence the design, what features of the context to consider, and which is the best strategy to pursue in the implementation. In general, it was important to fully perceive how the staff development preparation cycle unfold from goal setting to reflecting.

By tapping on the available knowledge base about learning, teaching and professional development, some guiding principle were developed, which were held as framed beliefs about the in-service program. The guiding principles were:

- All teachers are educable and capable of making the change.
- The inquiry approach must be built around observations and experiences, and in meaning making, by both teachers and students.
- The pedagogy of the in-service program must be congruent to pedagogy desired in the classrooms.
- In an activity-based approach to science teaching, technology is used as a catalyst.

The repercussions of these principles in the design of in-service program are these:

- All A-level physics teachers can be invited to participate in the training as long as the school-principal permits.
- The materials to be used in the training should emphasis observation skills and meaning making practices.
- Current learning and teaching theories must be introduced to teachers and the pedagogy the participants practice during the in-service program must also emphasis inquiry during peer discussion and teaching.
- Lesson materials must also help teachers to integrate MBL technology in the physics curriculum.

In the study the context was made up of many dynamic and interconnected entities, and each strengthened (modified) the design. The A-level students, who were the ultimate beneficiaries of this effort, have experienced traditional lab work and very little was known about their computer literacy level. The lab work they were used to was never directly linked to classroom lectures. Teachers on the other hand had enough content knowledge but deficient in
current knowledge about how their students learn (Osaki, 1999). They also lack knowledge and skills needed to integrate the computer in the physics lesson, as MBL was not part of the national curriculum. The pedagogy the teachers were familiar with was chalk and talk (Chonjo, et al., 1996). Teachers hardly use strategies that engage students in active learning and inquiry, in communicating scientific ideas, and problem solving as the study intends. The schools hardly had any in-service programs for teachers for lack of essential resources. School heads were cooperative and willing to release teachers during student-vacation to attend in-service education. Therefore the designer had to glean from the influence of both the context and knowledge base available about learner and learning, teacher and teaching, effective staff development, change and change process, in the planning in order to set success scenario for the in-service program.

Another important input to the design is choice of appropriate strategy for carrying out the in-service program out of numerous strategies in existence. The in-service education intended to be an opportunity for teachers to learn from a facilitator with MBL expertise as well as from peers. The occasion had to take place outside schools to give teachers from different schools opportunity to focus intensely on MBL-based physics teaching for an extended period of days. The occasion also was to be characterised by hands-on activities for participants to help them try ideas and lesson materials. According to Loucks-Horsley et al. (1998) the strategy that could accommodate all these requirements for success and implementation purposed is workshop strategy. Therefore workshop was the strategy for in-service education employed for the study.

As we have seen the quality of staff development is influenced by a variety of factors which can be classified into three major categories: content characteristics, context characteristics, and process variables. Content characteristics concern primarily the new knowledge, skills and understanding that are foundation of staff development effort. Content includes a deeper understanding of the academic discipline as well as pedagogical processes. Context characteristics involve the organisation, system or culture in which the staff development and new understandings will be implemented. Process variables refer to type and forms of activities, the way activities are planned, organised and followed-up. An important aspect to think and plan about is how the workshop strategy can be implemented.
There are good numbers of reference models mentioned in the literature to guide the phases of activity in the workshops. However the models support large-scale projects, theory driven, with many resources available to support many teachers in large area for considerable amount of time. In this study we need a model that support small-scale projects, where little is known about the whole context. In our in-service education, we intended to improve both the learning materials and teacher knowledge and skills first before classroom trials were done in a few schools and then if possible, replicate the exercise for more schools and a much larger area. Consequently an evolutionary model was needed. This model is based on the assumption that perfection is achieved through practice. The core of the model is the idea we learn by doing which revolve around first trying the proposed program/lesson, evaluate the effectiveness, modify based on evaluation results, and try again till perfection is attained. This idea stands on three keystones that orient the designer to focus the activity phase:

- Link prior knowledge to the new knowledge
- Learn by reflecting and solving problems
- Learn in a supportive environment, sharing problems and success.

This model concurs with our earlier desire to carry out the study in a developmental research approach. Thus by doing, we learn, and the feedback from learning guides us to perfect our method.

### 3.5 Prototyping Lesson Materials for Teachers and Students

The evolutionary prototyping approach idea introduced earlier in this chapter implies that the first draft (prototype) of lesson materials was iterated towards more definite version through continue refinements based on reflections of formative evaluation results. The third and final version can be considered the latest version. In this study the final version had more content-knowledge than the original prototype. This will be clear later in the chapter why it ended up that way. This section describes how the first prototype was developed.

The content of the part developed for the first prototype is described was taken from the mechanics\(^2\) section of the curriculum. The material consisted of lesson series aimed at assisting students to explore and learn about momentum and conservation of energy concepts. The topic was chosen because it is covered in the Tanzanian physics curriculum and also because evidence stemming from

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\(^2\) Mechanics is the study of motion and its causes.
literature claim students have difficulty understanding why and when to use energy and momentum concepts to study a phenomenon (Grimellini-Tomasini, Pecori-Balandi, Pacca & Villani, 1993; Lawson & McDermott, 1987). Energy is a fundamental concept in physics, necessary for understanding a wide variety of phenomena of importance to science, and the barrier to learning is of significant value. In addition, many topics in intermediate and advanced physics courses are based on energy and momentum concepts, more so than on kinematics and Newton's Laws. The application of conservation laws to solving problems and gaining deeper understanding is also a fundamental part of learning and doing physics.

The lessons series were made according to the lesson format described in section 3.3 above. The student materials were developed so as to enable students to use laboratory set-up, based on the principle of the ballistic pendulum, which were appropriate for computer-aided student investigation of momentum and the principles of conservation of momentum and mechanical energy in collisions. The set-up consists of two colliding carts on a low-friction track, two motion sensors, a force sensor, set of masses, and computer equipped with MBL interface and software. Position, velocity, momentum, kinetic energy graphs could be plotted against time data for each cart by using two motion sensors connected to the MBL interface. With the motion sensors and software for CoachLab II$^3$ interface, the behaviour of the kinetic energy and momentum of each cart individually, as well as the total kinetic energy and total momentum, can be viewed in real time. We believed that this set-up is suitable for helping students gain understanding as the processes involved are simple to follow visually, to manipulate, and analyse.

Teacher's Guide materials also includes (1) a specific plan outlining the necessary instructional procedures for the effective implementation of each lesson of the series, (2) supportive background information to assist teachers in their own understanding of the physical concepts, (3) questions to explore common applications of the concepts, and (4) test questions for the assessment of student understanding.

The materials developed were the first prototype of the exemplary materials to be developed. The second and third prototypes were designed after teachers used

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$^3$ A multifunctional MBL hardware interface, a product from CMA- Amstel Institute, Amsterdam, The Netherlands.
the materials in a workshop setting, where they recommended some few changes and requested additional topics to enrich the prototypes. The development of the second and third prototype adheres to the design specification and also incorporated evaluation knowledge gathered from the previous prototype.

The exemplary lesson materials were developed with quality consideration discussed previously in mind. Validity as one of the aspects was secured by number of activities carried out in the development phase.

i. Both lesson series and teacher support materials were reviewed by a number of content and pedagogical experts from the University of Twente, Utrecht University, Educational Faculty Amsterdam (EFA) and the university of Amsterdam, before teachers in a workshop tried them out. The expert input provided clear directions for the designer of the materials. The national curriculum provided prescription of the content of the topics. The teacher support materials (teacher guideline) complemented the design of student materials.

ii. State-of-the-art knowledge was used to draft design specifications for the prototype of the materials.

iii. Design and development of the materials were based on part i and ii above.

Practicality at this stage was tested in the in-service workshops where the prototypes were tried. In general teachers demonstrated that they were able to use the support materials without many problems, after they got used to the new style of teaching lab work. At first it was a struggle as they were learning new skills which were to be translated into classroom practices. After the first four days of trying the first prototype, local external observers from the University of Dar es Salaam were convinced that the teachers were using the materials comfortably. This trend was even more obvious with the follow-up prototypes. Practicality in classrooms and effectiveness will be discussed in the next chapter.

3.6 PROTOTYPING AND FORMATIVE EVALUATION OF IN-SERVICE WORKSHOPS

3.6.1 First in-service workshop

Physics teachers for A-level were invited from ten schools in the Dar es Salaam area. Each school could send two teachers. The invitations were sent to both
private and public schools. The schools were selected as a representative sample of A-level secondary schools that implement the physics curriculum in Tanzania. Thirteen teachers from seven schools turned up. It is unfortunate that in this and the rest of the workshops, the participants were all male teachers. The first workshop was conducted for five working days and each day the teachers met and work with the researcher for 7 to 8 hours.

As most teachers in Tanzanian schools are computer illiterate, it was most logical to assume that the physics teachers who attended the workshop do not know how to use computers. Our first step towards introducing MBL to secondary school physics teachers was to familiarise them with basic computer knowledge and skills, including how to interact with the machine and many other basic aspects. This step was also meant to remove anxiety, which some teachers might have. In the workshop, the teachers who were computer literate were of great help as they peer-coached others in whatever they were doing. This raised the confidence level and motivation of the computer illiterate teachers, and that made the job much simpler and took less time. Teachers were working in groups of two, and these groups were maintained throughout the workshop.

The second step was to introduce the MBL philosophy to the teachers. Basically what we did was, taking an example of a familiar experiment which physics teachers can perform in their own classroom and discuss how such experiment could have been done in traditional teaching, that is, we discussed the experimental set-up, data collection, analysis, and how to draw conclusions. The aspects of what quantities to measure, time required to perform the experiment, possibilities of repeating the same measurements several times within one practical session, easiness of processing and analysing the data, sources of errors and how reliable the measurements are, were all discussed. After that we looked at what computers could do and how we could transform the measurements of the example discussed into computer data. Thereafter it was clear that, with appropriate signal sensors it was possible to perform the whole data collection, processing and analysis by computers. That lead us into looking at the hardware (Computer, and CoachLab II interface), software (Coach 54) and sensors for MBL that facilitate doing different physics experiments, including how to connect them so as to work together.

4 A software support for MBL in learning and authoring environment, also product of CMA-Amstel Institute, Amsterdam, The Netherlands.
We then demonstrate how to run the MBL software in a Windows environment, how to do measurements and analyse the data. We did this through a simple experiment using a motion sensor. Through such simple measurement, we could explore data processing and analysis possible using the software managing the MBL system. Then teachers were given two different sets of sensors and were requested to explore MBL, and the possibilities existing by themselves. This was done with a minimum of guidance of the researcher. We thought this was sufficient for teachers to get acquainted with the basics to handle the MBL system.

Before teachers could embark into real MBL-based activities, we first let them try a simple heat-exchange experiment done in a traditional way. The idea was to let them experience for themselves the simplicity of the experimental set-up, the easiness of collecting, analysing and displaying data. With all that in place, more complex experiments could be performed with MBL technology to familiarise teachers with the real school situation. To begin with, exemplary MBL-based lessons necessary to help teachers grapple with the new MBL concept were needed. The exemplary lessons were designed beforehand, as part of preparation to facilitate MBL-lesson trials later. The details on how the workshop learning materials were designed are covered in sections 3.3 and 3.5.

As the thinking behind the design of these MBL-based lesson activities was different from traditional practical experiments, we discussed the philosophy behind the activities before any could be done. The first prototype of MBL-based experiments was all covering mechanics, and specifically momentum and conservation of momentum and kinetic energy. The prototype had six series of activities. As teachers were still new to the idea, and taking into consideration the limited number of days we had, they could do only three out of six activities.

In the workshop the teachers maintained their working pairs in undertaking the activities. Observations on performance were made together with compiling daily reports from teachers on operational and teaching difficulties, like and dislike of activities, and suggestions on improvements. On the final day, the teachers filled in questionnaires to evaluate the workshop and materials.

In summary we could say the workshop introduced high school physics teachers to a number of recently developed strategies for enhancing learning
through the creative use of computers. Sound principles of learning theory applied to the laboratory setting where computers are used to assist students in the collection and analysis of experimental data were discussed and applied. The computers provided teachers with visuals which made them realise how such visual can help their students bridge between concrete observations and abstract mathematical representation, produces graphs displaying relationships between physical variables. Teachers also observed that experiments could be repeated numerous times quickly and easily, thereby facilitating learning and the process of inquiry. The teachers followed the inquiry process embedded in the MBL-based activities, in which skills acquisition was expected.

3.6.2 Second in-service workshop

The second workshop was a follow-up of the first one. This was necessary as it was used as a testing ground for the second prototype of the student and teacher support materials. The recommendations from the evaluation of the first prototype gave birth to modified materials for the second prototype. In between the workshops, two participating teachers left the profession and joined other professions. Six of the participants were involved in other school related activities and that prevented them from continuing with the study. Seven teachers of which only five attended the previous workshop attended the second workshop. Two new teachers from private schools replaced two former ones who left the profession. These new teachers had no problem with the workshop, as they were computer literate and highly motivated. The duration of this workshop as was the first one was five days.

In the preparation of the lesson materials two new topics were introduced. These topics were chosen because they are recommended in the curriculum for the final practical examination in high school and also participants suggested to include them in the lessons. This is also because after looking at recommendations from teachers, not all schools were well equipped to support the first prototype set of lessons fully.

Two new items were also added in this workshop agenda. Instead of spending time to re-orient with computer basics, that time was used to discuss new didactical approaches in physics teaching. The driving force behind doing that was to inform how scientific knowledge is acquired, what hinders intended knowledge acquisition, and research-based methods in use to assist students in
the knowledge acquisition process. That proved to be very useful as the teachers could relate much of what was in the materials with the new approaches and also could see the rationale behind the teaching materials.

In the last day of the workshop, we introduced a new item. Each group of teachers was requested to design one MBL-based activity that follows the design principles in the exemplary lessons, but they were given flexibility to add or leave out whatever they thought was useful in their classroom. The activities designed by teachers were to be used as input in the design of the third prototype. Data gathering was done as in the first workshop.

### 3.6.3 Third in-service workshop

This workshop took five days. In this workshop as was the case of second one, same seven teachers from six schools attended. The workshop was meant to put final touches on everything before teachers could get ready for implementation of what they have learned in their own classrooms. The teachers spent the first day to try-out the final version of materials developed to teach sub-topics in electricity and magnetism. Later the teachers commented on the materials about its practicality, and the comments were very positive. The examples of the final version of the exemplary lesson materials and teacher guide are shown in appendices A6 and A7.

The second through the fifth day participants were working in pairs designing and developing lesson materials that they will later implement in their classrooms. The participants used the same design principles used for exemplary materials. The topics were picked from the school syllabus with anticipation that when the researcher visit the schools, the teachers will be able to demonstrate their skills with the lesson, otherwise the teachers could also demonstrate any other lesson they developed. These lessons were later taught by the duos to the rest of the participants. The participants were to have a clear view on what to look for when a lesson was presented, hence some guidelines were laid down to direct them. The participants discussed the taught lessons and the evaluation feedback from peers and the researcher enabled the duets to revise their lessons for improvements.

Though the schools had computers, they were lacking the MBL interface, sensors and software, which are basic requirement for MBL-based lesson
implementation in schools. Therefore it was agreed at the end of the workshop that the researcher had to borrow the MBL inputs to schools for at least two weeks to allow teachers demonstrate their skills and it was during that period the researcher could visit the schools.

At the end of the workshop, the teacher responded to a questionnaire that enables gathering information about their opinion of the workshop. The designer also kept a checklist that enable to evaluate the progress of the workshop.

3.6.4 Formative evaluation of workshops and materials

The first workshop was intended to evaluate the first prototype of the workshops together with student and teacher support materials to inform about their worthiness. The designer then used the results to improve the quality of the support materials for the second prototype. The evaluation sought to learn about the value of the content of the material, the acceptability of teachers to it, and the utility and appeal of the materials to teachers. The technique used for eliciting data include, self-reports (teachers' daily workshop reports, checklists and questionnaire (shown in appendices A1 and A2) and observations. The checklist and observation served two purposes, to quickly make changes that will facilitates continuation of the workshop without problems, and to give feedback information about changes necessary in the materials as participants fumble with lesson materials of the first prototype. One thing that came out vividly was that teachers will not use support materials that are complex in design with a lot of details, they will prefer simple, direct to the point material that is procedural. Secondly the computer literacy part was well attended without many problems, and this had positive effect on the task of introducing MBL-based learning.

The teachers had a lot to report in the questionnaire, after the first workshop. When asked whether problem-based activities poses problem to their teaching, all said no and they think this approach helps to focus their teaching, help them probe student understanding and also helps students to link science and applications. On implementing activity-based learning in their classroom, two thirds said it would be difficult as they lack skills but one third said it is not difficult as long as teachers are good in class management.

When asked whether the data collection, processing and analysis; supported by MBL could foster understanding, they all agreed that it will be so, if students
have good theoretical background and capable of using MBL thoroughly. All teachers agreed that group learning is useful for understanding, but they have doubt on their ability to implement it in their classrooms. Some classes have, as many as 50 students and without skills on group management and task assignment, the idea will be difficult for them to handle. Some thought that group monitoring to ensure learning, and at the same time maintain fairness in assessment is difficult at the beginning.

On lesson structure and the content the teachers had this to say:

- The structure is very good, and what they like most is the possibility of linking experiments or demonstrations with lectures, it discourages memorisation of facts and promotes understanding.
- The content is ok, not too much or too less but they want the exercises to reflect more on the local context.

All teachers expressed their concern about unavailability of funds and equipment as one of the bottleneck of MBL implementation in their schools. Another problem is that, lack of knowledge on MBL capabilities by both their colleagues and school leadership may also hinder implementation.

When asked what they like about MBL, teachers came up with the same advantages already identified in the literature. One teacher even said "MBL provided me with new method of asking questions and observing pupils performance in practical as well as theory. It also reminded me that as a teacher I should think before doing any activity"

Teachers had varied opinions on possible impact of such technology for Tanzanian science education. Some thought class issue will arise, only good, rich and government schools will afford such a technology. Some thought such technology can raise interest to pupils to do science; others think it will end the current wave of doing away with practical as most experiments can be done on one computer; but the majority thought that introduction of such system has a chance to improve science learning in Tanzania.

In the second workshop we also evaluated the materials through a questionnaire (see appendix A3) as well. The participants' general impression about the activities was encouraging. They found the lessons to be very good, well organised, challenging and interesting. They also thought that the lessons were focused to orient learners in a more accurate way of collecting organising, processing and analysing the experimental data in addition to learning science concepts and lab skills.
When asked to be more specific in what they found good about the lessons, they found the activities well organised, encourage understanding through problem solving; promote learning and understanding; and the language used was clear and expressive enough. However some thought the how-to information could be more descriptive and it could be useful. Some also thought the introductory part of the lesson should be summarised in points to motivate lazy students to read all of it.

When asked what they would like to be done more on the lesson, they wanted the lessons to cover other topics especially electricity and magnetism. In addition to that, some wanted more context-based problems, more clearly defined objectives, and the use of suggestive rather than commanding language. They also suggested having more open-ended lessons as lesson modules grow from simple to more complex.

On teachers' manual some wanted a much more step-by-step instruction on how to integrate MBL into the existing curriculum. Also they suggested adding more details on all experiments, questions, etc. in addition to more quantitative problems and worked examples. They also want open-ended suggestions to set up activities and problems.

They all held the opinion that the most significant they learned from the workshop was: doing physics through MBL activities, linking students learning difficulties with teaching methodology, knowing misconceptions which their students may have and how they affect learning and understanding, and finally using experiments as a problem solving technique.

The third workshop was the last in the series of workshops done. In the first two workshops, the evaluation was focused more on participants' reaction about the workshop experience, and the quality issues of the lesson materials. The evaluation of this workshop focused on participants' learning in addition to quality aspects of the lesson materials. This entailed setting up specific criteria and indicators of successful learning of the new knowledge and skills as a result of the experience. As the workshops general goal was to equip teachers with knowledge, skills and help to change attitudes or beliefs, that will enable them introduce science inquiry teaching approach in their curriculum, the researcher had to develop some indicators to evaluate cognitive, skills and affective attributes, to gather evidence of teacher learning as a result of participating in the workshops. An evaluation form was administered at the conclusion of the workshop. This was also complimented with information gathered through a checklist, as the researcher observed teachers design, develop lessons and teach.
to peers. Teachers’ skills related to handling of MBL technology as intended for productive teaching purposes were evaluated through observation and note taking, as they taught lessons to peers. (See appendices A4 and A5 for evaluation tools of this workshop).

The impression the researcher got from the information gathered through the assessment form, checklist and observation was that, the teachers were highly successful in learning about the subject matter, as well as teaching it as an intellectual and scholarly endeavour, but they need more support to improve their teaching practice skills that underlie constructivist approach to teaching, such as engage students in meaningful classroom discussion. They sometimes kept going back and forward between the old and the new approaches of teaching. However, two teachers were very good both in mastering the content and teaching it in a new ways introduced during the workshop series. In the workshop context, they also demonstrated sufficient skills to start the process of integrating MBL in their curriculum. On practicing science inquiry, they demonstrated they can do it but they might need extra support and/or push from the examination system to completely adopted. On the final version of the lesson materials, they find them very practical.
CHAPTER 4
Design of the evaluation study on teacher learning

This chapter describes the research design that was developed for the evaluation of the effects on teacher learning of the in-service arrangement. Section 4.1 introduces the effects on teacher learning that are distinguished in this study. An overview description of the indicators used in measuring the effects is presented in section 4.2. Section 4.3 offers background information on the participating teachers, their students and their schools. Finally, the procedures for data collection and analysis are depicted in section 4.4. The results of this study will be presented in chapter 5.

4.1 COMPONENTS OF TEACHER LEARNING

The central question that guides the evaluation is: to what extent did the in-service arrangement (workshops together with the exemplary lesson materials; as described in chapter 3) impact teacher learning. To evaluate this impact, the approach used by Guskey (2000) to evaluate the effects of professional development is used in this study. Guskey proposed a five level model of evaluation for any in-service education program.

The first level of evaluation addresses teachers' reactions to the experience. It measures teachers' initial satisfaction with the in-service experience, but not its quality or worth. The information gathered at this level can help improve the design and delivery of in-service programs.

The second level of evaluation focuses on measuring the knowledge, skills and attitudes that the teachers developed throughout the in-service experience. Analysis of information from this measurement provides a basis for improving the content, format, and organisation of the in-service program or activity.
The third level of evaluation focuses on gathering information about school support to encourage and facilitate the in-service participants with the implementation of the innovation initiatives. This information is used to document and improve organisational support, and also to inform future change initiatives.

The fourth level of evaluation concentrates on teachers' use of the new knowledge and skills (gained through the in-service program) in classroom practices. Measurement of use is taken after sufficient time has passed to allow teachers to adapt the new ideas and practices into their school settings. Analysis of this information provides evidence of the current level of use and can help to restructure future activities to facilitate better and more consistent implementation.

The last level of evaluation focuses on student outcomes. Measurements of student learning typically include cognitive indicators of student performance and achievement, but also affective indicators (attitudes and dispositions) and psychomotor indicators (skills and behaviours).

In the framework of this study, the evaluation focuses on teacher reaction (level 1), teachers knowledge, skills and attitudes (level 2), the implementation of new knowledge and skills in classroom practice (level 4) and student outcomes (level 5). The study did not extensively evaluate the organizational support (level 3) that the teachers received from their school during the implementation of the MBL-based lessons. The support that was provided to the teachers is described in section 4.3, where background characteristics of the teachers, students and participating schools are described. Regarding student outcomes, the focus was on indicators of attitude, as there was not sufficient time to assess cognitive outcomes, though some impressions of student learning are described and discussed in chapter 5. The four levels of the Guskey model are adapted to meet the specific needs (see table 4.1) of this study. We will use these labels and the meanings attached to them to position the instruments used, and to report about the findings in chapter 5.
Table 4.1  The Four levels of the Guskey (2000) model as used in the study

1. *Teacher Reaction* – Did the in-service arrangement meet teachers' expectations in terms of relevance, utility and timeliness? Was the in-service arrangement structure and format appealing to the teachers?

2. *Teacher Learning* – How did teachers' understanding and opinion change regarding the use of MBL and activity-based physics education?

3. *Classroom Practices* – How did teachers use the newly learned knowledge and skills in the classroom?

4. *Student Outcomes* – How did students experience and perceive MBL and the different learning approach?

4.2 **INDICATORS**

To be able to evaluate the impact of the in-service arrangement, indicators were used for each of the four levels. These indicators guided the selection of methods and development of data collection instruments. A detailed description of the data collection instruments is given in section 4.4.

The evaluation of *teacher reaction* was also part of the formative evaluation that took place as part of the prototyping phase described in chapter 3. This evaluation was focused mainly on improving the in-service arrangement. In the final study, the focus was on the evaluation of teachers' reactions to the in-service arrangement after the implementation of the newly acquired knowledge and skills in the classroom. The indicators used to determine teachers' reactions concentrated on the content and the process of the in-service arrangement. Table 4.2 describes the criteria that are used to interpret the evidence on teachers' reactions.

Table 4.2  Indicators of Teacher Reactions

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content of In-service arrangement</td>
<td>A positive reaction toward the relevance, utility and timeliness of the topics of the in-service experience will indicate satisfaction. Also, positive comments regarding the credibility and practicality of the changes required to implement the new knowledge is considered a sign of acceptance.</td>
</tr>
<tr>
<td>Process of In-service arrangement</td>
<td>Satisfactory comments on the structure and format of the activities of the in-service arrangement.</td>
</tr>
</tbody>
</table>
To gather teachers' reactions to the in-service arrangement after implementation of the lessons in the classroom, a reflective interview was conducted with each teacher.

The evaluation of teacher learning was achieved through examination of teacher perceptions of the in-service arrangement. The indicators that were used to determine the teachers' perceptions of what they had learned from the in-service arrangement focused on their understanding of and their opinions of the new approaches to physics teaching that were central to the in-service arrangement: MBL, student centred learning and activity-based physics. Table 4.3 describes the evidence that is collected to determine teacher learning.

Table 4.3  Indicators for Teacher Learning

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opinions</td>
<td>Teachers have a positive view toward MBLs, student centred learning and activity-based physics.</td>
</tr>
<tr>
<td>Understanding</td>
<td>Teachers are able to demonstrate their understanding of MBL, student-centred learning and activity-based physics in lesson plans.</td>
</tr>
</tbody>
</table>

Teachers' opinions were determined through the use of a questionnaire administered immediately after classroom implementation and more importantly through a reflective interview that took place six months after classroom implementation. Teacher understanding was assessed by analysing the lesson plans that they developed as part of the in-service arrangement.

The implementation of the newly acquired knowledge and skills in classroom practices is also evaluated. Changes in the teaching practices are considered the main indicator of the effects of the in-service arrangement. To measure which changes have occurred, the observed changes in teaching behaviours (teacher classroom practices) were compared with the intended changes formulated by the designer (see table 4.4). In the classroom observations, these indicators guided expectations in the teaching process. A classroom observation method was used to evaluate classroom practices. An observation checklist and researchers' notes were used as instruments of data collection.
Table 4.4  *Indicators for Classroom Practices*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lab preparation</td>
<td>Adequate attention is paid to check students' pre-lab preparation.</td>
</tr>
<tr>
<td>Promotion of science learning by inquiry</td>
<td>The predict-observe-analyse sequence is maintained in the teaching of physics topics.</td>
</tr>
<tr>
<td>Promotion of student involvement and active learning</td>
<td>The activity-based MBL activities are used in teaching and augmented with activities that actively involve students mentally and physically.</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Students work in well organised groups in which members are assigned responsibilities.</td>
</tr>
<tr>
<td>Formative assessment</td>
<td>An assessment which reflects learning goals and provides students with opportunities to revise and improve the quality of their thinking and learning.</td>
</tr>
<tr>
<td>Homework</td>
<td>The students' assignments emphasise reflection on what was learned, and application of knowledge in a variety of contexts.</td>
</tr>
</tbody>
</table>

An indication of *student outcomes* is ascertained through the evaluation of students' science process skills and understanding of scientific ideas, their perceptions of the learning environment, and their opinions of the lessons and the new teaching approach. The indicators used in the evaluation of student learning outcomes are shown in table 4.5.

Table 4.5  *Indicators of Student Outcomes*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opinions and perceptions</td>
<td>▪ Students are satisfied with the lessons and the learning organisation.</td>
</tr>
<tr>
<td></td>
<td>▪ Students perceive investigative learning in the lessons.</td>
</tr>
<tr>
<td></td>
<td>▪ Students recognize collaboration in the learning process.</td>
</tr>
<tr>
<td></td>
<td>▪ Students perceive advantages of the learning approach and environment.</td>
</tr>
</tbody>
</table>

To understand students' comprehension of or inclination for the new innovation, their opinions of MBL technology and the new teaching approach were assessed together with their perception of the activated-based learning environment. Different instruments were used to collect data about students'
perceptions and opinions toward the new technology and the new teaching approach. The data for assessing the opinions were collected through questionnaires and by interviewing students. Only questionnaires were used to assess student perceptions. The perception questionnaires were administered just before and after classroom practices while the opinion questionnaires and interviews were administered immediately after the classroom practices.

Students' understanding of scientific concepts and the development of their science process skills were assessed via analysis of work produced by the students. Analysis of the work of a few students in the classroom was used to get an impression of overall student learning, and was not used as a formal indicator of learning. The work analysed to get an impression of learning was entirely lab related. Student work was evaluated to find out whether they demonstrated initial mastery of skills in prediction, measurement, observation, explanation, and problem solving; whether students could use graphs effectively to support points being made; whether students analyse and interpret experimental data effectively; and whether students draw valid conclusion, choose appropriate methods, and recognise regularities in nature. The student work was collected for evaluation after they fully completed it.

Table 4.6 provides an overview of the relationship between component effects on teacher learning as evaluated in this study and the data collection methods that were used. Multiple sources and methods were used to obtain a broader view of the effects, combining strengths and correcting the deficiencies of any single source or method (Miles & Huberman, 1994). The data collection instruments, procedures and analysis will be described in detail in section 4.4.

<table>
<thead>
<tr>
<th></th>
<th>CO</th>
<th>TQ</th>
<th>TI</th>
<th>TP</th>
<th>SQ</th>
<th>SI</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Reaction</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher Learning</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classroom Practices</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Outcomes</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Note: CO = classroom observation, TQ = teacher questionnaire, TI=teacher interview, TP=teacher products, SQ=student questionnaire, SI=student interview, SP=student products.
4.3 CONTEXT AND PARTICIPANTS

4.3.1 Context

Initially, the plan was to implement the lessons and the new teaching approach in seven schools whose teachers participated in the preparatory workshops. However, due to time limits and the unavailability of teachers at the time of the exercise, we were forced to change the earlier plans. Some of the teachers who attended the workshops were assigned new duties by the Ministry of Education at the time of implementation in their schools. Four teachers from three different schools participated in the study with their classes. All schools are urban schools from the Dar es Salaam area.

The three participating schools are representative of the variation that exists in Tanzanian secondary schools. One is a large public secondary school (hereafter referred to as school X) and the other two were private schools. One of the private schools is relatively rich (hereafter referred to as school Y) and the other private school (hereafter referred to as school Z) is more comparable to public secondary schools. As we have seen in chapter one, secondary schools in Tanzania fall into one of the three categories presented. All three schools are coeducational.

The initial classroom implementation took place between October and November of 2001. The researcher supplied the participating schools with five MBL kits during the time that the lessons were conducted. It was then possible for students to spend a few hours familiarising with MBL technology before they attempted the lessons prepared by their teachers. Due to the limitation of available MBL interface kits, and also considering how many schools will be able to afford to invest in MBL heavily, five MBL kits were considered the optimal number for most schools.

All teachers involved in the assessment of initial implementation were males. They each had teaching experience of at least four years. Their experience with computer use for science learning was assumed to be the same, as they all received the same training and only one had very little previous exposure to computers. Prior knowledge included some computer programming.

The teachers executed the lesson plans they developed for their own students during the in-service arrangement. The teachers were not required to adhere to
a certain mode of teaching as long as they kept the essential parts of the
teaching approach, especially activity-based learning, student involvement
during the lesson activities and use of lesson activities based on problems that
are real to student life. The researcher observed how both teachers and students
were coping with the new learning environment.

The summary of information pertaining to the three schools with regard to their
corresponding teachers and students is shown in table 4.7.

Before the classroom implementation began, the school heads were informed
about the study. All showed interest after and eagerly invited the researcher to
countact the investigations in their schools. The school heads were also informed
about the in-service arrangement even before it started and all approved it. Generally, the administration of the three schools supported the classroom
implementation of the MBL-based learning. However, their support was limited
by their limited understanding of the potential of the computer technology for
education. Some teachers were satisfied with the support, while others were not.
The teachers’ impression was that the administration did not receive the idea with
the same enthusiasm as their colleagues because it would cost the schools more
money. However, the teachers also believe that with the pressure brought by
curriculum change, the administration may be willing to support them fully in the

Table 4.7  A summary of schools and teacher background information in a table

<table>
<thead>
<tr>
<th>School X</th>
<th>School Y</th>
<th>School Z</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teacher T1</td>
<td>Teacher T2</td>
</tr>
<tr>
<td>Class size</td>
<td>52</td>
<td>60</td>
</tr>
<tr>
<td>Grade level</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Age range (years)</td>
<td>18-20</td>
<td>17-19</td>
</tr>
<tr>
<td>Students’ computer experience</td>
<td>Few literate students</td>
<td>Few literate students</td>
</tr>
<tr>
<td>Teacher Background</td>
<td>BSc. (Engineering)</td>
<td>BSc. (Education)</td>
</tr>
<tr>
<td>Teacher teaching experience (years)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Number of hours spent on MBL lessons</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Duration (days)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Number of lessons per grade</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
The detailed description of the teachers' profiles, their students and the context of the schools is included to portray a picture of the conditions in which the initial implementation took place and is discussed in the succeeding sections.

4.3.2 Participants

School X: school, teachers and students

School X is a government school, providing education for A-level students only. This school is more than 40 years old with more than 1000 students. Each class has at least 30 students. Though the school has a large number of students and has been in business for many years, it had the least computer facilities compared to the other two schools. There were few teachers in this school who could use computers, and those that were computer literate used them mostly for administrative purposes and not for teaching or learning. The computer literate teachers could use the computers for lesson preparation. The school had a computer lab where the computers were kept and access to the room was restricted. One of the teachers who participated in the in-service training was responsible for controlling access to the computer lab.

Two teachers (hereafter referred to as T1 and T2) from this school participated in the study. Both of these teachers have bachelors' degrees, T1 had a Bachelor of Electrical engineering and T2 had a Bachelor of Science Education. These teachers were in their early thirties when the study was conducted and had been teaching for six years each.

One hundred and twelve students from grade 13 and 14 participated in the study and range in age from 17 to 20. Students at this school major in one of three different science/maths subjects. Because of the nature of the study, all of the participants were physics major. Students in this school had no previous experience working with computers in their schooling and few of them were computer literate.

During the implementation of these lesson materials, T1 taught grade 14 and T2 taught grade 13. The topics taught were electricity for grade 13, and harmonic motion for grade 14. Two grade 13 and two grade 14 classes were combined or this study. Each class used MBL-based activities for their labs, and met twice a week for two weeks. Each grade spent two hours and forty minutes on the lessons and each class was observed for approximately 11 hours.
School Y: school, teacher and students

School Y is a rich private school that was founded about 10 years ago with less than 300 students. The school provides education from kindergarten all the way through A-level secondary school. The A-level class size varies between 14 and 20 students. The school had many modern facilities, including computer facilities available to all students. However, the computers were not used for teaching or learning science. The computers were used mainly to prepare students to be computer literate in an information rich society. All teachers in the school were computer literate. The teachers are expected to produce and process exams along with student progress reports using computers. The school also had employs a network system administrator to help with software, hardware and network problems. The computer systems are kept in a computer lab.

The teacher (T3) who participated in the study holds a bachelors' degree in science education. He was in his late twenties at the time of the study and had been teaching for five years. He was very computer savvy though he did not much experience using computers to teach science. The only science related usage was the application of spreadsheets to generate graphs in mathematics classes and a bit in physics classes.

Thirteen students from grade 13 and 15 students from grade 14 participated in the study. The students can major in three different subjects as in school X. The difference is the large concentration of students in the lower end of the age group. Students who participated in this study ranged in age from 16 to 19 years old. All students were computer literate. They used the computers for communication such as e-mail and the internet, for producing assignments, and doing some creative work such as producing multimedia products. Sometimes the computers were used for graphing and solving mathematical problems.

MBL was implemented in grades 13 and 14, and they met four times a week for two and half weeks. They also used the MBL-based lessons twice for demonstration purposes. In total, each grade was observed using the new lessons for 10 hours. Less time was spent because the school used a different system and each lab session lasted only two hours instead of the normal two hours and forty minutes spent in other schools. In this school the teacher covered the topic of oscillation and waves for grade 13 and gravitation for grade 14.
School Z: school, teacher and students

School Z is a normal private school. The school has been operational for about 17 years and the student population is around 3000. The school had both O-level and A-level students, but the O-level students far outnumbered the A-level students. The school did not have many facilities but did have a computer lab. The school had qualified staff for teaching computer literacy courses recommended by the Ministry of Education. There was no record regarding the computer literacy of the rest of the staff members, but none of them were using computers even for administrative purposes. The O-level students were required to attend computer literacy courses for two years. However, no such courses were available to the A-level students.

One teacher (T4) from the school participated in the study. This teacher also held a Bachelor of Science in Education was in his early thirties and had seven years of teaching experience at the time of the study.

In school Z, only grade 14 students took part in the study. As with the other two schools, these students had three major subjects one of which was physics. A-level classrooms are composed of 20 to 25 students, most of whom attended other schools for their lower secondary education where computer literacy courses were not offered. However, almost half of the students were computer literate. Their age was between 19 and 20. Due to O-level national exams at the time of the visit, the A-level class could only meet in the afternoons, which was usually free time for the students. This may explain that only 11 students attended despite the period being compulsory.

The class met four times a week for two hours and forty minutes and used MBL for lab work for around 22 hours. The school used the MBL system to learn about heat energy transfer and exchange. In this school and the public school, the first meeting with the students was used to only familiarise the students with the MBL systems.

4.4 Data collection: instruments, procedures and analysis

Data collection involving both teachers and students was a step-by-step process involving classroom observation, questionnaires, interviews, and securing both lesson plans from teachers and student products (lab work and homework assignments). As classroom implementation was in progress, the researcher
observed teacher performance and recorded the observations. The instruments
used to collect data are discussed in the following sections. The discussion
covers the characteristics of the instruments, the measured constructs, how the
instruments were administered and to how many respondents, and the data
analysis approach.

4.4.1 Teacher questionnaire
The teacher questionnaire was not a standard instrument. It was developed for
this study. The questionnaire had 21 items, 3 of which were open-ended
questions. The closed items used a 1-to-5 rating Likert scaling (1 = strongly
disagree, 2 = disagree, 3 = no opinion, 4 = agree, 5 = strongly agree). The closed
questions focused on a number of underlying opinions from teachers after
experiencing MBL in their classrooms. The opinions had to do with: their
general impression of classroom implementation, teaching suitability of the
lessons, possible benefits to learning from the lessons and the new teaching
approach; opinions of MBL as a tool for promoting inquiry and collaborative
learning; and whether they felt the lesson materials could fit into the current
physics curriculum. The open-ended part of the questionnaire complemented
the information provided by the closed-end questions. The data gathered
provide information that is useful in understanding the teachers' reaction to the
in-service arrangement and to the classroom implementation of the newly
acquired knowledge and skills. The questionnaire was administered to four
teachers immediately after the classroom implementation. The questions are
available in Appendix B1.

The analysis focused primarily on the written responses to the open-ended
items. The information in the closed items provided a general impression of the
teacher' reactions toward the in-service arrangement and the implementation of
newly acquired knowledge and skills in the classroom. The written statements
by the teachers on the open-ended items resulted in a better understanding of
their general impressions.

4.4.2 Teacher reflective interview
The teacher interview provided teachers with the opportunity to express their
views more precisely after reflecting upon the whole process, from workshops
to classroom practice experiences.
The researcher had face-to-face interviews with the teachers six months after the
classroom lesson observations. All four teachers took part in the interviews, and
were interviewed individually. The interviews were taped and transcribed. The interviews were partially structured and concentrated on teachers’ reflections on expectations and impressions after using the materials in classroom environment.

The interview questions were derived from a variety of sources related to the study. Sources included reflection on the results of student surveys and interviews (see sections 4.4.5 - 4.4.7), classroom observations (section 4.4.3), questions that were designed to compel teachers to reflect upon the workshops, classroom implementation experiences, and student learning. For classroom implementation, the interview touched upon their opinions of what they had learned, difficulties experienced in the implementation, differences between observed lessons and their normal lessons, worthiness of the learner-centred teaching and science inquiry learning, and their perceptions of their students' experiences with the lesson materials and the learning experience.

The reflection questions were intended to glean more from teachers, their reactions and what they learned from the workshops, the degree of school support and change, how teachers were using the new knowledge and skills in their respective schools, and finally to what extent the knowledge and skills were helping them to improve student education and eventual outcomes. The interview enabled the researcher to assess how the teacher perceived and later put into practice the lesson materials. It also provided some explanations for discrepancies between observed and expected effects. The interview was also geared toward understanding what made teachers integrate or not integrate certain elements of the intervention into their teaching. The interview questions and schedule are listed in Appendix B4.

The interviews were coded following Miles & Huberman (1994) after the audio messages were transcribed. The coding enabled the responses to different questions by different individuals from different schools to be combined and summarised. However, a general view for a particular question was only ascertained after all of the statements from the different participants had been analysed.

4.4.3 Analysis of teacher products

As part of the in-service arrangement, teachers developed their own lesson plans. These lesson plans were modelled after the exemplary lesson materials
(designed by the researcher), which were used by the teachers during the in-service arrangement.

The lesson plans developed were physics lessons for different topics in the school syllabus and were to be taught in the schools after the workshops ended. The lesson plans developed by teachers were problem-based lab activities, used MBL technology to facilitate the activity-based learning process and had the potential to promote science inquiry skills.

Four didactical experts in physics education, and two general experts in the field of ICT in education, evaluated the lesson plans of the teachers. The evaluation of the lesson materials was intended to establish the knowledge and skills that the teachers gained during the in-service arrangement. Six of the lessons developed during the in-service arrangement were selected for the evaluation. Two conditions were used as criteria for the selection of lesson plans. Lesson plans had to be from the teachers that took part in the evaluation study and they had to be taught during classroom implementation. The expert evaluation of the six sample lessons measure the extent to which the teachers correctly perceived the intended curriculum. The lesson plan evaluation tool in appendix B.2, supported by excerpts from the exemplary lesson materials, guided the evaluators in the evaluation of the lesson plans.

The researchers considered a lesson plan complete if it consisted of three major parts. The first part should be an introduction to the lesson, clearly stated learning objectives, the preparations that students need to make, and the problem statement that clarifies the task the lesson should accomplish.

The second part is the body, which includes specification of the equipment needed, predictions of outcomes, questions to guide the experimental method and the exploration, and the guidance for measurements to be made.

The last part is the conclusion, which includes: guidance to data analysis, how to draw conclusions, questions to guide students' reflection on the task, and an exercise that makes the learning more concrete through application questions. The evaluators assigned a numeric value of ‘1’ to every element of the lesson that was reviewed positively, and numeric value ‘0’ to every element reviewed negatively. The positive sources were counted and its counts were expressed as percentage of the total. If all the elements of the lesson were marked positively,
then 100 points were awarded otherwise fewer points were scored. The results of the evaluation are interpreted as percentage with each point being equivalent to one percentage point. These numbers are used to express the extent to which success was realised in the student exemplary lesson ideals (i.e. the extent to which the implemented curriculum matches the intended curriculum).

All comments made by the evaluators for each element of the lesson were compiled and analysed to formulate general summary statements.

4.4.4 Classroom observations

A curriculum profile (van den Akker & Voogt, 1994) instrument has been developed to assess teachers' effectiveness in implementing the MBL-based lessons. The instrument is made up of statements about activities and the preferred practices of teachers during the observed lessons. It satisfies the definition of curriculum profile given by van den Akker and Voogt (1994) in which they define it as a set of statements about intended actions of teachers during lessons. The instrument is a modified version of a curriculum profile instrument developed and tried in Namibia for a similar study (Ottevanger, 2001). The data gathered through the curriculum profile instrument play a great role in establishing the relation of the intended curriculum and the implemented curriculum at the actual classroom level. This served as an observation checklist.

The statements of the curriculum profile are divided into three sections: the start of the lesson, the body of the lesson and the conclusion. The statements in these three sections constitute a checklist related to the categories of implementation mentioned in table 4.4.

In general the instrument statements are meant to extract information that can be used to evaluate three themes: the basic teaching skills that embrace collaboration among students, learner-centred orientation, and correctness of the subject matter covered that promotes science education by inquiry. In this way the instrument could help to evaluate how the teachers were able to use the new knowledge and skills in their classrooms. Table 4.8 shows segments of the instrument used for evaluating classroom practices with the last column added to indicate how the checklist relates to the classroom practice indicators in table 4.4. The following abbreviations with their meanings are used in the last column of table 4.8. ('p/lab'= pre-lab preparation, 'inquiry'=promotion of science learning by inquiry, 'active'= promotion of active learning,
'cola' = collaboration, 'forma' = formative assessment, 'h/work' = homework. Appendix B.3 shows the complete instrument with all the sections included.

Table 4.8  *Excerpts from classroom observations instrument*

<table>
<thead>
<tr>
<th>INTRODUCTION TO LESSON</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher checks homework (exercise, &amp; reflection)</td>
<td></td>
<td></td>
<td></td>
<td>p/lab</td>
</tr>
<tr>
<td>Teacher asks prompting and probing questions to introduce the activity</td>
<td></td>
<td></td>
<td></td>
<td>p/lab</td>
</tr>
<tr>
<td>Teacher takes opportunity to discover what students already know at start of activity</td>
<td></td>
<td></td>
<td></td>
<td>p/lab</td>
</tr>
<tr>
<td>Teacher makes clear science knowledge and skills to be developed</td>
<td></td>
<td></td>
<td></td>
<td>p/lab</td>
</tr>
<tr>
<td>Teacher clarifies what students will be doing in various lesson stages e.g. prediction</td>
<td></td>
<td></td>
<td></td>
<td>p/lab</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BODY OF LESSON</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher observes how learners choose to approach activity</td>
<td></td>
<td></td>
<td></td>
<td>inquiry</td>
</tr>
<tr>
<td>Teacher helps student to investigate, to construct meaning</td>
<td></td>
<td></td>
<td></td>
<td>inquiry</td>
</tr>
<tr>
<td>Teacher groups learners for activity</td>
<td></td>
<td></td>
<td></td>
<td>cola</td>
</tr>
<tr>
<td>Teacher assigns various group roles to members</td>
<td></td>
<td></td>
<td></td>
<td>cola</td>
</tr>
<tr>
<td>Teacher allows students 'room to choose' their own approach</td>
<td></td>
<td></td>
<td></td>
<td>inquiry</td>
</tr>
<tr>
<td>Teacher interacts equally with all groups</td>
<td></td>
<td></td>
<td></td>
<td>cola</td>
</tr>
<tr>
<td>Teacher allows students to draw own conclusions in groups</td>
<td></td>
<td></td>
<td></td>
<td>cola</td>
</tr>
<tr>
<td>Teacher asks questions to probe reasoning and understanding</td>
<td></td>
<td></td>
<td></td>
<td>forma</td>
</tr>
<tr>
<td>Teacher assists students when necessary (but not immediately)</td>
<td></td>
<td></td>
<td></td>
<td>active</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONCLUSION OF LESSON</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher provides opportunity for all students to demonstrate their learning by presenting their findings</td>
<td></td>
<td></td>
<td></td>
<td>active</td>
</tr>
<tr>
<td>Teacher asks students questions and waits for a response</td>
<td></td>
<td></td>
<td></td>
<td>forma</td>
</tr>
<tr>
<td>Teacher gives specific homework</td>
<td></td>
<td></td>
<td></td>
<td>h/work</td>
</tr>
<tr>
<td>Teacher explains homework clearly</td>
<td></td>
<td></td>
<td></td>
<td>h/work</td>
</tr>
<tr>
<td>Teacher guides learners to understand discrepancies in their results</td>
<td></td>
<td></td>
<td></td>
<td>forma</td>
</tr>
<tr>
<td>Teacher asks students to explain their results</td>
<td></td>
<td></td>
<td></td>
<td>inquiry</td>
</tr>
<tr>
<td>Teacher leads students to theory for the observed results through dialogue</td>
<td></td>
<td></td>
<td></td>
<td>active</td>
</tr>
</tbody>
</table>
The completion of the instrument was accomplished by scoring '1', that is 'yes', for all observed teachers' actions that correspond to the instrument statements, and '0', that is 'no', if that was not the case. The researcher completed the curriculum profile partly during the classroom observation, and finalised it immediately afterward using his notes of what happened in the class. The instrument was used to observe a total of 26 lessons taught by the four teachers. The observations correlate teachers' classroom practices with the components (categories) shown in table 4.4.

The analysis of the curriculum profile data mostly involved counting the scores of individual statements for each checklist of the 26 lessons and then expressing the counts in percentages. As the instrument had three sections, the start, the body, and the conclusion of the lesson, each section was analysed separately. All statements with a score '1' were counted and the total was divided by the total number of statements per section. A general conclusion was reached after considering the three sections together.

4.4.5 Students' Computer Classroom Environment Inventory

The computer classroom environment inventory (CCEI) questionnaire is a standard instrument designed to assess students' changing perceptions of their learning environment as they are engaged in inquiry learning. Maor & Fraser (1996) developed the instrument at the Science and Mathematics Education Centre in Curtin University of Technology (Perth, Australia).

The CCEI questionnaire has 30 items rated 1-to-5 Likert scaling (1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = very often), and is intended to gather data about the perceptions held by students on the classroom learning environment for activity-based science classes supported by computer technology. This instrument evaluates the effects on student learning through their opinions and perceptions of the learning environment.

The instrument measures students' perceptions on five scales: Investigation, Open-endedness, Organisation, Material environment and Satisfaction. Table 4.9 clarifies the meanings of each of the five scales. The CCEI instrument is presented in its entirety in Appendix B5.
Table 4.9  *Descriptive information for each scale of CCEI instrument*

<table>
<thead>
<tr>
<th>Scale name</th>
<th>Description</th>
<th>Sample item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td>Extent to which the student is encouraged to engage in inquiry learning.</td>
<td>In these computer sessions, I found out the answers to questions by investigation (+).</td>
</tr>
<tr>
<td>Open-endedness</td>
<td>Extent to which the computer activities emphasise an open-ended approach to inquiry.</td>
<td>In this class, the teacher decides the best way for me to proceed with my work (-).</td>
</tr>
<tr>
<td>Organisation</td>
<td>Extent to which classroom activities are planned and well organised.</td>
<td>I find the computer sessions to be well organised (+).</td>
</tr>
<tr>
<td>Material environment</td>
<td>Extent to which the computer hardware and software are adequate and user friendly.</td>
<td>The computers are not suitable for running the program that I use (-).</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Extent to which the student is interested in using the computer and in conducting investigations.</td>
<td>After this class, I felt satisfied (+).</td>
</tr>
</tbody>
</table>

Maor and Fraser (1996) validated the instrument by testing it with a sample of 120 Grade 11 students in Australia, and optimised it for validity and reliability. Appendix B.6 provides information about each scale's internal consistency, reliability (coefficient alpha) and discriminant validity (using the mean correlation of a scale with the other scales in the same instrument as a convenient index) as it was found in the Australian context.

In determining the reliability of the instrument for this study in the Tanzanian context, it turned out that for two scales (open-endedness and organisation) the reliability was quite low. This is probably due to cultural differences between Tanzania and Australia, and other contextual differences such as the teaching styles that students are used to. Nevertheless, through deletion of some items from the original instrument, the reliability was reasonably improved. Table 4.10 reports the internal consistency (Cronbach's alpha reliability), for the remaining items in the scales. The reliability data suggests that the refined scale has acceptable internal consistency, especially for scales containing a relatively smaller number of items.
Table 4.10  *Number of items and alpha reliability for the refined version of CCEI*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Number of items</th>
<th>Alpha reliability (post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td>6</td>
<td>0.73</td>
</tr>
<tr>
<td>Open endedness</td>
<td>4</td>
<td>0.60</td>
</tr>
<tr>
<td>Organisation</td>
<td>4</td>
<td>0.67</td>
</tr>
<tr>
<td>Material environment</td>
<td>5</td>
<td>0.64</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6</td>
<td>0.83</td>
</tr>
</tbody>
</table>

The CCEI was administered to 126 students before and after classroom implementation. The activities had the potential to promote science inquiry-skills and collaborative active learning. The inquiry learning environment perception was expected to be a result of subjects interacting with the MBL system and the curriculum materials; and the collaboration resulted from how the lessons were taught. The data collected could be used to find out whether an MBL-based learning environment influenced the students' perception of the physics classroom.

Quantitative data analysis was used to analyse data from CCEI instrument. The analysis included descriptive statistics (mean and standard deviation), comparative means (paired sample t-test, independent sample t-test) and the Kruskal-Wallis test. For example, the study sought to find out whether the students' perceptions of activity-based science learning were influenced by the lessons; therefore a paired t-test mean-score of the instrument before and after experiencing the lesson was necessary.

**4.4.6 Students' attitude questionnaire**

The student attitude questionnaire was not a standard instrument; it was designed for this study. The instrument was designed to assess and give an indication of the students' attitudes towards MBL-based lesson activities that intended to promote science inquiry and collaborative learning. The students' attitude questionnaire had 15 closed items of 1-to-5 Likert scaling (1 = very helpful, 2 = helpful, 3 = moderately helpful, 4 = of little help, 5 = not at all helpful), and two open items.

Two experts on ICT and science contributed evaluating the content and validity of the instrument. The experts also judged clarity of language and suitability of the questions for that age group. The number of items chosen was decided upon to minimise the time required to fill in the questionnaire. 126 subjects
completed the survey after they concluded the lesson activities. Factor analysis was applied to the raw data to detect structure in the relationships between instrument items (variables) and to reduce the number of items that do not correlate highly with other items. The factors obtained corresponded to what was expected and confirmed what the instrument is intended to measure.

The refined instrument measures students' attitudes on four scales: Learning, Structure, Laboratory and Collaboration. Table 4.11 below clarifies the meanings of each of the four scales. A complete instrument and its factor analysis results are presented in Appendix B.7.

<table>
<thead>
<tr>
<th>Scale name</th>
<th>Description</th>
<th>Sample item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Extent to which MBL-based activities helped students to learn physics</td>
<td>MBL activities helped me to understand more about topic</td>
</tr>
<tr>
<td>Structure</td>
<td>Extent to which lesson organisation motivates students' learning</td>
<td>Doing the prediction before the activity assisted in solving the problem</td>
</tr>
<tr>
<td>Laboratory</td>
<td>Extent to which an MBL-based activity lab has an advantage over a traditional lab</td>
<td>Use of MBL to analyse experimental data contributed to tackling the problem</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Extent to which collaboration in learning was useful</td>
<td>Discussing problems with a partner helped to tackle the given problem</td>
</tr>
</tbody>
</table>

The reliability data of table 4.12 suggest that the student attitude scale has acceptable internal consistency, especially for scales containing such a relatively small number of items. The discriminant validity data suggest that the instrument measures distinct although overlapping aspects of student attitudes.

Table 4.12 reports two validity statistics for the final 13-item version of the instrument – the internal consistency (Cronbach's alpha) and the discriminant validity (using the mean correlation of a scale with the other three scales as a convenient index).
The instrument was administered to students at the end of two weeks, which was the period of time that their teachers took to try the MBL-based lesson materials in their classrooms. The information gathered through the instrument indicates the attitudes of students towards MBL-based lesson activities and also their impression of the usefulness of the learning approach and lesson materials.

The open-ended items of the instrument ask students to describe what they like and dislike about the lesson materials and the new teaching approach, supported by MBL technology.

A quantitative data analysis approach was used to analyse the data gathered by the instrument. Descriptive statistics, comparison of mean values, and the Kruskal-Wallis test were the main analytical procedures used to extract information from the raw data.

The data gathered through the open-ended questions of the questionnaire were analysed through qualitative data reduction to guarantee information extraction and preservation. The phenomena revealed within the data were then grouped according to themes by the researcher.

### 4.4.7 Student interviews

The student interviews were used to be able to interpret the quantitative findings and add more value to the data that reveal how the students perceived the new lessons and the new teaching approach. The interview and the two questionnaires mutually reinforced each other, with interviews providing more depth and richness to the information collected through questionnaires and observations (Krathwohl, 1998). The interview questions specified the

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of items</th>
<th>Alpha reliability</th>
<th>Discriminant validity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>4</td>
<td>0.74</td>
<td>0.28</td>
</tr>
<tr>
<td>Structure</td>
<td>3</td>
<td>0.68</td>
<td>0.35</td>
</tr>
<tr>
<td>Laboratory</td>
<td>3</td>
<td>0.73</td>
<td>0.38</td>
</tr>
<tr>
<td>Collaboration</td>
<td>3</td>
<td>0.65</td>
<td>0.29</td>
</tr>
</tbody>
</table>
operations that were brought about, the situations that were evoked, and behaviours that could be used as indicators of effects resulting from teacher learning. The student interview schedule is included in appendix B.8.

The student interviews were conducted one day after the students completed the two questionnaires. These were face-to-face interviews, conducted with a few of the original 126 students that participated in the study. Teachers from the three schools selected the students according to their ability and gender. In each school, 9 students participated, divided equally into low, medium and high achievers. This mixture of students was believed to provide an appropriate picture of students' opinions of the lessons. Gender balance was also ensured. Students were interviewed in groups of 9 at all of the schools. The interview schedule was partially structured and students' answers were taped and later transcribed to capture all their opinions. As the questions were only partially structured, the researcher had the opportunity to expand them to include more input as to why students held the opinions that they did.

The interviews were coded (Miles & Huberman, 1994) after the tapes were transcribed. The coding enabled different students' responses to be combined and summarised. A general view was compiled after all of the statements from different students were analysed and a theme was established. In some few cases, different themes were combined to form opinions that support attitudes or perceptions already established in the questionnaires that the students had completed.

4.4.8 Analysis of students' classroom products

To get an impression of how well the students learned the lesson materials through the ideals of the new approach to teaching, it was necessary to scrutinise the quality of some of the items produced by the students after they completed the lesson. The materials produced could reveal the students' knowledge and understanding of science concepts and reasoning, and of the procedures of science inquiry. The evaluation of the products contributed to the monitoring of students' disposition about the lessons, their development and judgment towards the lessons and the new teaching approach.
A sample of 12 items produced by the students, four from each school, was used in the evaluation process. The items were lab reports on MBL-based lessons and the associated homework assignments. Each school supplied two homework assignments and two lab reports. The teachers from each school used their past experience with the students to select the products from four different students with average performance.

To gain a general impression, a checklist of criteria was prepared and referred to when analysing the products. The criteria included content and form. The content refers to the substance of the items produced: data, results, interpretations and conclusions. The form refers to how the content was presented: organisation of material, graphs and tables, and clarity of writing.

A variety of elements were checked including the ability of a student to give a clear statement of a problem or question addressed by the activity; whether a student employed a method that ensures that the techniques used justify the conclusion, and the information gathered allows the work to be repeated. It also involved checking whether the discussion of results obtained indicates a trend in the data and whether the data are consistent with relevant models or hypotheses. It was also important to ascertain whether or not the interpretations of the data made by the student were thoughtful, and the student analysed the why and what of the occurrence. The evidence of good interpretation or analysis involved students' identification of patterns or contradictions and a specific, plausible and well-supported explanation of the results.

In summary, the product assessment was intended to ensure the accuracy of important skills in scientific content and reasoning, that all possible inferences were made and that the students drew no illogical inferences.
CHAPTER 5
Effects on teacher learning

This chapter describes the effects of the in-service arrangement on teachers’ learning. Section 5.1 examines the teachers' reactions towards the in-service arrangement after the implementation of their learning in the classroom. Section 5.2 describes teachers' learning through the in-service arrangement. The classroom practice as observed by the researcher and the way it was perceived by teachers is described in section 5.3. Section 5.4 depicts how the results of the in-service arrangement and classroom implementation impacted on students. The student outcomes are viewed from the perspective of their perceptions and opinions towards the new approach to teaching physics, and the learning accomplished using the new approach. Section 5.5 summarises and reflects on the effects of teacher learning.

5.1 Teachers’ reactions

Teachers' reactions were focused on the content and the process of the in-service arrangement. They expressed mixed reactions about the content and the process. These reactions were categorised as “general” or “individual” in the description. The reactions were weighed against relevance, utility and timeliness of the content covered; the credibility and practicality of the change needed to implement the content in schools; and the structure and format of the activities that facilitate the in-service arrangement process.

Generally, the teachers thought the in-service arrangement had been a crucial stimulus to initial implementation of the lessons in their classrooms; without the in-service arrangement none of them would have dreamt to start such an endeavour in their schools. Though it constituted their first experience with creating lesson plans, teachers felt the in-service arrangement adequately prepared them for the task. Consequently, they think MBL should be part of the science school curriculum.
All teachers expressly agreed that the content covered during the workshops was fitting and suitable for teaching physics for understanding. However, teachers caution that for it to work in schools and have an impact, they need more help in terms of additional guidance or materials for topics other than those covered in the exemplary lessons. It is not particularly surprising that teachers found the materials to have utility in their teaching practices, as the exemplary lesson materials used in the workshops were modified during the prototyping to fit the current curriculum. The teachers thought the lesson materials did not demand anything unattainable, as long as necessary resources are available and the school environment allows. It was judged that materials could be implemented in the current school timetable. These opinions suggest that the materials could be practical in a real classroom environment. Teachers also thought the inservice arrangement came at a time when it was clearly needed, as their schools were provided with computers but they could not make much use of them for lack of sufficient knowledge and skills.

Teachers were also satisfied with the process of the in-service arrangement. There are a number of the workshop characteristics mentioned by teachers which satisfied them:

- the workshop organiser took care of the teachers' transportation and lunch, which the teachers saw as an incentive that prevented them incurring unexpected extra costs;
- the workshop's arrangement never interfered with their teaching schedule in schools;
- the workshops were not run continuously, allowing them time to reflect before they attended the following one. However, they regretted they could not practice what they had learned between the workshops;
- they appreciated the choice on the content and the method of presenting it, which provided them with a chance to try out the content with peers before they went back to their schools;
- they also liked the fact that they were able to develop their lesson plans the same way as they will do in their schools and be able to discuss the plans with peers. In all, they liked the learning environment, the curriculum materials, the instruction and the formative assessment used.

Teachers also expressed opinions individually on matters concerning the content and the process of the in-service arrangement.
Teachers T1 and T2 from school X agreed that the in-service arrangement was beneficial to them as it provided them with timely and relevant knowledge. These teachers also expressed the wish to witness such knowledge permeating all physics classrooms. The two teachers equally acknowledged that the training workshops were the source of many new ideas on teaching and learning physics, in addition to learning new skills necessary to handle data collection and data processing using MBL technology. Although they were not optimistic that the government will do something meaningful in the near future to speed up the integration of ICT in the science curriculum, they said the workshop shed light on how they can improve learning by re-structuring the lab work. For example, in responding to a question about what they are now doing differently, teacher T1 replied, "I now include guiding questions in the method part of the lab lesson, instead of following the normal practice in which we prescribe all the steps to students."

Teacher T3 described the in-service arrangement as being very enlightening, relevant, credible and practical, because through the workshops he was exposed to new ways of using the computer for teaching physics and the workshops opened his mind on how to guide students to construct physics concepts and principles with the help of computers. Here are some of his views: "The MBL seminars were very educative and opened my mind into so many things especially the usage of computer as a tool for teaching. As you know we have computers in school and students are used to computers. But they normally abuse the machines. They don't use the machines constructively. Even we teachers we did not know much on how to use the machines better. So the MBL seminars expose one on how to guide the students to use the machines."

The arrangement benefits teacher T3 in many other ways, for example he said, "I was able to team with other teachers to discuss the content and how to prepare lesson plans." What's more, "I was introduced to misconceptions and how to deal with them. That does not exclude skills required to gather and process data with MBL system."

To teacher T4 the in-service arrangement in general was relevant and a success as he came in knowing nothing about computers in education but left with quite a lot of useful ideas and skills. The ideas, in his words, included: "being able to do an experiment in a shorter time and be sure of accuracy, and additional skills using modelling to create graphs that fits perfectly my data." The workshop has also made him aware of misconceptions, which he was unwittingly promoting, as he admitted by saying, "before the workshops, I was
not very keen about concepts or principles I was teaching; e.g. though I taught heat and temperature, I was always mixing certain things, which could mislead or promote misconceptions on students, but now I am more careful."

In reaction to a question requiring them to be more precise on what they specifically liked about the experience of the in-service arrangement, the teachers responded in a variety of ways. This can be seen in a few excerpts indicating the relevance, practicality, credibility and utility of the workshops:

- "There were many of interesting things we learn in the in-service which intrigue me. The content was not new but I liked the different way of presenting it to students. I also like the philosophy behind it. It really forces students to learn …" Teacher T1.
- "There are many but let me start by saying I liked the way it was organised. It was intensive and each time we met we were doing something different but linked to what we did previously …" Teacher T2.
- "For me I was more interested in the new form of teaching physics. The experimentation, the questioning were all different from what I was used to in my teaching… it promotes students' inquiry in physics …" Teacher T3.
- "… we were dealing with concrete teaching tasks applicable in our syllabus and these tasks also allow us to share our experience with students. It was not only you telling us what to do but we too shared our views in the process …" Teacher T4.

5.2 TEACHER LEARNING

Teacher learning discussed here is based on the teachers' opinions and understanding of the MBL and a new didactical approach in teaching physics. The learning that teachers acquired through the in-service arrangement was judged by: the degree of understanding demonstrated in the MBL-supported lesson plans they developed; and their opinions about the new approach to teaching and learning physics, which focuses on hands-on inquiry-oriented and student-centred learning.

5.2.1 Teachers' opinions

Teachers first expressed their opinions concerning their learning in response to open-ended questions found in the teacher questionnaire. However, the answers were usually brief. In the interview six months later, the teachers confirmed their positions by giving answers similar to those from the
questionnaire. Since little additional information can be gleaned from the questionnaire, and the responses in the interviews were more complete, this section will focus on the reflective interviews.

In the interviews, the teachers acknowledged the acquisition of new knowledge and skills during the workshops, some of which they went on to apply in the development of their own lesson materials. The knowledge and skills learned were also put to use in their classrooms, as they used the lessons that they had developed in their teaching. Teachers' perceptions of their newly acquired knowledge and skills were expressed in many ways. Some teachers reported having learned skills for incorporating MBL technology in their lab lessons. Others thought they had gained knowledge and skills to develop lessons that facilitate inquiry-oriented learning, and skills of classroom management in a student-centred teaching approach. All teachers assert to have learned how to use MBL purposefully. Excerpts from the interviews substantiate these claims.

Teacher T1 pointed out, "... one of the important ideas I gained is the application of MBL for laboratory use and in creating an ideal classroom-learning environment. The skills I gained were being able to use MBL software for collecting and processing data. Also being able to use MBL kits to perform a number of physics experiments ..."

With teacher T2 the view is a bit different and he stated, "... The important ideas I gained were the awareness of computer use in science especially physics, and how I can incorporate computers in my teaching. My school does not have enough computers, but with the small knowledge I have, I know how useful it can be utilised in science learning. ... Also the importance of group work was obvious. If students are divided into groups, they can share ideas. Sharing ideas can help weaker learners to learn things, which were not understood in classroom. ... Any skills gained? Yes, I can say yes. We used computers to collect data, using different sensors, etc. I can use say the distance sensor or other sensors to demonstrate say Doppler effect or other concepts which we cover in A-level physics."

Teacher T3 expressed his opinions by acknowledging: "There are so many new things I learned. One is teaming with other teachers to discuss the content and how to prepare the lessons plans and everything. And obviously the idea that; you can use computers for educational purposes. Also in the course of the seminars, you exposed us to misconceptions and how to deal with them, which was very useful. The whole idea of seminars, meeting with teachers, and experts from University was something. ... New
skills! Yes. I never have seen MBL interface, the sensors and everything else before. Whatever I did or learned from the seminars was a new skill. I also learned how to use MBL to help my students think about the science they are doing. I know a bit now how to organise and manage teaching in which the focus is the student."

Teacher T4 also contributed his thoughts by saying: "The important ideas are that you can do the experiments within a short time and be sure of accuracy of the data and perfection of the results. … Gained any new skill? Yes there are many, for example before I did not know you can plot the graph that fit so accurate on your data, but with computer that is possible. In principle I learn a lot concerning graphing skills including zooming, etc. In addition, we realised more experiments can be done within a short time."

Teacher T4 after experimenting MBL-based lessons with his class, also concurs with other teachers that it is a suitable teaching tool. However, he is not very sure of the learning benefits advocated for MBL in his class. For example, he disagrees that his students were motivated by MBL-supported lessons. Nevertheless, he found the MBL fits and is suitable for the current curriculum and supported the idea that ICT should be a requirement for the physics curriculum.

Nevertheless, all teachers expressed feelings of inadequacy regarding the skills and knowledge required to fully implement MBL-supported inquiry-oriented learning in their classrooms. Teachers T1 and T2 would like to see more computer courses that involve them in integrating computers in the teaching and learning process. The additional knowledge and skills they referred to include: to know more about what is possible and what is not possible with MBL (and that this should be accompanied with guiding materials); and formulating and evaluating lab problems. They also insisted that the new learning also should be followed with provision of equipped computers in their school, enabling them to practice what they have learned. Teacher T1 also thought there is a lack of communication among teachers who are working in the same field and suggested they should have "inter-school meetings where teachers from same field can exchange ideas."

Teacher T3 on the other hand felt that what he needed more is follow-up support in his classroom by University staff members rather than another in-service course.
Teacher T4, similar to teachers T1 and T2, felt he needed more in-service courses on MBL application in teaching and learning science. The teacher proposes few ideas that can improve knowledge and skills the teachers possess. The teacher suggests that more workshops and seminars be held to sharpen teachers' knowledge and skills with the newest developments in physics teaching and learning. The new learning should be followed up with simple pamphlets that guide teachers with do's and don'ts on how to use MBL and other technologies useful for physics teaching and learning.

### 5.2.2 Teachers' understanding

Teachers' understanding of the activity-based physics learning approach, which is supported by MBL technology and taught in a student-centred approach, was determined by an evaluation of the lesson plans developed by the teacher. The results of evaluation were expressed both quantitatively and qualitatively. The quantitative results are expressed in percentages, using the researchers' exemplary materials as the benchmark. If the exemplary materials are considered to be 100 (also the maximum score), the results indicate how much of the intended curriculum was achieved by the teachers. The three categories of a normal lesson (the start, the body and conclusion of the lesson as discussed in section 4.4.3) are used to summarise the results for each lesson evaluated. The summary of eventuation is shown in Table 5.1.

#### Table 5.1 Average scores of all teachers on lesson plans for all lessons L1- L6*

<table>
<thead>
<tr>
<th>Teachers</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson Plans</td>
<td>L1</td>
<td>L4</td>
<td>L2</td>
<td>L3</td>
<td>L5</td>
</tr>
<tr>
<td>Start of the Lesson</td>
<td>61</td>
<td>49</td>
<td>53</td>
<td>18</td>
<td>51</td>
</tr>
<tr>
<td>Body of the Lesson</td>
<td>58</td>
<td>64</td>
<td>41</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Conclusion of the Lesson</td>
<td>23</td>
<td>16</td>
<td>19</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

Legend: * Scores as percentages of maximum possible scores.

The lessons evaluated are the ones prepared and taught by the four teachers: lessons L1 and L4 by teacher T1; lesson L2 by teacher T2; lesson L3 by teacher T3; and lessons L5 and L6 by teacher T4. The average scores of the three parts of the lesson—the start, body, and conclusion of the activities—indicate that satisfactory learning took place on the part of the teachers through the in-service arrangement, though to a varying degree for the three parts. Also there was variation in the degree to which various teachers understand the exemplary lesson materials. On average, the start of the lesson was performed
better than other parts and the conclusion was the worst. Lesson L3 was the most poorly designed and lesson L6 was the best.

The evaluators also made a number comments regarding the quality of the lessons. The most important points that surfaced from the evaluation of the materials are summarised below:

**General Comments**
- Lessons L1 and L5 were more of a verifying nature and not challenging. Thus they were not demanding enough to promote critical thinking and problem solving skills.
- One evaluator in didactics felt the advantages of MBL were not well utilised by the teachers, obviating the need for using computers in the activities.

**Start of the lesson**
- The start (introductory) part of lessons L1, L3 and L4 lacked a relation to a real life situation, which was one of the requirements. Sometimes the explanation of concepts introduced was given but were not translated into the form of a useful problem.
- In lessons L1 through L4, the objectives were not properly formulated; hence objectives ended up coming across as activities to be carried out rather than learning objectives.
- In lessons L1 through L4, and L6 the reference text to students for prior preparation were not explicitly related to the textbook chapters, sections, etc. Also, the information given to students was sometimes not sufficient.
- In lessons L1 and L3 the problems suggested were not very inspiring, nor was it clear how students should approach the problem in working toward a solution.

**Body part of the lesson**
- All lessons had a list of equipment to be used but not all had explanations that would guide students as to how the equipment functions, or how to use them or set them up. For example in lesson L3 a list of sensors and other equipment/materials necessary for the activity was the only thing given to students.
- All the lessons had prediction questions but these were not always up to standard; some were not challenging enough while others could not lead to proper problem solving. For example in lesson L6, in which students were
asked to investigate cooling, the three prediction questions were: (i) prediction of the relationship between heat and temperature after a certain time \( t \); (ii) the prediction of the final temperature of a cooling substance; and (iii) the prediction of cooling rate as the surrounding temperature varies. This prediction was relatively good, but not for lesson L3. In lesson L3 that involved measuring the speed of sound waves in different media, the prediction comprises a description of how to measure an air column in a cylinder, and predicting the relationship between period and the height of the air column in the cylinder.

- The guiding questions on the method for carrying out the activity were not always given, and if given were sometimes not sufficient or did not give students freedom to develop their own plan.
- The exploration questions of lessons L2 and L5 lack sufficient guidance to enable students to think for themselves. Not much was in the activities to encourage the students to explore the MBL software and hardware in different ways to endow them with the skills needed to accomplish a specific activity.
- The measurements carried out in the activities were proper and reasonable, despite the fact that more could have been done.

The Conclusion

- Though the lessons had an analysis section, this section often fell short. Sometimes the analysis section was lacking guiding questions that would stimulate students to achieve the expected level of understanding. In other cases, this section did not relate to the predictions made at the beginning of the activity. The story was the same with the conclusion section of the lessons.
- None of the lessons included a reflection section or questions that would lead students to actively reflect upon the activity, to re-examine their answers and look for patterns.
- The exercises given as homework were sometimes very traditional, very academic and did not make students think about their experimental plans, nor did they often relate to real life.

As the comments indicate, the teachers tried to achieve the intended skills but they were not there yet; they may need more practice to further improve the skills. The quality of the lessons developed indicated that the teachers were still in transition from a traditional teaching style towards an inquiry-oriented
teaching style. As a result the lessons developed had elements of both styles. It is also possible the teachers had not yet completely mastered the new knowledge introduced and needed more time to reflect and practise.

Looking at the evaluation results and the comments made by the evaluators, there were some common problems encountered in the lessons. The lesson plans suggested that the teachers were not used to preparing lesson plans. The teachers made a lot of assumptions about the users of the lesson plans and did not explain the lessons in detail. Developing realistic problems that relate to the activities and are linked to students' daily life was a problem for all teachers. None of the lessons evaluated had questions that require students to reflect on their lab-work. This may suggest that the teachers themselves are so busy teaching in their classroom that they hardly have time to think critically and reflect on their own teaching.

**5.3 Classroom Practices**

The assessment of classroom practices was based on the indicators described in table 4.4. In the assessment, the components of the indicator guided the observer in what to look for in the classrooms. The pre-lab preparation assessment monitored whether the teacher checked on how well the students were prepared for the activity. The science inquiry components checked whether the teacher was able to implement the predict-observe-explain sequence in their complete lesson. For the active learning component, the teacher's ability to create and maintain active learning in the teaching of the lesson was observed. Regarding collaboration, the focus was on the teachers' ability to create a collaborative learning environment in the classroom. The formative assessment component gauged the teacher's ability to monitor students' progress and give appropriate feedback that will improve both students' learning and understanding, as well as teachers' teaching. Also assessed were whether the teacher gave homework and how useful the homework was in helping the students to reflect on the lessons.

These indications were observed for four teachers while teaching. Individual portraits of classroom implementation are described first, followed by a detailed analysis that captures the whole classroom practice for all four
teachers. The section is concluded with opinions expressed by the four teachers about their experience with the new approach in their classrooms.

5.3.1 Four portraits of classroom implementation

This section describes in detail the classroom observations for individual teachers. The details are presented as a general description of all lessons, but also included are vignettes of portions of particular lessons, as examples to highlight some important points. The scores of curriculum profile for individual teachers are excluded.

Teacher T1 from School X

Teacher T1 who was teaching grade 14 knew clearly from beginning what to do, but was hesitant on how to do it. He was familiar with the suggestions in the guide accompanying the exemplary teacher support materials and tried to incorporate these tips into his lessons and classroom teaching practices, though not always very successfully. In the first lesson, he spent most of the time familiarising the students with MBL technology and helping students to get the activity going. As the teacher was alone and students were many, he formed three groups of 10+ students each, to facilitate his communication and increase the amount of time he could devote to each group. As most of the time was spent in familiarising students with MBL basics on data collection and analysis, the remaining time was not sufficient to realise what had been planned for activity-based lab work. Consequently the first lesson was not carried out very differently from traditional lab work.

In subsequent lessons, however, teacher T1 tried his best to achieve the goals of the lessons. He introduced the lessons as normal, but now he would also check and give some feedback on the previous homework before introducing the new lesson. The teacher talked a bit about the lab-problem to be solved. Judging from students' reactions to the teacher's interactive questions, it seems the students felt the activities were relevant not only to learning but also in their daily life. It was however very clear that both students and the teacher were used to a different kind of introduction. When the teacher posed questions, students sometimes gave answers that were neither completely right nor completely wrong, but the teacher did not probe further with more questions; instead he ignored the answers and moved on to ask other students.
After the introduction, the teacher divided the class into two groups of about 25 students each. Each group had about an hour to work on the activity. As there were two adjacent lab rooms, one group was sent to the other room to discuss their answers to the prediction and method questions for the activity. The second group was subdivided into 5 small groups based on the number of computers and MBL kits which were available, and started working on their lab activity. The teacher guided the students through the activities and modelled a bit of what the learners were supposed to do. The teacher always reminded the learners about the three important stages necessary in the activity, that is: prediction, observation and explanation. As usual this group started by reaching agreement on what would be the outcome of the activity as guided by the prediction questions. His students were eager to learn, even though their learning seemed to be exam driven, as they were concerned whether they will be able to master MBL before exams, which were 6-7 months away. After they were informed MBL-supported learning was not part of the curriculum, they were more relaxed.

As the lesson proceeded, the teacher would circulate through the room, checking what the students were doing, asking questions and offering assistance where it was needed. Some groups were struggling either with the apparatus or the measurements and the teacher would spend time helping them get going. The groups seemed to be well organised, as the group members were all involved and working as a team. The students' confidence in doing the activities grew as time went on. In the first meeting the students

Vignette: The follow-up of teacher T1 students' discussion about their predictions before the activity began.

The topic of investigation was springs and harmonic motion. The first question on prediction was to ascertain the relationship between the force exerted by a spring and by the extension or compression of the spring, and predict the spring constant. The students first argue about the laws to apply. One boy suggested applying Hooke's law directly, but a girl reminded him the spring would be attached to a force sensor, and there is gravitational force. After an exchange of arguments they agree that Hooke's law and Newton's third law should guide them in establishing a mathematical relationship, and with the methods questions they started discussing the appropriate approach to do the measurements and to process the data.

The second question in the prediction required them to predict how the graphs of force, mass position, and velocity, will look like, if the mass attached to the end of an ideal spring can be made to oscillate with minimal friction. After quite an argument, the students couldn't agree, three thought if Hooke's law really behind it, the force measured by sensor should be exactly in phase with the mass' position, and if the position is a sine function, velocity is a negative cosine function. Two students were unsure, but agreed to start the experiment and observe the graphs.
were very enthusiastic but had to fumble a bit with the equipment and were asking the teacher lots of questions.  
But as they grew more accustomed with the system they were able to spend more time carrying out the activity and discussing among themselves. After about one hour the second group was called in and did about the same thing that the first group had done. The first group was left doing nothing in particular, though most students were discussing their results in groups to come up with some sort of preliminary report. The first group always had an advantage over the other in understanding the lesson since students had more time to reflect on the activity. This was made evident by the fact that the first group presented their results before the lesson was concluded.

After another hour, the teacher brought the two groups back together and spent the last fifteen to twenty minutes to conclude the lesson. As there were a total of ten sub-groups, only a few (in most cases 5) presented their results to the rest of the class. Sometimes the presentation was only oral, however there were times when results were also written on the blackboard for discussion. The results were written on the blackboard immediately after the group work was done, even before the final discussion started. The group leaders were responsible for reporting the results. The teacher guided the discussion. Nevertheless this was the most difficult part for teacher T1. Sometimes, instead of summarising the findings of the activities as different groups report their results accompanied with explanation on how the results agree or differ from the predictions, teacher T1 led the students to conclusions. He sometimes asked the groups to explain how the results compared the prediction, but at the end it was not clear which group had used a proper approach and achieved the right conclusion. This left some learners unable to make a connection between the lab-problem and theory.

Teacher T2 from school X
Teacher T2 was teaching grade 13, and was very traditional in most of his thinking and actions. He was strong in subject matter although he was not very good at stimulating students, whether in work or other lesson activities. He was very sharp and eloquent in explaining things. As with his colleague, teacher T1, teacher T2's first lesson was a struggle, for he had to cope with uncertainties within himself (using a new method for the first time), and pressure from students who wanted to master the MBL basics in measurements and data analysis. Unfortunately, the first lesson was too long and he could realise only
the first part in the first meeting, with the second part carried over to the next meeting.

**Vignette of selected portion of start of a lesson in Ohm's law by teacher T2**

For Ohms' law lab activity the, teacher started the lesson by quickly reviewing Kirchoff current and voltage laws; resistance in circuit circuits, resistor colour coding; and emphasis on interpretation of graphs. He later introduced the activity, which was to establish the relationship between electric potential difference (voltage) across a conductor and the electric current through it. He then explained necessary safety precautions for working with electricity. He reminded the students the activity is to be conducted in groups of five, defined tasks for each member and ask each individual to hand in completed lab report which also included some post-lab questions to foster reflection on outcomes. He asked them to discuss and complete pre-lab questions before they begin the new activity.

Teacher T2 spent the first meeting familiarising the students with the MBL system and lesson materials. Teacher T2 introduced the lessons satisfactorily by explaining what the activities were about, but centred on the problem that the students were to solve using the experimental approach. Students were generally positive about the activities, as the problem-solving task seemed to motivate them. He then divided the class into two groups before the students started working on the lab activity. The students were working in small groups of about 5 students. The teacher's role seemed rather distant, only checking whether everything was ok, but the students seem self-motivated. After doing the activity, students reported the results by group, led by the group leader.

In the discussion, the teacher was too quick to provide answers and denied students the opportunity to think about and contribute to the discussion. The teacher led the discussion but groups couldn't present their findings in a way that other class members could look at it, digest it and contribute their ideas. Instead the teacher asked leading questions, which pre-empt the discussion on the methods used, and later asked the students to write the lab reports. Even the questioning style he employed was not that impressive as it was rather closed, with him giving short answers, and so discouraging further discussions. The general conclusion or the solution of the problem was presented to students in the next meeting session after students had handed over their lab work. The teacher also gave few questions as homework to students.
Teacher T3 from school Y

Teacher 3 was in his late twenties and taught grades 13 and 14. He was very good in stimulating students in the whole lesson through his very easy and friendly way of communicating with students. Though he was friendly with his students, he was at the same time firmly in control of the class. In his class discussions he allowed the students room for contribution. Students also took the opportunity to share happily and usefully. The classes were very lively. Students participated actively, asking lots of questions and providing answers and solutions to problems. It seems that was the culture of the school for it would have taken ages for children in that part of the world to behave that way with teachers.

Since the students were all computer literate the teacher went straight to the first lesson which he decided to make a demonstration of the principle he was about to teach. He followed that approach so that students could also see how the MBL sensors could be connected to the interface and how the software could be operated so that they could practise on their own after the lesson was over. As lessons in this school took half of the time of the lessons in government schools, the teacher used the last 20 minutes to introduce the principle he intended to teach.

In the subsequent lessons, teacher T3 was well organised, and competent in teaching skills and subject matter. The teacher introduced lessons in different ways depending on whether the activity called for lab work or a demonstration. But whichever the case was, he started by asking questions to determine students existing knowledge, summarised the ideas and linked them to the lab-problem to be solved. Following this, students were asked to predict the outcomes of the demonstration or the lab work. In the case of lab work, students were supposed to solve a lab-problem posed in the activity. After predicting the solution to the lab-problem, students explored the validity of their solution through experimentation. The inquiry process culminated with explaining the findings of the exploration. In the case of demonstrations students were asked to explain their predictions before they were given an opportunity to observe. The teacher made the activities short so that they could be covered in 50 minutes only.
Students were working in groups of two or three and the teacher clearly explained the roles that the students in a group should divide/among themselves. The groups were running smoothly and students were confident in what they were doing. They were happy, discussed their predictions and planning strategies for carrying out the activity, checking the equipment, doing measurements and discussing their findings as they progressed with the activity. The teacher was also going around the groups asking questions and helping those with problems in deciding the method approach or setting up the equipment. He was also trying to push students to keep track of time and finish on time.

The conclusion part was not done properly because of insufficient time, and in most cases it was very cursory. As usual, group leaders orally presented the results together with the group's interpretation of the results, with the teacher compiling the results on a white board. Then the results were discussed, most often by the teacher picking out an incorrect result and using it as a springboard for discussion. In most cases the discussion would not be completed and the teacher would have to somehow wrap up quickly to enable students or even himself to rush to the next class. On two occasions some students had problems with the conclusions after the activity was over and the teacher had to spend more time with such a group or individual to help them understand. The teacher always reminded the students to bring a written report of their lab-work together with the assignment that accompanies the activity to their next meeting.

Teacher T4 from school Z
Teacher 4 was quiet, very cooperative with students, serious with his work, but sometimes too carefree. He was well prepared and tried very well to introduce
MBL-supported lessons to his grade 14-class. He scheduled his lessons in the afternoon, as his students were all free after 1:30 p.m. He maintained a positive and encouraging learning environment, and students liked him and worked with him very closely.

He spent the first meeting familiarising his students with MBL basics on measurement and data analysis. The students hardly did anything else in the first meeting. In the following meetings he taught lessons as usual, starting with introduction, which was very interactive with T4 taking the lead in asking most of the questions. The problem was that his students were not used to asking good questions, therefore the questioning was more in one direction. The students were not used to being actively involved in the learning but slowly they were picking it up. Sometimes the teacher had to try really hard to make them speak their mind.

Vignette: Introduction of the problem in the lesson on heat transfer by teacher T3

After covering the heat transfer topic teacher T4 gave student the following thought provoking statement for reflection. "Back in 1969 a Tanzania high school student named Mpemba observed a phenomena that: hot water freezes faster than cold water; while making ice cream. This does not seem to make sense, and his teachers did not believe it was possible, it took several years until university professors finally accepted his discovery, and now it has been accepted to be true". The questions to students were:

- What factors cause water to freeze
- How can Mpemba effect be explained
- What are the experimental conditions necessary for this effect?

To assist the students he suggested them to consider the following conditions: evaporation, super-cooling, convection, dissolved gasses, and conduction.

The body portion was well done as 2 to 3 students shared a computer and had ample time to carry out and discuss the lesson—more than at any other school. Discussions centred on the predictions of what was expected in the activity. While students were carrying out the activity, the teacher was also going around the class helping students in many ways. Because there was so much time, the teacher spent a lot of time with each group working closely. In some cases, he helped the students set up the equipment and produce the first results. Since each group had only two members it was easy for them to define roles.

Though many activities were performed all were lab work. The teacher introduced the labs by asking a few questions that related to previous knowledge needed for the activity to be performed. Then he posed a problem that related to the activity and explained what was required of students.
even when the teacher did not assign them. Some students were not confident in doing the activities, and they required a lot of support from the teacher. Despite that, the students were very interested in the activities. The topic the teacher was dealing with was heat energy. Since this topic sometimes requires more time to collect data (the rate of heat exchange can be slow) the class didn't discuss results until after the second session.

More time was devoted to the discussion than in other schools, but as the students were not asking many questions, the discussion was dull. The conclusions were mostly teacher driven and not always clearly explained to the students. Sometimes when groups presented their findings the teacher would inject some input to the conclusion. In some other instances the teacher randomly asked a few groups to present their findings and asked the rest of the class if they agreed, but no further discussion took place. In another instance the conclusion was arrived at in a teacher directed manner. In a few instances teacher T4 gave students some difficult and reflective questions to help students anchor the newly taught ideas.

5.3.2 Detailed analysis of classroom observations

In this section a detailed overview of the classroom practices demonstrated by all four teachers is presented. The observation of teachers' classroom practices focused on the six components of the indicator as presented in chapter 4, that is: pre-lab preparation, science inquiry, active learning, collaborative learning, formative assessment and homework. The classroom observation instrument simplified and guided the observation of classroom practices, complemented with information from the running notes.

The teaching of the lessons followed a general pattern: the start, the body and the conclusion of the lesson. In the start section, the teachers prepared the students for the activity ahead. It was in this section that pre-lab assessment played a dominant role. A bit of formative assessment was done in this part. At the end of this section the lesson was introduced. In the body portion the actual activity was performed. This is where inquiry learning, active and collaborative learning, and formative assessment were checked. In the conclusion part, all six components, except pre-lab preparation, were checked.
As the teaching progressed, the researcher observed and sometimes noted the practise and judged whether it was in line with the expectations, summarised as questions, in the observational checklist. In the observational checklist, the questions that investigate the six components were grouped in the three lesson parts.

The observed positive practices scored points in each of the lesson parts. The average scores in the pre-lab preparation, learning by inquiry, active learning, collaborative learning, formative assessment and homework components of the curriculum profile show encouraging result, as portrayed in table 5.2, which summarise the scores for all teachers. The scores in table 5.2 are averaged over all lessons, as well as the average of all teachers in the six areas. The scores do not show large differences between teachers. Teachers T3 and T4 scored slightly above the average in most cases.

Table 5.2  Average score of classroom observation of all lessons all four teachers

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lab Preparation</td>
<td>70</td>
<td>72</td>
<td>70</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>Learning by Inquiry</td>
<td>53</td>
<td>49</td>
<td>59</td>
<td>61</td>
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<tr>
<td>Active Learning</td>
<td>55</td>
<td>49</td>
<td>60</td>
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<tr>
<td>Collaborative Learning</td>
<td>69</td>
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<td>75</td>
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<td>68</td>
</tr>
<tr>
<td>Formative Assessment</td>
<td>52</td>
<td>56</td>
<td>57</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>Homework</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Average per teacher</td>
<td>60</td>
<td>59</td>
<td>64</td>
<td>62</td>
<td>61</td>
</tr>
</tbody>
</table>

Legend:  * scores are expressed as percentage of the maximum possible score.

Teacher T3 taught lesson L3 and two other lessons that he developed after the training workshop was over. Teacher T3 also used the MBL very well to demonstrate some concepts before teaching them on two occasions. Teacher T4 was not very good in formative assessment, whereas teacher T1 was relatively good in developing lessons (see L1 and L4 in table 5.1) although he was not as skilled in teaching them. Teacher T2 was less enthusiastic about the new teaching and learning approach than the others. The next three sections examine the teacher performance in each of the lesson parts separately.

Start of the lesson
Apart from a few problems related to teachers adjusting their class to a new teaching and learning approach at the beginning of the observations, all
teachers seemed well prepared for the lessons that were observed. The learning materials and equipment were organised, teachers were prepared for the execution of the lessons and proceeded with confidence.

The general set-up of the start of the lesson section began with an introduction of the lesson topic and important concepts by way of a short inventory of student ideas. Next, the teacher summarised the discussion and introduced the problem to be solved. Students were then asked to break into small groups of at least two members and discuss their predictions about the outcome of the practical activity. This discussion resulted in a solution to the problem just introduced. The initial group formation was not complex; students who were sitting together formed a group. After working together on a few activities, students tended to form permanent groups. Both teacher T1 and T2 created big groups due to the (perceived) lack of enough MBL equipment. It was also during the small group discussions that students discussed the method questions and the equipment they would need (with guidance from the lesson materials), and developed the plan they were to follow to solve the problem. After the group discussion, the students were ready to start the lab activity. It was also at this stage that teachers reminded students about the responsibilities the group members should share. The teacher also took this opportunity to explain what would and would not be possible during the activity, and also mentioned any precautionary measures to be taken.

It was during the introduction that the teacher brought forth the theory behind the activity by asking the students questions and tying together the ideas from their answers. For example, in one lesson, which was to investigate the rate of cooling, the teacher used an example of a cooling cup of tea, and asked students to justify different traditional methods practiced to cool it. The teacher used the black board to write down the reasons put forward by students and also to illustrate important points, and later related the ideas to theoretical background information the activity was pursuing. All teachers tried to probe students' prior knowledge but not all could use students' prior knowledge properly to introduce the new activity. In few instances the teachers used part of the introduction to check homework. Table 5.3 show summary scores for all lessons per teacher for the starting part of the lesson.
Table 5.3  *Scores for the Starting part of the lessons per teacher*

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lab Preparation</td>
<td>70</td>
<td>72</td>
<td>70</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>Learning by Inquiry</td>
<td>52</td>
<td>48</td>
<td>58</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>Active Learning</td>
<td>55</td>
<td>49</td>
<td>60</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Formative Assessment</td>
<td>50</td>
<td>54</td>
<td>55</td>
<td>54</td>
<td>53</td>
</tr>
<tr>
<td>Homework</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Average per teacher</td>
<td>57</td>
<td>56</td>
<td>61</td>
<td>59</td>
<td>58</td>
</tr>
</tbody>
</table>

*Legend:  * scores are expressed as percentage of the maximum possible score, ** N/A= Not Applicable.

All teachers did pretty well in preparing the students for the lab activity in the pre-lab preparation part of the lesson. Nevertheless, their performance was not that good with the other indicator components. The results were generally fairly good, considering the fact that the teachers were implementing new teaching methods in their classroom for the first time. In this section, T1 and T3 performed above average in the learning by inquiry part. On active learning, teachers T3 and T4 performed slightly above average but T1 was below average in formative assessment. Teacher T2 performed worse than the others in the active learning and learning by inquiry parts.

**Body of the lesson**

The actual practical activities took place during the body of the lesson. In this part the students explored the experimental plan and the equipment they were to use, took the necessary measurements and carried out some preliminary analysis of the data gathered. The teacher's role was to provide guidance and assistance to the groups whenever necessary. Working with the groups was a bit tough at the beginning of the observations. The teachers were overwhelmed by the requests for assistance from students, as the teaching method was new to all parties and students were not ready to take the first uncertain steps without their teacher's assistance. In the first few meetings teachers T1, T2 and T4 often needed to instruct students regarding many of the basic computer skills necessary to conduct activity-based lab work. As a result the teachers were very actively involved; basically, one could say that the teachers carried out the activities themselves. However, teachers maintained a positive learning environment during the activity in all lessons, prompting questions from students and responding positively to them.
Activities were carried in groups formed at the start of the lesson and teachers usually did not assign specific roles to group members. All teachers interacted with student groups in all lessons, but their role varied. Some teachers were moving in and out of the groups, asking questions and giving advice. Others spent a lot of time assisting the supposedly weak groups. Yet others were more distant, just checking the progress. Table 5.4 provides summary scores for all observed lessons per teacher.

Generally the scores for all 26 lessons observed were satisfactory. The teachers' scores in this part of the lesson were higher than for the starting section. The collaboration component surpassed other elements in the way it was carried out. Maybe this could be attribute to the fact that collaboration is a cultural part of most students' life and teachers did not have to do much to bolster it.

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lab Preparation</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Learning by Inquiry</td>
<td>59</td>
<td>55</td>
<td>65</td>
<td>67</td>
<td>62</td>
</tr>
<tr>
<td>Active Learning</td>
<td>60</td>
<td>54</td>
<td>65</td>
<td>63</td>
<td>61</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td>71</td>
<td>67</td>
<td>77</td>
<td>66</td>
<td>70</td>
</tr>
<tr>
<td>Formative Assessment</td>
<td>53</td>
<td>57</td>
<td>58</td>
<td>57</td>
<td>56</td>
</tr>
<tr>
<td>Homework</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Average per teacher</td>
<td>61</td>
<td>58</td>
<td>66</td>
<td>63</td>
<td>62</td>
</tr>
</tbody>
</table>

Legend  * scores are expressed as percentage of the maximum possible score, ** N/A = Not Applicable.

In this lesson section, as was also the case with the starting section, teachers did not fare well in the formative evaluation component. This may be caused by the fact that many teachers lack questioning skills; the questions they asked were not very invigorating but rather perfunctory, in some cases a mere information check. This poor performance was in spite of the fact that the teachers did not lack explicit knowledge. The students were not usually asking difficult questions, either. On the other hand, the learning by inquiry and active learning components earned almost identical scores on the average scale. As the two were going hand-in-hand in the classroom practice, any further improvement of the two may require equal emphasis.

**Conclusion of the lesson**

This part of the lesson the consisted of several activities, which included: groups of students presented their lesson results and conclusions; groups
Effects on teacher learning

cmpared and discussed their results before a consensus was reached on
general conclusions; teachers posed some reflective questions; and finally, the
teacher assigned homework including writing a report of the experiment. This
section proved to be the most challenging part of the lessons for all teachers.

The conclusions were done improperly in most cases. More often it ended up
being a summary of the experimental results instead of being an opportunity to
discuss the discrepancies in the results. In some cases the conclusions section
simply consisted of stating the correct answer. This was of no benefit to students—
especially those who had not supplied a correct answer, as they could not find
out where they went wrong. The conclusion of the lesson was intended to be an
opportunity for teachers to derive the theory from the findings of the students;

hence enriching the subject matter covered and grounding the theory in the
students' own experience. But this opportunity was not always taken advantage
of. The teachers were also supposed to discuss the method used and to sum up
the activity, but this was also not done properly. The weakest point was the way
in which the conclusions derived from the data analysis were related back to the
predictions made previously or the theory developed. This establishment of a
link between predictions and results of the analysis was rarely done.

Teachers seldom posed the type of questions to students that would require
them to reflect upon the experiments. When such questions were posed, they
were very superficial. The general teachers' performance for this part of the
lesson is summarised in table 5.5. The scores were lower than for the body
section of the lesson, but generally they are fairly satisfactory. All teachers did a
satisfactory job of assigning homework, although the assigned tasks were not
very reflective in nature.

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lab Preparation</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Learning by Inquiry</td>
<td>47</td>
<td>45</td>
<td>53</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>Active Learning</td>
<td>49</td>
<td>43</td>
<td>54</td>
<td>52</td>
<td>50</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td>67</td>
<td>63</td>
<td>73</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>Formative Assessment</td>
<td>52</td>
<td>56</td>
<td>57</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>Homework</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Average per teacher</td>
<td>55</td>
<td>53</td>
<td>60</td>
<td>57</td>
<td>57</td>
</tr>
</tbody>
</table>

* scores are expressed as percentage of the maximum possible score, ** N/A = Not Applicable.
5.3.3 Teachers' reflections on classroom implementation

This section examines some reflections expressed by the four teachers in the interview and from the open questions of the questionnaire. The section begins with a summary of the thoughts put forward in the questionnaire, supplemented with comments made by teachers. The last part of the section presents some thoughts about the classroom as expressed in the interviews.

The following are commonly expressed opinions about the classroom implementation derived from the open-ended questions of the questionnaire:

- Teachers viewed MBL as an effective teaching tool that students find easy to use and can be integrated in the current physics curriculum. They think that if feasible MBL should be a requirement for the high school physics curriculum.
- Regarding MBL as a learning tool, teachers observed that it can: motivate students in learning physics; help to develop high level of thinking skills; enhance comprehension and retention; and is also an excellent tool for individualising student work.
- Concerning implementation, the teachers did not find the preparation of MBL-based lessons and lesson plans difficult, nor more time-consuming than traditional lessons. They were also satisfied with the implementation of MBL in the classrooms.
- They all felt the need to integrate MBL into the curriculum. A comment made by all four teachers was to make MBL a mandatory part of the curriculum.

Also, the teachers expressed common views on the educational benefits of MBL activities in connection with the approach to teaching and learning:

- The MBL activities can provide more accurate and reliable data, which can be employed to verify specific scientific principles or help students to build models accurately.
- MBL activities and the teaching approach can motivate students and improve students' interest and participation in physics learning.
- MBL activities can help students to learn computer skills beyond basic computer literacy skills, such as skills in handling real scientific data with computers.
- With MBL, more can be achieved within the current school timetable schedule, which is a big advantage as time can be reallocated to pursuing other goals. However, the teachers also realise that learning science by inquiry requires more time than traditional classes.
• MBL-supported lessons can widen the student's scope of learning through the use of different media.

Teachers T3 and T4 wrote down additional opinions that differ slightly from the common ones. Teacher T3 had some different views on how the students benefited from an MBL-supported teaching approach. He asserted that his students were more motivated to do physics than before, and that this was because of MBL technology. The students love to work with computers, but unfortunately, they were not used to using computers for science learning. To the students, MBL-supported lessons widen their scope of computer applications for a different field. As MBL was new to them, the teacher thought it made the students more up to date with ICT in education.

Teacher T3 was also aware of the snags that may hinder progress if MBL has to be implemented in the school. One of the problems he felt needed to be addressed in light of MBL is the current body of lesson schemes and plans, which are not amenable to MBL. A second hurdle that needs consideration is a revision of the assessment technique, which currently does not have room for MBL. To him, in the absence of proper assessment, the cognitive advantages of MBL will not soon be realised. The teacher suggested that such revisions need to be reflected in the final examinations as well.

Furthermore, teacher T3 felt that, "the future of teaching is swallowed by ICT". Hence his suggestion was to equally computerise libraries and all information sources in his school to make information access easy. He thought, "Science and especially physics cannot afford to lag behind in ICT for education. Therefore teachers and students of physics have to use ICT in teaching and learning, and MBL can help them to achieve that."

Teacher T4 also found that MBL is suitable for the current curriculum and supports the idea that ICT should be a requirement for the physics curriculum. However, he suggested some necessary basic changes. The first thing is a revision of the curriculum to reflect changes advocated in the new science education. This would require the universal availability of computers for educational use in schools, for both teachers and students. He added that even if MBL technology would be introduced in the classrooms, not too much should be expected from teachers too soon; teachers should be given time to learn before they can be expected to deliver.
During the reflective interview, the four teachers had more opportunities to clarify their opinions and even venture into other related areas. Their reflection on suitability of the lesson materials after the classroom implementation experience indicated that MBL-supported lessons were suitable for teaching and learning physics when used properly. They mentioned many learning benefits including: supporting the retention of physics concepts; shorter time required to collect and analyse data, leaving more time for students to concentrate on grasping the concepts; very suitable for promoting and motivating students in learning physics for understanding; and can give more accurate and consistent data for all students if all MBL systems are equally calibrated. MBL's improved level of precision in data collection can help teachers discuss the results, as much of the measurement noise resulting from the un-standardized equipment used in traditional lab is avoided. Teachers also thought that MBL could raise the level of students' participation in the learning of the lesson, in addition to students acquiring new skills in computer use.

Teachers T1 and T2 jointly agreed the MBL-supported lessons were well executed except for group work, which was done poorly. They believed if they were to redo the same lesson, they could use what they had learned from the first experience to achieve more with the same resources. The teachers believed that the students had a positive view about learning with MBL, especially because it produced accurate measurement and assisted in analysing results, while also saving time. Certainly because of the new and different lesson plan and MBL software, students had some difficulties in making the transition from the traditional teaching. Teacher T1 affirms that the lesson structure made students think, and that thinking on the part of students was necessary to complete the lessons. This is in contrast to the traditional approach, in which where students follow a rote procedure that may not necessarily involve them mentally. However he cautions that the students may see things differently since the traditional approach is teacher directed and thus places fewer demands on the student. Teacher T2's position was that MBL and traditional lesson plans achieve the same thing, only that MBL is more efficient and good in data analysis.

In conversations about what actually happened in the classroom, it came to light that some students had some negative thoughts about their classroom
experiences. Teacher T1 thought, "Those students thought MBL was not going to feature in exams, so why bother." Teacher T2 however reasoned "... mainly due to differences between the traditional lesson plan and MBL-supported lessons." T2 also added "... the low teacher-to-student ratio contributed, as groups were very large." Reacting to whether conducting the lab before theoretical aspects are discussed (as is currently done) is more enriching to students, teacher T1 suggests, "The approach is good, when you do a focused lab, students understand the theory much easily." His colleague on the other hand insisted, "It is not good as in theoretical part we discuss concepts and principles and verify them in lab. Doing it the other way round students can lack information. If you investigate a new concept then you can start with lab, but as we do nothing new in physics we better teach students the theoretical part, then verify by lab work."

Teacher T3 upon reflecting on classroom implementation and reactions of students had a lot to say. The lesson plan had some aspects that his students liked, for example making predictions and carrying out challenging exercises. His comments were, "If a student exposed to that, will be privileged because (s)he is geared towards making a good scientist. However, the approach is good for optimistic students; pessimists will get tired because of the seriousness of the whole thing." Reflecting on the structure of the lesson materials and its implications for implementation, he said "... if the activity could include more of day-to-day life experiences is ok, as there is more to life than the serious life. So if part of un-serious life of theirs is included in physics, I’m sure we will get up. I know it is a good idea but I do not know how to set it ..." Responding to a question on what he is now doing differently in class as a result of the in-service arrangement he explained, "Earlier I will just go to class give students the experiment as it was in the text but, but now I redesign the experiment such that students will learn in a more productive way. I include prediction as part of experiment. Also when I teach I am concerned about the misconceptions students have before I teach a new topic."

The teacher felt students were highly motivated as asserted this by the following: "Majority of students liked the lessons. I have never seen something else moved my students the same way in physics. They don't like physics very much but the activities were different." He also emphasised the importance of context-rich exercises by saying the more the exercise questions have something to do with students' hobbies the more they will respond positively.
The workload for each activity was sufficient, and students were adequately supported, which motivated them and led to success in learning physics. The teacher revealed, "Students who before were not active in class, were very active in doing MBL activities... so physics learning was very good." To him the MBL activities had benefits related to laboratory studies such as quick data analysis, and cognition such as development of concepts.

In spite of the lack of full support from his school, Teacher T4 perceived the implementation as a success for a number of reasons. First, the students liked the lesson plan. Second, the students received enough support during the lessons. Additionally, through the group work students were able to exchange ideas that made learning easier for them. Teacher T4 also thought the students greatly enjoyed MBL, but he was slightly reserved and cautious in making claims about its effectiveness, partly because the amount of experience using MBL in school was relatively short compared to the traditional approach. Using the computer for doing science was also a new experience for most students as many students were only familiar with using the computer for word processing. Students could do more in the time allocated for lab work and probably learn more. A final measure of success for MBT according to teacher T4 was that the lessons support group learning, which he saw as the best way for helping them to cooperate, learn and understand from each other. These perceptions are validated by what he said in the interview:

"... Because the lessons introduce the students to a new idea at the beginning of the lesson, then try the idea, and finally evaluate it. This gives me an impression they liked it ... Evaluating how effective the implementation was, is very difficult ... students were introduced into new ways of using computers for data collection and processing ... students could do more in the prescribed time, and that could contribute to their learning, because as one practices understanding also develops ... students sometimes are not willing to ask question, but they do ask peers."

The differences in opinion among the teachers arises partly from teachers' personal beliefs about teaching and learning, but also from the school environment where teachers work, as the school environment affected the priorities these teachers had. Teachers from the government school depended heavily on what the government set for priorities and even the school heads are not able to exert much influence. This is in sharp contrast to the private schools where the government did not influence their decisions on financial matters at
all. Another difference may be due to differences in students' characteristics in these schools. Most students in government schools are from rural areas where parents are relatively poor. Most parents of students in private schools are relatively rich and live in urban areas. Some can even afford computers or send their children to private computer lessons.

5.4 STUDENT OUTCOMES

This section describes the effects on students. The results reported emphasise students' opinions and perceptions concerning MBL and the new approach to teaching. In the study we also explored the knowledge and skills students gained by analysing a selection of products (lab reports and homework) made by students.

Generally in all schools, the observations indicate that most students experienced difficulties at the beginning of the lessons in shifting from a traditional approach to conducting lab experiments, in which everything is procedural, to the new activity-based setting where students have more freedom to think and make their own decisions. Also observed, whenever there were problems associated with new terminologies related to MBL or unclear steps in the activities, students were having discussions amongst themselves in the groups or with the teacher.

There were indications from classroom observation that support the idea that MBL-supported lab work simplifies students' work in the areas of data collection and data organisation before students undertake investigation or analysis. The MBL system enables students to focus on their problem-solving tasks. It also helps students to analyse relationships, commonalties or differences, and to look for patterns or trends in the collected data. Students progress slowly to learn to establish their own strategies for solving the problem at hand. The teacher's role was mostly to guide students to be more focused on what they were doing and to lead them to the completion of activities.

In the following sections we shall discuss the student outcomes portrayed by results gathered through questionnaires, interviews and students classroom products.
5.4.1 Student perceptions of the learning environment

This section presents the results obtained from students' responses to the computer classroom environment inventory questionnaire. To begin with, a table shows the sample mean score for students' perception of the classroom environment before and after experimenting with the new approach to learning in a new learning environment. Then the comparisons of the perceptions by gender are presented. At the end, a comparison is made of the students' perception of the learning environment as created by the four teachers in their classrooms.

To get a general feel for the change in students' perceptions of their classroom environment at the beginning and end of the implementation process, a t-test for matched pairs was carried out. Table 5.6 reports a summary of the results.

Table 5.6  Pre-test and Post-test mean, standard deviation an t-value for CCEI (N=124) with the scores range from 1 ('never') to 5 ('very often')

<table>
<thead>
<tr>
<th>Scale</th>
<th>Testing</th>
<th>No. of items</th>
<th>Scale Mean</th>
<th>SD</th>
<th>Effect Size</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td>Pre</td>
<td>6</td>
<td>19.5</td>
<td>4.4</td>
<td>0.21</td>
<td>2.87*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>20.2</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open endedness</td>
<td>Pre</td>
<td>4</td>
<td>13.4</td>
<td>2.7</td>
<td>0.14</td>
<td>3.22*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>13.9</td>
<td>2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organisation</td>
<td>Pre</td>
<td>4</td>
<td>14.4</td>
<td>3.2</td>
<td>0.10</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>14.7</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material environment</td>
<td>Pre</td>
<td>5</td>
<td>19.2</td>
<td>3.2</td>
<td>0.43</td>
<td>8.29*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>20.4</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Pre</td>
<td>6</td>
<td>24.5</td>
<td>4.3</td>
<td>0.05</td>
<td>0.75</td>
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<tr>
<td></td>
<td>Post</td>
<td></td>
<td>24.7</td>
<td>4.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * is statistically significant ($p < 0.05$).

The values of effect size suggest that there was a slight improvement in students' perception the of classroom environment. A significant increase ($p < 0.05$) in the mean score occurred for investigation (approximately 0.21 of the standard deviation), open endedness (approximately 0.14 of standard deviation), and material environment (approximately 0.43 of standard deviation).

The results on table 5.6 are summarised in graphical form in Figure 5.1; showing the scale mean scores for students' perceptions of the classroom environment.
environment before and after implementing the lessons. Even though the increase shown in Figure 5.1 is not large, it illustrates that there was increase in students' perceptions and occurred in all scales. The figure captures students' responses to the learning environment as it allows more investigative, and more open-ended work; the organisation level was perceived positively; the interaction with computer software and hardware met with a high level of approval, despite the fact that there was little improvement in student satisfaction with using computers for investigation.

The increase in 'investigation' implies that students perceived that they were engaged more often in inquiry-oriented learning. Students also perceived that MBL-supported activities emphasised a more open-ended (as signified by the increase on open-ended sub-scale) approach of inquiry than they experienced before the implementation of activities.

The students did perceive a significant change in the material environment. This could be due to the fact that the majority of students had barely used computers in class before. But after working with computers, they were familiar with the hardware and software, and appreciated that both hardware and software were in good working condition to solve their problems. They could work with computers individually and probably confidently. This could explain the high post-test mean score of the sample (with much smaller variation) and relatively high effect size.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure51.png}
\caption{Students' perceptions of the learning environment (N=126)}
\end{figure}

\textit{Note:} 1=never, 2=seldom, 3=sometimes, 4=often, 5=very often.
The students' perception generally indicated a relatively high degree of satisfaction at the beginning and at the end of the MBL-supported activities. It could be that the students had higher expectations and they were not disappointed at the end.

The insignificant increase in the students' perceived level of organisation of the class may suggest that the students had a positive impression regarding the lesson organisation, but the planning and organisation of the classroom activities did not impress them. The net result of such a scenario would be that they did not perceive a better overall organisation than the traditional activities they were used to. Perhaps they perceived more confusion rather than organisation in the process of carrying out the activities.

The results analysed above are for all participating students. But the difference in perceptions by gender and by the school categories is of interest for Tanzanian readers. In terms of gender, as Table 5.7 illustrates, differences were apparent across all the data. Male students scored higher (not statistically significant) than their female peers in four domains and subsequently in their overall perceptions towards the MBL-supported activity-based learning environment. However, females had a slightly more positive perception (though this difference was not statistically significant) on open-endedness of the learning activities in classroom.

To determine how the difference of perception by students in the schools is related to individual teachers, a Kruskal-Wallis test was performed and the test reveals a significant difference ($\chi^2=11.99, p<0.007$). The results are shown in table 5.8.

<table>
<thead>
<tr>
<th>Table 5.7</th>
<th>Students Scores on five sub-scales by sex on the post-test: scores range from 1 to 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (N=92)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Investigation</td>
<td>3.3</td>
</tr>
<tr>
<td>Open-endedness</td>
<td>3.1</td>
</tr>
<tr>
<td>Organisation</td>
<td>3.4</td>
</tr>
<tr>
<td>Mat. Environment</td>
<td>3.6</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>4.1</td>
</tr>
<tr>
<td>Overall</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Note: * is statistically significant ($p <0.05$).
There was an overall significant difference amongst the students of the four teachers, though not in every domain. Looking at the scales individually, a significant difference was demonstrated for 'satisfaction' and 'open-endedness' dimensions. The significant differences in perceptions related to open-endedness and satisfaction were largely due to differences in perception contributed by students of teacher T3 and T4. As table 5.8 illustrates, students of teacher T4 from the Z school consistently displayed a more positive perception towards the classroom environment than their peers in other schools—a trend consistent across all five perceptions sub-scales. This could be due to students of teacher T4 spending more time practising with the lesson materials in an activity-based learning environment. The students from the two teachers in school X did not perceive the lessons very differently.

Table 5.8 Students’ score on five perception sub-scales by teachers

<table>
<thead>
<tr>
<th>School</th>
<th>T1 (N=27)</th>
<th>Mean ± s.d</th>
<th>T2 (N=58)</th>
<th>Mean ± s.d</th>
<th>T3 (N=28)</th>
<th>Mean ± s.d</th>
<th>T4 (N=11)</th>
<th>Mean ± s.d</th>
<th>χ² df Sig*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invest.</td>
<td>3.3 ± 0.8</td>
<td>3.3 ± 0.7</td>
<td>3.0 ± 0.6</td>
<td>3.5 ± 0.7</td>
<td>4.46 ± 3.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open-</td>
<td>3.2 ± 0.5</td>
<td>3.1 ± 0.6</td>
<td>2.8 ± 0.6</td>
<td>3.5 ± 0.6</td>
<td>11.29 ± 3.01*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organ.</td>
<td>3.3 ± 0.6</td>
<td>3.4 ± 0.6</td>
<td>3.3 ± 0.5</td>
<td>3.6 ± 0.8</td>
<td>1.83 ± 3.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mat.En.</td>
<td>3.7 ± 0.5</td>
<td>3.6 ± 0.6</td>
<td>3.5 ± 0.6</td>
<td>3.9 ± 0.4</td>
<td>6.08 ± 3.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satis.</td>
<td>4.1 ± 0.8</td>
<td>4.2 ± 0.8</td>
<td>3.5 ± 0.6</td>
<td>4.4 ± 0.4</td>
<td>21.20 ± 3.00*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>3.5 ± 0.5</td>
<td>3.5 ± 0.5</td>
<td>3.2 ± 0.4</td>
<td>3.8 ± 0.3</td>
<td>11.99 ± 3.01*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * is statistically significant (p <0.05). Scale values: 1=never, 2=seldom, 3=sometimes, 4=often, 5=very often.

It is interesting to note that students of teacher T3 from the Y school have less favourable perceptions compared to the students for the other teachers, in spite of the fact that these students had more experience with using computers before the lessons. One of the reasons to explain this could be that the students’ previous experience with computers had shaped their perceptions on how computers can be used for educational purposes. And the time the students of teacher T3 spent with the new MBL-supported application was not long enough to change these preconceived notions.

In general we can conclude the students' perception of the classroom learning environment in which activity-based physics learning supported by MBL-technology was introduced, was satisfactory.
5.4.2 Student opinions about MBL

This questionnaire, as with the computer classroom environment questionnaire, had data that could be analysed statistically to provide a general picture of all schools and their corresponding teachers. Apart from the general impression of students' opinions towards lessons, information about differences in attitude according to gender, schools and teachers was also extracted from the data.

To start with, let us consider the gender differences. As with classroom environment perception, there was no statistically significant difference in the scores between male and female students (see table 5.9), though male students display a more positive attitude across all scales.

Table 5.9  Students' Opinions Scores on five sub-scales by sex: (scores range from 1-very helpful to 5-not helpful at all)

<table>
<thead>
<tr>
<th></th>
<th>Male (N=89)</th>
<th>Female (N=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St. dev.</td>
</tr>
<tr>
<td>Learning</td>
<td>2.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Laboratory</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Structure</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Collaboration</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Overall</td>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Note: * is statistically significant (p <0.05).

However, the story is different when the comparison is made between students of teachers from different schools. The comparative results are presented in table 5.10.

Table 5.10  Students’ score on four sub-scales by teachers. Scores range from 1 (very helpful) to 5 (not helpful at all)

<table>
<thead>
<tr>
<th>Schools</th>
<th>T1 (N=28)</th>
<th>T2 (N=60)</th>
<th>T3 (N=27)</th>
<th>T4 (N=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers</td>
<td>Mean</td>
<td>s.d</td>
<td>Mean</td>
<td>s.d</td>
</tr>
<tr>
<td>Learning</td>
<td>1.9</td>
<td>0.7</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Lab Advan.</td>
<td>1.7</td>
<td>0.8</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Structure</td>
<td>1.9</td>
<td>0.7</td>
<td>2.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Collaboration</td>
<td>2.3</td>
<td>1.0</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Overall</td>
<td>1.9</td>
<td>0.5</td>
<td>2.1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Note: * is statistically significant (p <0.05).
In general, there was a significant difference between students' opinions of the three participating schools as confirmed by Kruskal-Wallis test ($\chi^2=9.17$, $p<0.027$). The significant differences were evident in three scales, that is, Learning of Physics, Laboratory Advantage of MBL, and Lesson Structure. The much bigger level of difference shown for learning and laboratory advantage scales are due to differences in the scores of students of T3 and T4, with students from school Z expressing more positive opinions about the lessons. As the Lesson Structure scale did not produce any statistically significant difference due to teachers T3 and T4, we can conclude that students of T1 and T2 from school X contribute to the observed difference.

Students of teacher T4 display a more positive opinion towards the lessons than students from other teachers in respect to MBL being good for lab work and learning physics. Students of teacher T1 perceived the structure of the activity-based lessons more positively than the students any other of the teachers. Students of teacher T3 demonstrated a more negative opinion towards the lessons than other students with respect to learning physics and lab advantage of MBL. On Collaborative Learning, students of teacher T3 reported a more positive impression than the other students.

The data were also analysed in order to reveal how students reacted to different items in the scales. The descriptive statistical information about the scales and their corresponding items about students' classroom experience with the lessons is shown in Table 5.11. The percentages shown in table 5.11 represent students who chose either '1' or '2' in the 1-to-5 rating Likert scale, that is, they rated the items to be either helpful or very helpful.

The Learning Physics scale is characterised by four items with a statistical item mean score of 2.0. The item mean value of almost 2 indicates that students who experienced MBL-supported, activity-based lessons were convinced that MBL is 'helpful' and helped them to learn physics. In view of the individual contribution of items forming this factor, we note that more than 3 in 4 students (76.2%) were of the opinion that the lessons helped them to understand more about the topic they were studying. Not only that, 70.6% of the students expressed certainty that the MBL-supported lesson activities helped them to prepare for other parts of the course. This is interesting and useful information because lesson activities played a role in understanding the topic and creating coherence in the learning in a majority of students.
### Table 5.11  
*Scales statistical information with score ranges from 1 (very helpful) to 5 (not at all helpful)*

<table>
<thead>
<tr>
<th>Scales</th>
<th>Mean</th>
<th>Item</th>
<th>Scale items</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning physics</td>
<td>2.0</td>
<td>MBL helped to understand more about the topic</td>
<td>76.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MBL lessons linked other parts of the course</td>
<td>70.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MBL activities explained some difficult concepts</td>
<td>68.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MBL helped to learn more about the subject</td>
<td>81.7</td>
<td></td>
</tr>
<tr>
<td>Laboratory advantage</td>
<td>1.9</td>
<td>Usefulness of MBL to collect data</td>
<td>78.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usefulness of MBL to analyse data</td>
<td>77.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MBL is helpful in planning the experiments</td>
<td>52.0</td>
<td></td>
</tr>
<tr>
<td>Lesson organisation</td>
<td>2.3</td>
<td>Usefulness of doing the end of activity exercise</td>
<td>72.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usefulness of consult the textbook in preparation</td>
<td>56.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teacher allowing room for personal initiative</td>
<td>68.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usefulness of teacher giving individual help</td>
<td>70.6</td>
<td></td>
</tr>
<tr>
<td>Collaborative learning</td>
<td>2.2</td>
<td>Usefulness of teacher not explaining everything</td>
<td>73.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usefulness of prediction before activity begins</td>
<td>73.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usefulness of discussing problems with partner</td>
<td>73.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of discussing problem with whole class</td>
<td>68.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Scale value: 1=very helpful, 2=helpful, 3=moderately helpful, 4=of little help, 5=not at all helpful.*

Furthermore, 81.7% of the students were of the opinion the MBL-supported activities helped them to learn more about the subject. Consequently, students were able to explain concepts as indicated by the fact that 68.8% of students claim that the activities help them to explain some difficult concepts. As the item analysis indicated, students' opinions suggest that the MBL lesson had potential to promote learning of physics for A-level students in Tanzania.

The factor *Laboratory Advantage* had three items related to the role that collection and analysis of data with MBL could play in the learning process. The statistical mean score for this factor is 1.9. Students clearly view MBL as a helpful system for collecting and analysing data due to its time efficiency and integrated software tools for data analysis.
Considering the data collection process, 78.4% of students thought the MBL system was helpful for collecting data compared to the traditional system. Less than 3% of students though MBL system was not helpful in collecting data. 77% of students expressed the opinion that the MBL system is helpful in data analysis, and 2.5% of students did not share that opinion. A marginal majority of 52% of students asserted that MBL played a role in their planning on how they would carry out the lab activities.

The third factor dealt with was the *Usefulness of the lesson organisation*. The lessons were organised differently compared to the typical lab (which has more or less a cookbook kind of instruction). In the lessons, one of the intentions was to make the lab work more engaging both mentally and physically. These interactions and cognitive involvement can promote learning. This factor has three items, with item mean value of 2.3. In this case, students found the lesson organisation helpful in their learning.

The reference textbook and materials included at the beginning of the activity to support student predictions was perceived as being useful by 56.7% of the students. The lessons had a number of activities that required students' personal initiative in order to proceed. About two thirds of the students found it useful that teachers allowed them room for personal initiative. An exercise was included at the end of the activity that enabled students to reflect on what was learnt and even to apply it in a different context. A little more than 70% of students thought these exercises were either helpful or very helpful. As MBL lesson activities were being introduced in schools for the first time, it was judged that teacher support to students would be necessary to a certain degree. Indeed, 70.6% of the students thought individual help from the teacher was helpful for them to accomplish the activity, and only 2.4% found teacher guidance of little help.

The last factor relates to usefulness of collaboration between students in the lessons. This factor has a mean score of 2.2. 73% of students consider the prediction part of the activity, which was supposed to be finished before the actual activity began, to be helpful and served to seed the group discussion of the whole lesson. As the activity progressed, students were very much encouraged to discuss the problems with their partners. 73.4% of students found this to be helpful. They thought that allowing group work promoted group discussion and only 5.6% reject the idea of group work and group
discussion. Students were also pleased that teachers were not explaining everything, and they had the opportunity to discuss problems among themselves to come up with a common idea, which they could later verify with teachers to before a common consensus was reached. 73% of the students considered the teachers' temporarily assuming a less prominent role to be helpful in encouraging them to learn. As activities were wrapped up, or sometimes at the beginning of an activity, teachers had the opportunity to discuss any problems that arose in the activity with the whole class. 68.5% of the students favour this idea as it helps to clarify any problems, but it also helps to clear up any remaining doubts or grey area pertaining to the activity.

The questionnaire on student opinions also had two open-ended questions, in which students were asked to write down what they liked most about the lessons and also what they disliked. The opinions expressed in the open-ended question support the findings discussed above, but additional information was also gleaned from it. After a thorough qualitative data analysis of the students' responses to the open-ended questions, some interesting outcomes were found and are reported on below. These outcomes first were coded and grouped into several thematic groups. The grouping resulted in seven clusters, which are: laboratory advantage of MBL, changes in pedagogy, MBL cognitive advantage, satisfaction with MBL, implementation difficulties, negative students' perception and miscellaneous. The following section examines these clusters in detail.

**Laboratory advantage of MBL:** Fifty-seven students (N=126) appreciated the fact that with MBL, the lab measurements were more accurate as the sources of errors could be minimised with standardised procedure available within MBL software for all electronic sensors used. Consequently, comparison of results from different groups made sense and was made easier. Another advantage students mentioned was efficiency with which data could be collected using MBL. In experiments that required students to take measurements of more than one variable, sometimes at the same instant, is a painstaking job in a traditional lab. In addition to efficient data collection, students like the tools available with MBL software to analyse and present collected data. They mentioned that data presentation could be in tabular or graphical form, and in both cases it could be viewed in real-time. In addition, the MBL software provided them with analytical tools to analyse or model the data.
Change in pedagogy: Forty-two students mentioned that they were very keen on the idea of working in groups, which is currently not common in classrooms in Tanzania. They thought group work could facilitate their learning. An important consideration with group work is the kind of activity in which students are involved. The activities were organised such that working in groups was compulsory to achieve the objectives. Students liked the way the lessons were organised, as it was the core for working in groups, but also they appreciate the lesson activities, themselves.

In the activities, the teacher was supposed to be a facilitator and not the sole source of knowledge. Therefore, the kind of support teachers were offering to students was a bit different from that found in the traditional classroom. Seven students expressed being satisfied with the teacher support and indicated this as one of the things they liked about MBL-supported activities. As the activities were revolving around the computer, doing physics with computers was one of the pedagogical changes particularly appreciated. Twenty-seven students expressed this view.

Cognitive advantage of MBL: Forty-six students went further to mention aspects related to cognitive advantage of MBL over the traditional lab approach. These students pointed out that the MBL-supported activities helped them to learn more deeply about the topic they were studying. Twenty-seven of these students felt that the lessons helped them to more easily understand the materials they were studying.

Satisfaction with MBL: Another area where students expressed their satisfaction was with MBL based activities. This was expressed in many ways. One aspect that satisfies the majority of the students is the time efficiency of the system. They realised they could do more in a short time than what could be achieved in a traditional lab setting. To add to that, they enjoyed using the system. It is difficulty to pinpoint exactly what they enjoyed, as many did not bother to be specific. The satisfaction was not limited to mere enjoyment; they recognised the system could help them to link one of a lesson or topic to other parts. Students also experienced satisfaction with MBL as it opened their eyes to the fact that computers can be used in more areas than simply for computer literacy tasks. It was not a good time for all students. Moreover, there were 12 students who experienced negative satisfaction; they indicated that the lesson activities were too taxing mentally and in terms of time.
Implementation: The students did not like everything in the implementation. Sixty students expressed some resentment in connection with MBL based activities because of perceived implementation difficulties. The complaint registered most often was an insufficient number of computers. On the surface, the criticism is genuine. Students expect a computer classroom to be more or less like an Internet Café where every user has his/her own computer, although this is not feasible in secondary schools. Well-managed groups were supposed to curb this problem, but somehow the teachers did not inform the students and the students' sharing of these computers was not done properly. Related to this is a lack of sufficient MBL resources. MBL resources were available for only five computers. The assumption was that in an ideal situation not many schools could afford more than five MBL kits with all electronic sensors available. Therefore, if teachers could work with five kits without much problem, implementation in classroom will not be a problem for many schools. However, not all teachers thought in advance how to manage the class properly. Another obstacle in the implementation was a lack of basic computer knowledge. This problem was more evident in the government (public) school where computer literacy courses are not taught. Students had to rely on personal intuition and individual knowledge rather than common understanding about the computer system. Students felt it was unfair to expect much from them while they had to wrestle with the two new knowledge problems of learning basic computer skills and MBL activities. The problem of perceived lack of enough computers together with insufficient computer skills hindered some students from doing as much as they would have liked to in the given time. This was clearly reflected in the fact that those students who complained of insufficient time were the same students who either complained of too few computers or insufficient computer skills. Furthermore, even more students felt the two weeks spent in schools was not sufficient to learn much.

Negative Perceptions: Apart from implementation difficulties, some students harboured negative feelings about the lesson activities. These students did not like group activities. Six students thought the groups were a waste of time, as a few slow students impede the progress of the whole group. In some cases they thought the group discussions were too noisy. In other cases the complaints concerned an insufficient level of teacher support. To these students, learning cannot occur if the teacher is not in front of classroom leading everything. If the teacher was just a facilitator and the group took a leading role, to them learning
was not occurring and they would want the teacher to be more involved in their learning process. Due to a dislike for group work and lack of sufficient teacher support, those students also disliked the lesson organisation. A handful of students' dislike of MBL was based on an opinion that computers are impersonal. In this case, the reactions range from wrong computer operation to an unfriendly user interface. Most of these complaints were either due to improper expectations of the computer or a lack of basic operational skills on the part of students. Through these negative reactions towards computers, the students wanted to say computers cannot replace human relations.

Miscellaneous: Some opinions were so varied, or so seldom expressed that they were not easy to classify. Fortunately, these were not many. For example, one student thought MBL is too expensive for schools to afford; another student was afraid that some sensor like a distance sensor—which had sonar waves—could radiate harmful signals. Another student raised a serious issue that using MBL may reduce thinking skills and other skills such as graphing or skills acquired by doing lab work the hard (traditional) way. Others thought they were denied an opportunity to set up the experiments and computers themselves, and in that way there was a missing link. On the positive side there were students who liked the MBL but wanted to see it in other science subjects and in all schools.

There is also a group of students who were undecided. They could not mention anything they like or dislike about MBL. It could be that the questionnaire came too early for them to make a credible assessment or they felt the question was a waste of their time but the sheer number of student makes it necessary to mention. About 10% of the students (N=126) could not find anything they like and 30% did not respond on what they dislike.

5.4.3 Student interviews

The interviews provided an inventory of students' experiences with the learning materials and the new learning approach. The student interviews yielded a large amount of information similar to what teachers had already mentioned either in interviews or in the open-ended questionnaires. This is illustrated by a representative sampling of some questions and responses from different students.
1. How have the lessons you did in the last two weeks been different from your normal classes, if at all? "Yes there were, Data was much easier to collect … was possible to have immediate graphing and data processing using modelling equations to find slope etc … With MBL experimental errors were less … shorter time was used to complete the experiments … Higher accuracy in its measurements…. Modelling tools (equations) were useful."

2. Do you think the whole class understood these lessons, or do you think that there was some confusion and if so where? "Lack of enough computer skills could have hindered the understanding … The instructions were clear enough, but technicalities may have led to some negative consequences … At first the lesson plan was confusing, but after clarification and experience using it everything became clear."

3. If you could have less of anything in your physics classes, what would that be? "The traditional way of doing practical is not useful and it could as well be removed …"

4. Can you think of anything new that you learned from these physics lessons? "Using computers to do physics. …. Computer skills. …. The additions in the lessons e.g. prediction, methods questions, assist enhance and support learning. …. The inclusion of prediction, do the practical, trying to explain the results to others were new and challenging."

5. Do you have any comments, suggestions or other things you would like to say which you think might be useful? "Integrate MBL into the school syllabi. …. Integrate MBL into O-level syllabi as well. …. Introduce MBL into other branches of science. …. More computers into schools."

Summarised in the following paragraph is information from the interviewees that has not been covered elsewhere in this chapter.

One thing that came out of the interview was that the lesson structure employed was clear to the students; with the help and support of the teachers, students were able to understand the lessons. Without support from the teachers the students might have gotten confused, since it was the first time they had used the technology. Where confusion or misunderstanding might have arisen, the illustrations helped to clear up the concerns held by some students. The support was largely needed because not all students were computer literate. Though the activities were rather open-ended and students were using MBL for the first time, the information given in the activity was sufficient to provide proper guidance.
Also the lessons plans and the way they were taught made the students aware of the scientific skills to be learned in the activities, as the introductory part helps to guide students through the activity. The use of MBL also strengthened the learning of science inquiry skills, as its use enabled students to repeat an activity several times, errors were few and graphs could be produced immediately.

The students, who were probably lower achievers, found the lessons a bit difficult, as new concepts to be learned build upon existing knowledge. However, the assistance from teachers, illustrations and graphs produced additional help. But it could have been even better if there had been a greater number of computers and all students had time to practice individually as advised in the instructions.

The activity objectives were realistic but some students felt that the theoretical part of the experiment could be covered first, and the lab part comes later as a verification of the theory. Also, they thought that a more complete introduction of topics during the lessons was needed, as well as a computer literacy course. Some students also felt that MBL demonstrations were very helpful in providing clarification and building understanding of new concepts.

What could be done to improve the lessons and implementation process? The students thought the instructions were clear enough but the number of computers and amount of time that each student could spend on a computer was a problem. However, the students agree that with better management, even the few computers available in the schools can be used to good effect.

5.4.4 Student products

Student work provides important indicators for student growth and learning and the effectiveness of teaching practices. The evaluation of the products provides the connection between teaching and learning; it lets us know the result of the educational activity. The results presented are considered to be the first impression of the impact of the lessons in student learning. The evaluation showed the extent to which students were able to choose appropriate methods, use and interpret graphs correctly, recognize patterns in nature, and draw valid conclusions. The products assessed were students' lab reports and assignments given to students as homework.
The students' products were evaluated using the goals of the exemplary materials as a benchmark. These goals were synchronised with the expectations of the products as expressed in the learning impression discussed earlier in chapter 4.

In their lab reports, students demonstrate their understanding of physics. The reports were presented in a systematic way, including terminology and the mathematics relevant to the problem at hand. As the reports were from average students, not much variation was observed in them. The impression from the reports was moderately good. The reports begin with one or two sentences stating the problem the students were trying to solve, followed by a list of equipment they used and the reason for selecting such equipment. For example, for lesson L2 of teacher T2, one of the students wrote, "In the lesson, the problem was to investigate springs and harmonic motion. We first connected the force and motion sensors to the interface, then we calibrated the force sensor while the computer was on and Coach 5 software was running. We then placed the spring on the force sensor hook, and hang a 10g of mass (and keep on adding by 20g till it was 190) from the spring … A second step was to attach a mass to the end of an ideal spring and make it oscillate with minimal friction … In the third step we used a rubber band instead of spring … see the sketch for set-up figure below."

Then, students explain their prediction, and physical reasons for choosing the prediction. The prediction is what the students thought about the outcomes before carrying out the lab work. For lesson L2 a student wrote, "Our group predicted that by Newton's third law, a force applied to a spring is the negative of the force the spring exerts. For a mass m, suspended in equilibrium by a spring with spring constant k, stretches the spring by amount x equal to x = mg/k …. In the second part of the experiment, we predicted that a mass, m, suspended by a massless, ideal spring with spring constant k, will oscillates harmonically—that is, in such a way that its instantaneous position relative to the equilibrium position is x(t) = Acos(ωt +φ) …"

After prediction the students also describe how they went on to check whether their predictions were correct or wrong.

In the data result section, the students described their experimental method, the data they collected, any problems in gathering the data, and any crucial decisions they made. Their actual results also show them whether or not their prediction was correct. For example in lesson L2 the students wrote, "… In Hooke's Law the force exerted by the spring is always 180° out of phase with respect to
the mass' position. The force sensor measures the force exerted by the spring on the force sensor hook, not the force exerted on the mass. The difference is the direction of the force. Thus, if Hooke's Law really is behind the motion observed, the force measured by the force sensor should be exactly in phase with the mass' position …" The students then present their results in tabular form and also do a bit of analysis and present the results in graphical form. For example, in lesson L2 the students recorded their measurements on the logbooks as well and produce graphs in addition to graphs the MBL software produced and use that information in the analysis to justify their findings. This also helps them to enhance their skills in producing graphs. Appendix C.1 shows examples of results for the first part of lesson L2.

As no measurement is exact, a discussion of uncertainty follows all the measurements to indicate the reliability of the data. For example for lesson L3, developed by teacher T3, which was dealing with measurement of speed of sound by two different techniques, one student wrote, "The first technique doesn't seem to suffer from any sort of systematic error, since a systematic error (an error in the execution of the experiment) would shift all of the points on the graph in the same direction. Such a shift would not affect the slope of the best-fit line, and so it wouldn't affect the calculated speed of sound…"

In concluding the lab, the students summarised the results in a very concise manner, where the original question of the lab is answered. The students also tried to compare the results obtained with their predictions. If the predictions were incorrect the students were supposed to discuss where their reasoning went wrong, and if correct they were supposed to review their reasoning and discuss how the lab served to confirm their knowledge of the basic physical concepts. Unfortunately, none of the students did this entirely properly. In lesson L3 for example, one student concluded, "This experiment was performed in order to determine the speed of sound in air. Both techniques seem to have worked well. Even though the second result is a bit closer to the theoretical result, the first technique is probably better from an experiment point of view. The first experiment is better because it gives a better sampling of data (i.e., more data points) for analysis. The second method might improve significantly if the water column were longer. This would allow us to take a better sampling of data."

The homework was assigned to reinforce the knowledge learned through the lab work. Assignments dealt with many aspects, such as data interpretation, error analysis and applying the acquired knowledge to a different context. Examples of
such homework and the solution one student gave are shown in appendix C.2.
There was variation in the quality of student homework.

5.5 SUMMARY OF EFFECTS ON TEACHER LEARNING

The interpretation of the results is multifaceted as data was gathered by different instruments and also embodied a variety of information. The interpretation is presented to reflect the kind of data discussed above.

The responses from the teachers suggested that they were satisfied to a great extent by the in-service course and through it they acquired much knowledge and skills, which they later put to use in their classrooms. The knowledge and skills learned are difficult to quantify but were all useful and probably the teachers need more time to practice in order to master them.

The teachers were equipped with new knowledge and skills to develop MBL-supported lessons. External evaluators were enlisted to assess quality of the developed materials. These evaluators detected a disparity between the intended and experienced curriculum. However this should not be seen as a disheartening finding, as the teachers were accustomed to teaching in a very traditional teacher-centred approach. The indication of some progress towards activity-based teaching observed in two parts of the lesson, i.e. the start and body parts, could be due to the existence of some commonalities between the traditional and new way of teaching these parts. As a result it may have been easier for a teacher to make a switch there, rather than in the conclusion part, where commonalities were few, and teachers needed more time to practice before they could master the new teaching approach. Also to be noted is that the teachers developed their lessons to fit into the current curriculum because at the end of the school year, the students will be evaluated based on the current curriculum, which favours a traditional teaching approach and not the new approach. They probably did not want to compromise too much.

The teachers did not get enough support from the school administration. It appeared that the school heads did not take what teachers were trying in the their science classrooms seriously, as they were not bound by the national curriculum. Otherwise there is a possibility the innovation will be supported if
necessary prerequisites are kept in proper order. In spite of little co-operation from the school heads, some the teachers were able to share the idea with their colleagues and attract their interest. In addition, all teachers were able to begin the initial implementation in their schools.

Regarding classroom observation, the teachers were in the learning process of trying to find the best way that they could implement the lesson plans in their classrooms. During the first few observations, the teachers were struggling to get by, but as time went on, they were learning from their previous mistakes and were showing improvement. This indicates that with time the teachers might catch up with the ideas introduced in the new teaching approach if sufficient support is given to them. The lessons were not taught exactly as they were produced. Their teaching was much better than the lessons they developed, which suggests that if the teachers had had a chance to develop new lesson materials and later been evaluated, the evaluation reports could look much better.

The majority of the students experienced the lesson materials, MBL technology and the new teaching approach positively. The students' results suggest that students who spent more time with the lesson materials had a more positive opinion than the others. Previous computer experience alone did not seem to have any positive effect on how the students perceived the lessons. In fact, the opposite seems to be the case, as students with the most computer experience were the most resistant to changing to new and different ways of using the computer.

The teachers' reflective interviews reveal additional useful information about: their classroom experiences; the potential of MBL-supported activity-based teaching to promote students' learning; and provided some reasons as to why part of the implantation did not proceed as expected.

In general we can wrap up by saying that the results suggest that the lessons had a positive impact on both student learning and teacher teaching. Both teachers and students realised computers can be used for teaching and learning physics. A majority of students like the ideals embodied in the MBL-supported lesson activities they engaged in. The implementation process had shortcomings, which might have influenced how some students reacted to the lessons.
The teachers indicated that MBL has a promising future in teaching and learning in a way that employs an inquiry-based approach, although this is contingent upon several factors, such as: teachers are supported appropriately by school heads; the Ministry of Education in Tanzania puts a suitable policy in place that clarifies, among other things, the modifications required in the science curriculum, the assessment procedure, the achievement examinations and also the provision of basic resources to public schools.

The results also suggest a number of ideas that are crucial in answering the research questions. First, the perceived change in teachers' teaching is a result of learning the teachers acquired through the in-service arrangement. The in-service arrangement provided new knowledge and skills to design lesson materials and suggested how to teach the lessons. It also provided teachers with an opportunity to acquire some knowledge about how students learn, which after reflecting upon it, they utilised to modify their beliefs about teaching and learning, and they tried the ideas in their own classrooms.

The exemplary lesson material design and teacher guide also played a role in the apparent change. The lesson materials shed light to teachers on how to develop their own lessons, and the teacher guide directed them how to implement the lessons productively. The experienced curriculum is the product of the perceived curriculum and how it was implemented in the classroom. The results of students' perception and opinions of the implemented curriculum, together with their products suggest the learning materials and the approach may have potential for teaching physics in a way geared towards a more hands-on inquiry-oriented approach in a Tanzanian context. Therefore the thinking that went into the designing of the in-service had some positive effect not only in teacher learning but also in teachers' practices and students' opinions and perception of MBL-supported activity-based physics learning.

The major problem in the in-service arrangement was lack of proper coordination between the workshops experience and opportunity for teachers to experiment with the content in the classes in-between the workshops. To make the study complete, it was necessary for teachers to: acquire basic skills in computer and MBL technology; to learn a bit about learning theory and learning problems associated with physics; to learn some pedagogical skills and didactics to teach science by inquiry in a learner-centred approach; to develop lesson plans and finally try to teach the lesson to peers. Though this was
accomplished in three weeks spread over a period of six months, and teachers had time to reflect on the content, some of them could not practice what they had learned in their schools for a number of reasons. The schools never had MBL kits and MBL was not part of the examinable curriculum. As a result the participating teachers could not get sufficient support from their schools. The real classroom experience was necessary, as in the workshops the number of participants was small and classroom management skills were hardly needed. This lack of experience was clear during the classroom practices, as teachers had problems initially but were getting better with each new attempt. To add to that, the conclusion part of the lesson was not done properly, even though in the workshops the practice was much better. Therefore teachers needed more practice to adjust to the classroom environment.

On the other hand, something can be done to improve the arrangement in the future. The problem areas in classroom implementation suggest that more time be spent on hands-on, inquiry-oriented learning and a student-centred teaching approach. As teachers recommended the exemplary materials as being practical, the in-service arrangement can focus on a few topics (using the exemplary material format) and pedagogical and didactical skills needed to successfully teach such topics. Follow-up support to teachers in form of resources and knowledge can be added on. The resources may be to make the MBL-kits and exemplary lesson materials available to teachers through TRCs. Also, a network of teachers can be established during the in-service arrangement to help teachers reach-out and share ideas among themselves and with experts.
CHAPTER 6
Discussion

This study developed and evaluated an in-service scenario that equipped teachers with the knowledge and skills needed to implement an MBL-supported physics curriculum in an activity-based classroom environment. The findings of the study are discussed in this chapter. A summary of the rationale and the design of the study will be described in section 6.1. In section 6.2, the results will be framed to answer the research questions and relate them to the literature. This section will end with reflections on the research methodology. Finally, in section 6.3 conclusions are drawn about the study and recommendations are made for changes to in-service education practices in Tanzania and for further areas of research.

6.1 SUMMARY

6.1.1 Rationale
The importance of science in the development of a country cannot be underestimated as it plays a major role in the economy and the social life of its people. Consequently, the emphasis on teaching science in a way that is understandable to both the science educators and the policy makers has been on the rise in the recent past. Information and communication technology (ICT) is viewed as a vehicle that supports the science learning process.

In Tanzania, science education has remained stagnant and teacher-centred for many years. This approach to teaching is characterized by transmittal techniques (chalk and talk, dominated by teacher talk), students are completely dependent on the teacher, and planning and assessment are conducted solely by the teacher. With this teaching approach, students can reproduce facts and use formulaic algorithms, but they rarely internalise and develop deeper insights into the science they are learning.
Recent research findings from cognitive science and science education on learning reiterate the thought that students construct knowledge through active participation in the learning process. Hands-on, inquiry-oriented science instruction is suggested as an effective teaching approach that can aid students to actively construct science knowledge the same way that scientists do. The student-centred approach is favoured, in which the focus is on the students and their learning rather than on the teacher. Both students and teachers adapt to new roles with this approach to teaching and learning. ICT has been shown to have the potential to support science learning that focuses on understanding and can enhance learning in a student-centred environment. However, for ICT to be used effectively in everyday teaching, radical changes are advocated in teaching styles and approaches to learning. Teachers and students must adapt to new roles. Such radical changes in teaching style cannot be expected in Tanzania overnight. Teachers may need time to transition from the traditional teaching approach to a student-centred inquiry-oriented science learning approach. To support the teacher transition, an activity-based approach, which is hands-on but inquiry-oriented in nature, is advocated in the study.

In 1996 the Tanzanian government included some new topics and new subjects in the revised national curriculum for secondary schools. One of the newly added subjects was computer studies, which includes computer literacy courses and computer science. With the introduction of computer studies into the curriculum, problems arose in the implementation process. No trained teachers are available to teach the new subject. Only a few schools have computers, and those computers are under-utilised, as they are used mostly for administrative purposes and not for teaching and learning purposes.

This study focused on effective teacher support for A-level secondary physics teachers in the integration of computers in the physics curriculum. As such, the study shed light on how computers can be integrated in school subjects.

### 6.1.2 The study

The central question in the study required establishing the characteristics of an in-service scenario that facilitates the implementation of an MBL (Microcomputer-Based Laboratories)- supported physics curriculum in an activity-based classroom environment. Designing an activity-based curriculum that is supported by ICT and fits into the Tanzanian context is an arduous task.
Most research evidence that advocates activity-based teaching and learning supported by ICT is rooted in the developed world. However, the Tanzanian context is much different and adoption of such research findings requires modification.

Our intention was to determine the characteristics of an in-service scenario that facilitates the implementation of MBL activities in the physics classroom. To determine the characteristics, three research questions were formulated:

a. What workshop characteristics contribute to teacher preparation for the implementation and the use of MBL technology in the physics classroom?
b. How can MBL-based lesson materials be structured to support teachers in the implementation of activity-based learning in the Tanzanian context?
c. What is the impact of the in-service scenario on MBL-based lessons in classroom teaching and on student motivation in physics education?

In the succeeding sections, we will provide answers to these questions supported by the findings of this study.

In this study, teacher support was developed that involved engaging teachers in learning new knowledge and new teaching skills to support MBL-supported, activity-based learning in an in-service arrangement. That arrangement, which included in-service workshops and exemplary lesson materials, was designed and realised in a development research approach. The in-service arrangement activities were designed and evaluated in several cycles. This approach incorporated: (1) extensive use of prototypes of both workshops and lesson materials; (2) a high degree of iteration through cyclic development of the prototype; and (3) participation of teachers in the development and realisation process.

The in-service workshops were designed to help teachers develop the in-depth understanding of science content and ICT that they needed, and to teach them how to help their students learn the content.

The MBL-supported activity-based approach to learning was made explicit in the exemplary lesson materials. Central features of the lesson materials were:

- the design of lab activities that assumed student collaboration in small groups;
- questions and exercises aimed at supporting student reasoning while carrying out the lab-activities, such as the prediction-observation-explanation cycle.
MBL was used as a support tool for the student lab work. The reasons for MBL inclusion were the following:

- It facilitates repetition of experiments and measurement of different variables at the same time and over different time ranges.
- It makes graphical data representation possible in real time, which makes it easy to connect the phenomenon being studied and the changes to the graphical representation.
- MBL saves instructional time in data collection and it can be used for analysing and interpreting data.

The evaluation of the in-service arrangement and its effect on teacher learning was based on Guskey’s (2000) approach to evaluating professional development. Only four of the five levels of the approach were used for this study. These were level 1 (teachers’ reactions), level 2 (teacher learning), level 4 (classroom practices) and level 5 (student outcomes). Level 3 (administrative support) was left out because it was not supported in the study.

6.2 REFLECTION ON THE FINDINGS

Key information was generated that provided answers to the research questions. The discussion in this section focuses on weighing how close and how clear the findings to the research questions were. We also relate the findings to other research and literature, and reflect on the effects of the methodology used in this study.

6.2.1 The characteristics of the workshops

This section provides information that answers the first sub-question: *What are characteristics of an in-service strategy that contributes to the preparation of teachers for the implementation and use of MBL technology in an activity-based physics classroom?*

From the results presented in chapter five it is clear that the teachers appreciated the way the workshops were organised and run, the content covered and the tasks they were engaged in.

It can be concluded from teacher reactions that organisation of the workshops was important. First of all, the teachers attended the workshops during the
school vacations so that they would not interfere with their normal work schedule. Since the workshop venues were outside the participants' schools, the teachers were able to concentrate on the workshop activities the whole day without being distracted by mundane activities. Secondly, the workshops were intensive. They ran continuously for three weeks at a time in intervals of at least four months. This was in line with the findings of Supovitz and Turner (2000), who suggest that intensive and sustained staff development activities of more than two weeks could be effective in improving teaching practice and classroom culture.

Appreciation of the new knowledge and skills learned by the participants is another indication of the usefulness of the in-service arrangement. The workshops equipped teachers with knowledge that can help to diagnose the students' misconceptions and use them as a starting point for devising a teaching strategy that could help students to overcome their misconceptions. The pedagogical skills learned and the skills needed to use MBL in lessons were also appreciated.

The content covered in the workshop was appropriate as it immersed participants in activity-based learning and experimentation. Also, it came at the right time to contribute to the move to integrate computer technology in the education system. The content covered also enabled teachers to prepare for their classroom practices as it directly fit into the curriculum. Supovitz and Turner (2000) also argue that content preparation is by far the most powerful factor to influence teaching practice and classroom culture. This reinforces the critical importance of content knowledge in science teaching.

The participants also liked the fact that there were prototype exemplary lesson materials that they could use and later contributed in modifying as the exemplary lessons evolved from one prototype to much better prototypes. The participants had the opportunity to study the exemplary lesson materials, reflect on their teaching discuss their views with the researcher and suggest changes to the materials that would make the teaching more effective. These characteristics confirm findings from other recent studies. For example, Borghi et al. (2001) concluded that effective teacher preparation should include activities in which teachers reconsider their disciplinary knowledge and cooperate in making it suitable for teaching.
In the workshops, concrete teaching tasks were carried out in which teachers worked collaboratively. The workshops also enabled teachers to design their own lesson materials based on the student exemplary lesson materials. Borghi et al. (2003) support the idea of lesson plans by asserting that it is essential to create the proper conditions for teachers to personally prepare work plans and teaching materials for their students.

However, the participants expressed the need for more time to practise the newly learned knowledge and skills. Their reactions confirm previous research (Thurston et al., 1997) that has shown that hands-on practice is more critical than theory and demonstrations in a technology based in-service course.

### 6.2.2 The structure of lesson materials that support implementation

The question, *How can MBL-based lesson materials be structured to assist teachers in the implementation of activity-based learning in the Tanzanian context?*, is addressed in this section.

The exemplary lesson materials that were developed to help teachers learn to understand the innovation and translate it into teaching and learning activities for their context, were appreciated by the participants. The materials offered concrete indications of essential but vulnerable elements of the innovation. This confirms earlier findings as in studies from Marx et al. (1998), van den Akker (1988), and Voogt (1993). This made the materials a critical component of the in-service arrangement.

Generally, the exemplary lesson materials used in the workshops were considered valid and practical. The validity of the materials was secured by incorporating state-of-the-art knowledge and by optimising the internal consistency of all components of the materials. Practicality was based on the dimensions of instrumentality, congruence and cost (Doyle & Ponder, 1977). Instrumentality is related to clarity of the procedures, congruence refers to the appropriateness of the materials to the prevailing conditions in schools, and cost involves the time investment that the teachers need in order to implement the lesson. As part of the workshops the participants put forward ideas on how to make the exemplary lessons more appropriate for their students.
The interviews indicated that the exemplary lesson materials provided the participants with the information and guidelines that they needed to be able to prepare and implement their own classroom materials. The lesson plans that were developed by the teachers showed that the teachers were still in transition from a teacher-centred teaching style towards a student-centred teaching style. For instance, the lessons lacked questions that required students to reflect on their lab-work. Also, there was difficulty relating the lab activities to realistic problems that are linked to the students' daily lives. Despite these remarks, the teachers, after implementing their lesson plans in the classroom, jointly agreed that the lesson materials were suitable to teach activity-based physics. Also, most students thought that the lesson structure, as suggested through the lesson materials, was helpful in their physics education. Some students specifically mentioned what they found special about the lessons. For example, some mentioned that the lesson structure and organisation of the lessons helped them to learn deeply, and to better understand the topics they were learning.

6.2.3 The impact of the in-service scenario on classroom teaching and student motivation

This section discusses the third sub-question: What is the impact of in-service arrangement on MBL-supported lessons in classroom teaching and student motivation in physics education?

The effects of the in-service arrangement have been portrayed in a variety of ways associated with content and process. The workshops were appreciated by the participants and seen as a necessary stimulus of the in-service arrangement. The participants expressed a positive view about MBL and its appropriateness to the new teaching approach. All participants thought it was appropriate technology and useful for learning physics.

The classroom practices indicated that the four teachers were able to translate the new knowledge and skills into the context of their classroom. They succeeded in many ways to display their mastery on the new knowledge and skills as they taught the lesson plans they developed. Generally, their performance was satisfactory though there were variations in the way different parts of the lessons were taught. The introductory part was well done, as was, to a certain extent, the lesson body. However, the conclusion section of the lesson was executed rather poorly.
The introductory part of the lesson was adequate in checking students' pre-lab preparations and conceptions prior to the introduction of the actual lab activity. The lab activities had a problem-solving character; each problem began by briefly stating the question. The equipment was described in enough detail in the body to allow the students to predict the outcome of the problem. Then the students (working in groups) had to test the predictions through experimental observation and analysis, and had to draw conclusions through group/classroom discussion. The four teachers who participated in the classroom practices were not able to lead students to draw their own conclusions from the data in a manner that promotes science inquiry and at the same time preserves a student-centred teaching approach. The teachers showed varied ability in implementing the lesson plans. Some were more flexible with the new teaching approach, but others only changed marginally from the traditional teaching practice.

Regarding student outcomes, the results were interesting in many ways. Overall, the findings showed that students were satisfied with the learning environment, that they perceived it as more investigative, open-ended and well organised, and that the computer hardware and software was user friendly and adequate. These indications suggest that the teachers were able to create an activity-based learning environment supported by MBL. The students who spent more time with the lessons indicated a more positive perception toward the activity-based learning environment. Also, the students appreciated the MBL-based lesson materials. The lesson materials were good for learning physics concepts and principles, were well organised and supported collaborative learning. Also, because of MBL, the labs had advantages, such as a better data collection and analysis process, over the traditional lab activities. Students also mentioned other aspects of the lessons that suggest they were satisfied with both the lessons and, to a certain extent, the way they were taught.

The evaluation of student classroom production gave the impression that the learning approach initiated a more inquiry-oriented process. Because the time students spent on the new learning approach was short, the students were unable to master all the basics of learning science through an activity-based approach and reporting their results properly. The major outcome from this part of the study suggested that the interaction with computer-supported lab
activities provides students with enhanced opportunities to develop skills such as interpreting graphs, constructing predictive answers to problems, testing their viability and generating creative solutions. It was, however, too early to assess the effect of the new approach to students learning and understanding.

Teachers gave a lot of positive feedback about the in-service education during the reflective interviews. Some of the positive impacts of the in-service arrangement on teachers and their teaching reported are mentioned below.

For some teachers, the in-service scenario was a vehicle to implement new teaching approaches and strategies that reflected where they were and where they wanted to go. For others it was a conflict, a challenge, and an opportunity to reflect on long-held ideas and beliefs about student learning and teaching.

Some teachers found the workshop to be a valuable opportunity to talk with other teachers about problems that they faced or will experience in their classrooms and to hear the solutions of the other teachers. In those settings, teachers addressed possible difficulties with the learning materials, solved problems, and also talked about what was going well and what was not, in terms of materials and the learning approach. Their interaction with other teachers was in itself an effective means of learning about implementation, student collaboration and other learning strategies with students.

Teachers learned new content and pedagogy through the in-service arrangement. This was a result of reflection about their practice, collaborations and problem-solving activities with colleagues as well as content and pedagogy instructors. The impact of their learning could be seen in changes in their classroom practices. But change can be a difficult and complex process depending greatly on how much teachers incorporate what they learned into classroom (Davis, 2003). This is because over time, in the context of their classroom work, teachers construct 'personal practical knowledge' – 'an integrated set of knowledge, conceptions, belief, and values' – which greatly influences their practice and how they respond to educational change (van Driel, et al., 2001, p.141). Therefore, creating strong links with personal learning and classroom contexts is important for inducing teacher change in beliefs and practices (Davis, 2003). Beliefs are the determinant factor in the change process. Beliefs, according to Richardson (1996), are thoughts derived from actions.
However, Richardson thought experiences and reflection on actions might lead to changes in and/or additions to beliefs. Luft (2001) emphasized that teachers need to explore and examine their underlying beliefs about teaching and learning in order to assimilate an accurate representation of the reform into their conceptual framework.

### 6.2.4 Suggestions for improving implementation

When reflecting upon the problems encountered in the implementation of MBL-supported activity-based physics lessons, some points of attention could be derived that should be taken into account in next versions of the in-service arrangement.

- Problems, questions and issues raised in lab work must be of interest to students, and must be used to motivate the kind of information sought and scientific method employed. This implies trying from the beginning to shift the current students' goal of simply generating outcomes, and move them towards reflecting about and understanding relevant concepts, relations and principles. Restructuring does not require drastic change in the lesson; the structure proposed in the exemplary lesson materials can be maintained, as it has proved favourable to teachers and the majority of students. The content of the exemplary materials can be slightly improved to make it relevant to student interest. The teacher guide requires some modifications to match the exemplary materials and also help teachers cope with emerging problems that became evident during the classroom practices.

- Clear teacher guidance is needed in discussing the relationship between the objectives and the procedures of the experiments and aspects of the world they represent. This is essential because some students may fail to see the experiments as models and may also fail to recognise that the experiment is a replication or representation of the world.

- To some students, the logic behind the sequence in the experiments was mysterious. Therefore, it is necessary to hold a discussion of the meaning and reasons for manipulative features in the experiments and the rationale behind the procedures.

- During the observation, some students failed to make comparisons that were informative. Teachers must learn to draw students' attention to a wider range of observations and ideas in the experiments. This will foster students' skills in making comparisons and evaluations.
One of the aims in the discussion section of the experiment was to give students the opportunity to discuss relational patterns that they detect in the data. However, in some cases they concentrated on prototypical instances. The teachers can initiate a discussion of the meaning of patterns in the data, starting with cases that students know well and moving to influences based on multiple cases.

These are certainly difficult tasks for teachers as well as students. Teachers have to invent new skills to work effectively with the unfamiliar challenges that this kind of instruction demands. With this kind of instruction in place, we can expect students to plan and carry out investigations, raise questions, use observations, critique their science practices, communicate in a variety of ways, propose explanations, and build a store of concepts and principles.

6.2.5 Reflections on the research methodology

The study was based on a development research approach. This research approach was favoured because of its strength in areas where the intervention is part of a dynamic context. The underlying strength of the approach is the possibility of realising of a series of small-scale interventions and drawing methodological guidelines for the design and evaluation of such products in an interactive manner (van den Akker, 2002; van den Akker & Plomp, 1993). Development research is particularly important for the Tanzanian context. The approach provided a better way of understanding the local implementation conditions and the daily problems that teachers face during the process. The development research approach also supports professional growth and an increase in expertise of various in-service participants in the development process. The approach not only produced promising results but also revealed pitfalls. Guidelines can be drawn from these findings for future development and evaluation of useful educational activities in similar settings.

In the study, the outcomes of the front-end analysis were used as the basis for designing the exemplary lesson materials that were later used in the in-service arrangement and in the development of lesson plans by the teachers. The essence of the iterative approach in the development of lesson materials was to improve the quality of materials in each cycle. Teachers' suggestions were welcomed in the process, and some of their ideas were reflected in later exemplary curricular materials. Due to length of time of the intervention, it was
only possible to have three iterative cycles. Nevertheless exemplary lesson materials were produced that were practical and partially effective.

In the workshops, teachers were seen as science students that were provided with opportunities to (1) reflect on their personal knowledge and prior experiences; (2) participate in interactive, hands-on and minds-on activities; (3) ask questions, solve problems, and use new knowledge; and (4) communicate and work with others in cooperative teams. In this way the curriculum materials were effectively introduced, and teachers could strengthen their content and pedagogical knowledge and skills (cf. Loucks-Horsley *et al*., 1998), and gain clarity about the use of the materials and strategies in the classroom. By teaching some of the lesson plans that they developed together with other teachers, they actually experienced new ways of teaching and increased their understanding of the new instructional approach (Davis, 2003).

In the classroom, teachers were observed teaching the lessons they developed while employing the knowledge and skills learned during the in-service experience. The results, as described previously, were encouraging. However, through observation of the lesson execution, several areas were identified that needed more thorough and clear support in the administration, resources, teaching materials and teaching process.

The researcher played a mixed role through all this. In the development of the exemplary materials, he took on the role of designer, in the in-service education he was a professional developer, and in the classroom he was a researcher. The mixed roles were rewarding but could pose problems in the future as they may affect the results and how the results were interpreted. Being a facilitator versus a researcher in the professional development activities could have affected the kind of answers that the in-service participants provided and the way the answers were interpreted. Being a designer and evaluator of teacher exemplary materials and an observer of how teachers were implementing their lesson plans, could have made teachers reactions overly positive about the intervention, and could have led to an overly positive interpretation of the data collected through classroom observation, questionnaires and interviews. This danger was averted by triangulation of data sources, methods and researchers (Krathwohl, 1998). Triangulation also assisted in strengthening the data collection methods from students through attitude questionnaires, open-ended
Discussion

questions and student interviews. Questionnaires were used and complemented with interviews in the data collection.

The study combined qualitative and quantitative methods to give both breadth and scope to the research. In conjunction with the utilization of these methods, decisions regarding data collection and analysis were made to understand the different aspects of the opinions and understanding of the innovation by the physics teachers and students. In this way, data collection techniques existed simultaneously while the data were analysed throughout the study.

The research methodology had both positive and negative elements. The methodology made it possible to improve and ensure the quality of the lesson materials. The lesson materials proved to be practical and partially effective in local settings. The inclusion of participants in the design process of the materials improved the chances of its acceptability and success in classroom implementation. Similar materials developed for similar contexts have proved to be successful as well (Ottevanger, 2001). However, the exemplary lesson materials could have been different if the research design had been changed slightly. The teachers' feedback incorporated in the exemplary lesson materials were only impressionistic, based on their past experiences. This could be better if the teachers had tried the materials in the classroom environment and provided their feedback based on their experience in the classroom. In this way it would have been possible to have student input through interviews or other data collection methods. Classroom-based feedback could have improved the quality of exemplary materials.

Also, some problems arising during the design, development and classroom implementation of the lesson materials are worth noting. Stringent measures to maintain good quality control of lesson plans were not carefully taken in their development; as a result consistency was lacking in the lesson plans developed. The classroom trial of the lesson plan was done only once and in that event the conclusion part of the plan was spotted to be the weakest in the teachers' classroom implementation. This clearly indicated that more reinforcement was needed in training the teachers to tackle the problems observed in the classroom practices. Also, the time taken for implementation was too short. If the actual classroom implementation would have taken longer, cognitive impact could have been evaluated, and a much stronger case could be argued
for impact of the innovation. A much earlier implementation was, however, hampered by a lack of supportive infrastructure in the schools.

6.3 CONCLUSIONS

The motivation for this study centred on the need to design an intervention that closes the gap between traditional teaching practices and an activity-based physics teaching approach supported by MBL technology. This is a difficult and complex process as it involves change in teachers' beliefs, in the school learning infrastructure, and the administrative support system. The in-service education was used as a means to bring about a change in teacher beliefs. Different phases of the in-service education contributed to enhancing the match between the learning and teaching needs of the teachers. A number of issues emerged that are important in this conclusion.

- The content covered in the in-service arrangement was appropriate and teachers learned from it. The content involved, among other things, creating and solving problems related to the real world. Nevertheless, when problems and phenomena of the real world enter the curriculum, the need to master physics content grows. The textbooks are often not sufficient to assist teachers in addressing such problems; hence more help is still needed in this area. The content covered was revised in cooperation with teachers, benefiting from their knowledge and experiences in the field. The exemplary materials that resulted were a manifestation and also a reflection of their knowledge and skills. This process emphasizes that in-service education should include activities that help teachers to reconsider their disciplinary knowledge and to encourage its revision in order to make it suitable for teaching.

- The in-service scenario process enabled much to be accomplished during the in-service arrangement. However, one essential ingredient that would have created more conducive conditions for teachers to personally prepare plans and teaching materials was not emphasised. Teachers did reflect on their learning but not in ways that gave them the opportunity to discuss their views and make use of explicit feedback from colleagues and the researcher. For example, their reflection on the content was not emphasised enough to help them express their doubts about the content and special needs, and also
to build their confidence to later influence their choices and implementation of teaching strategies. This implies that more emphasis on teacher reflection on content, coupled with analysis and discussion about the lesson plans that they wrote, could have given them the opportunity to reconsider the content and didactical problems related to it, thereby improving the chance of better classroom implementation.

- Teacher classroom practices were adequate, and teachers attempted to guide or facilitate the student-centred, activity-based learning process. Nonetheless, classroom observations suggest that a more extensive range of teacher roles is required in the Tanzanian context. For example, just being a facilitator might not be sufficient, especially in the initial stage of wider classroom implementation. The teacher role may include competencies like being able to carefully conceive and develop the initial lab questions (problems), gather resource materials, orchestrate the instruction, mentor students in designing data collection plans, guide them in carefully collecting data, model for them how to systematically analyse and grapple with the data, encourage students to ask questions and draw initial inferences and finally mentor and critique the write-up of the lab reports. These kinds of roles can help to sustain student interests and reinforce the importance of grappling with data and presenting findings backed with valid and reliable evidence, in activity-based learning. Students groomed in the traditional learning system find it difficult to make the transition to the new approach. Support and coaching from teachers is an absolute necessity in this case; facilitation of learning alone may not be enough.

- As observed from the results, changes are needed to create effective and meaningful lab work for high schools in Tanzania. The current practice in schools provides students with science process skills but what is needed is an inquiry approach that will give the process skills coherence and meaning. Such a change will require students to perform and interpret experiments designed for the specific purpose of verifying or revising theories that students hold. Then they will communicate and debate those theories among a community of similarly engaged peers. As the results show, that kind of change is not easy for students. Teachers must provide the scaffolding needed to negotiate difficulties that arise along the way. Few teachers can adequately provide such scaffolding. These are teachers informed by cognitive science research concerning the development of scientific reasoning, and not uninformed and untrained teachers. Also
important to note, is that students best learn about the nature of experimentation through sustained periods of real investigation, not through a series of unrelated activities that feature rote procedures (Schauble, Duschl, Schulze & John, 1995). During sustained investigation, students learn how to ask questions, analyse unfamiliar problems, decide what heuristics or strategies to apply, realise the benefits and limitations of the strategies and decide when to persist on a line of investigation or to try a radically different one (Schauble et al., 1995). This kind of logical and systematic approach to meaningful experimentation is yet to be witnessed in Tanzanian schools. The classroom implementation demonstrated by the four teachers indicated that the teachers were going in the right direction but were not experienced enough to offer sufficient scaffolding needed by the students in full-fledged science inquiry-oriented learning.

- Although the student outcomes were encouraging, no firm statements can be made about student learning. The positive attitude demonstrated by both male and female students towards the lesson materials and the new teaching approach is a good sign of possible success in the future if efforts are made to properly implement the innovation. The positive effect also suggests that the technology component can be successful in increasing technology expertise and activity-based learning to students regardless of gender.

- The study was a small-scale example of intervention in which the participating schools were representative of A-level science secondary schools. Berliner (2002) emphasises the fact that variations in the context (e.g. rich-poor schools, teacher beliefs), and in the interactions (e.g. teacher-student, student-student, student-learning material) that abound within a context (as in the case of Tanzania) make it hard to generalise educational research findings. Nonetheless, the perceived variations can be minimised if certain requirements are fulfilled as preconditions for successful implementation.

- Education, as with any other worthwhile endeavour, is not a cheap business; investment is crucial. In the case of activity-based learning, which is supported by MBL, appropriate investment in learning infrastructure and teacher training are required. As the government is willing to put computers in schools, it would be worthwhile to invest more money in MBL hardware and software to strengthen the learning infrastructure. This would narrow the gap between public schools and the few rich private schools, but also encourage the majority of private schools to invest more in ICT. In addition
to that, teachers must be trained and retrained to gain the skills and knowledge essential to science inquiry and integration of ICT in the instructional process. One in-service training workshop will not be enough. Teachers need sustained support in order for them to change their beliefs about students, teaching and learning. The support must start from school administration and continue upward into the educational hierarchy of leadership in the country.

- Teachers and schools may not feel pressured to change their classroom practices if nothing is done in the curriculum and the final examinations. Changes are necessary in the national curriculum to reflect inquiry learning supported by MBL. These changes must also be reflected in the final examinations.

6.4 RECOMMENDATIONS

The overall goal of much development research is to learn and eventually produce knowledge about both that which is being developed, and the process through which it comes to fruition. Toward eliciting insights from the study that could be useful to future endeavours, this section provides recommendations for continued exploration of effective in-service scenarios for inquiry-oriented science learning that is supported by ICT. The suggestions put forward to improve future in-service experiences in Tanzania that are geared towards promoting activity-based learning of science, are outcomes of reflecting on the results and discussions dealt with in the previous section. The recommendations also suggest some future research areas.

- For teachers and future professional development in science education in Tanzania, it is necessary to be cautious about how the content is selected and implemented. Identification of motivational context of the content to be covered, good selection and sequencing of activities, and an adequate support system, are key to the success and sustainability of the innovations in the schools. Selection of content that does not consider the students' context may not motivate students to commit themselves seriously to hands-on, inquiry-oriented learning. Additionally, the activities involved and the sequencing are important. A complicated sequence of activities in a lesson may not help all students, even if it is explained by teachers. A support
system for teachers in terms of knowledge and other resources is also necessary to maintain continuity.

- The future looks promising for MBL as both teachers and students who participated in the study were highly impressed by it and showed interest in using it in the future to pursue science knowledge in their classrooms. Also, both teachers and students suggested that it is time for the government to include it in the curriculum. This brings about the need to have more courses, for teachers to know more about it and to give them the necessary support in their schools. The ministry of education and other affiliated stakeholders should make this assistance available.

- As participants to an in-service can vary in behaviour and beliefs, it is necessary to configure the programme to attend to the diverse behaviours and beliefs of its participants. Experienced teachers in certain areas may not need as much help as beginners in the profession, but incorrect beliefs based on experience may also need special attention different from the rest. The learning activities must begin with their knowledge, beliefs and skills. Such an approach will enable them to reflect on their beliefs and understanding of learning, teaching, students and subject matter.

- The in-service education should contain follow-up experiences with multiple opportunities for interaction with participants. Such follow-ups can serve more than one purpose: to strengthen the implementation and also as a means of gathering information from students. Such information can serve to improve the feedback to teachers or even to develop another improved intervention. The follow-up might be augmented with support through a web-based communication environment. Almekinders and Voogt (2003) have shown how such communication environments can be useful in bridging the isolation facing teachers who are secluded geographically. University experts can moderate communication in a web-based environment; teachers can exchange their classroom experiences and lesson plans, initiate a discussion related to their profession, etc. Announcements and other useful news to participating teachers can also be posted through the media.

- As the results indicated, the in-service workshop lacked input from schools and that somehow affected the design of the exemplary materials and the classroom implementation. Also, between the in-service workshops, the participants lacked the opportunity to practice what they learned in their classrooms. To strengthen future in-service education, it might be better to
combine both in-school and out-of-school in-service education experience. This view is consistent with other studies (e.g. Putman & Borko, 2000; Showers & Joyce, 1996), which insist on the combination of the two as it facilitates situated cognition of teacher learning.

- Teacher Resource Centres can play a key role in disseminating information and distributing resources, which the lead teachers in schools may need in order to enrich their knowledge to facilitate the change process. Resources, such as exemplary lesson materials, information about new MBL sensors, new version of software, etc. can be made available to teachers electronically or through visits to the centres. Also, follow-up meetings with experts can be arranged to take place in the TRC in order to discuss with teachers the problems that they might face in the classroom as well as possible solutions.

In the development of exemplary materials, it should be understood that the traditional textbooks used by students do not promote science education by inquiry. The textbooks were not analysed by the researcher together with teachers from the perspective of current thinking about physics education. Such an activity may suggest topics for the in-service education, so that teachers are involved in the whole process from the beginning and they can follow the same procedure to analyse the text materials and solve problems on their own. Further research should be done in this area to investigate how such inclusion can affect student outcomes.
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ENGLISH SUMMARY
Teacher support for the use of MBL in activity-based physics teaching in Tanzania

BACKGROUND

In Tanzania as in many other countries, science and technology education is viewed as a very important element in the social and economic development of the country. However, teaching in schools has not reflected what real scientists do. The large rift between the scientific methods as experienced by the scientific community and the process that it is taught in schools has raised concerns worldwide, and has spawned suggestions for improving the situation by adopting a style of teaching whereby students identify problems, manipulate variables and design experiments.

A recent analysis of science teaching in Tanzania revealed that most teachers used transmissive rather than interactive pedagogy in their teaching. Their teaching approach is the traditional teacher-centred lecture (chalk and talk) approach, emphasizing transfer of knowledge and skills and rewarding memorisation, which is uncharacteristic of currently promoted methods of teaching science. This poor teaching methodology widens the gap between the classroom and the broader scientific community. Students who successfully complete their studies nonetheless perform poorly and find themselves unable to apply the science learned beyond classroom contexts.

Recently, the government has revised the curriculum. New topics and courses that incorporate recent changes in science, society and technological developments were added. One of the new courses added in secondary education is computer studies, which includes computer literacy and computer science courses. The introduction of computer studies in the curriculum carried many implications, including the introduction of computer hardware in schools and
the education and retraining of teachers on the integration of computers into the curriculum. A few schools have been furnished with computer hardware and basic software, but as there are no trained teachers, the computers in schools remain under-utilized. Computer use is mostly limited to administrative purposes. In some cases, students are introduced to the most rudimentary skills of computer use. Adequate integration of computer use into teaching and learning is practically absent.

This study aimed at developing and testing ideas and materials for computer uses in schools to improve the quality of teaching and learning science in an interactive pedagogy.

**CONCEPTUAL FRAMEWORK**

Recent developments in the field of cognitive science and information processing have offered a new understanding of how people learn together with the consequent implications for knowledge, learning and teaching. Research evidence suggests that three ingredients are essential for learning science:

i. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom.

ii. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

iii. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

The implications of these requirements to teaching suggest that:

i. Teachers must actively elicit students' pre-existing understanding to provide the foundation on which formal understanding of the subject matter is built, or provide opportunity to challenge their initial understanding.
Some subject matter must be taught in depth, providing many examples relevant to the concept at hand and also providing a firm foundation of factual knowledge.

The teaching of metacognitive skills should be integrated in the curriculum.

Research affirms that student achievement improves if these principles are incorporated in science teaching.

To realize this approach to science education, activity-based science learning seems a promising approach in the Tanzanian context. Activity-based learning implies instructional techniques/methods that enhance learning and comprehension, with an emphasis on learning by doing. Such an approach requires the creation of a student-centered learning environment that allows students to handle, manipulate or directly observe scientific processes.

Activity based learning can be implemented in many forms, one of them being through science experimentation. The activity-based approach to learning is appropriate in science lab work that fosters collaboration and discussion. It actively engages students both physically and mentally and may help students to develop an understanding about the way scientific facts are established. In this study, lessons for activity-based physics labs are developed and discussed.

Modern computer technology holds the potential to create powerful, easy to use scientific tools to collect physical data and display them in a fashion that is readily manipulated and easy to think about and remember. These characteristics help make lab work engaging and effective for deploying scientific intuition. Such tools enable students to concentrate on scientific ideas, and eliminate some of the drudgery associated with data collection and display. Microcomputer-based laboratories (MBL) refers to a technology that inherently satisfies the suggested conditions desired of the scientific tools. In brief, MBL refers to any laboratory where a microcomputer gathers and displays data directly from the environment. The MBL software has subprograms for data collection, data processing (smoothing, filtering, spreadsheet, etc.), data representation (various graphical representations) and data analysis (mathematical operations). MBL teachers can structure the learning process such that students actively construct knowledge while engaged in hands-on activities. Some benefits attributed to MBL are: improve student ability to interpret and produce graphs; real-time data
collection that makes it possible to repeat experiments, to measure different variables at the same time, to use a short or long range to analyze and represent data graphically; and to facilitate group work interactions because of its ability to contribute information during group discussion. MBL serves as a catalyst for change towards activity-based learning of science as it can facilitate students' participation in the process of understanding scientific phenomena.

Teachers can make effective use of MBL in their classroom if they are willing to adopt new instructional practices, such as the activity-based approach. For many teachers, also in Tanzania, this implies that they need to transform their knowledge and skills pertaining to subject matter, epistemology, their conception about how knowledge is constructed, and their view about science. Studies on teacher learning show that most of the experienced teachers' knowledge has become routine and automatic. For teachers to be successful in moving towards new instructional practices, teacher knowledge and beliefs about teaching and learning should be the target of change in professional development arrangements.

Many studies on innovations have reported a lack of sustained impact on classroom practice. Teachers, like other learners, need support in the form of materials to facilitate the change process. Well-tried exemplary lesson materials, designed to address teacher learning as well as student learning, are an important component in in-service arrangements that emphasize classroom implementation of newly learned knowledge and skills.

In this study an in-service arrangement has been developed that applies a workshop strategy combined with exemplary lesson materials.

**RESEARCH QUESTIONS AND DESIGN**

In the study the main research question was: *What are the characteristics of an in-service arrangement that facilitates the implementation of MBL-supported lesson activities in the physics classroom?*

Three sub-questions guided the process:

i. What are characteristics of an in-service strategy that contributes to the preparation of teachers in the implementation and use of MBL technology in an activity-based physics classroom?
ii. How to structure MBL-supported lesson materials that assist teachers in the implementation of activity-based learning in the Tanzanian context?

iii. What is the impact of in-service arrangement on MBL-supported lessons in classroom teaching and on student motivation in physics learning?

To answer the research questions a development research approach was employed. The strength of this approach is the opportunity to realize a series of small-scale examples of interventions and drawing up methodological guidelines for the design and evaluation of such products in an interactive manner.

Development research is particularly important for the Tanzanian context because it provides good opportunities for understanding local implementation conditions as well as problems teacher face daily in the implementation process. The development research approach also supports professional growth and increase in expertise of various in-service participants in the development process of the in-service arrangement. The approach not only produced promising results but also revealed some pitfalls. Out of all these findings, guidelines can be drawn for future development and evaluation of useful educational activities in similar settings.

The study was divided into four stages, i.e. front-end analysis, design and development, implementation, and evaluation. The outcomes of the front-end analysis were used as the basis for the design and development of the in-service arrangement. That arrangement consisted of workshops and exemplary lesson materials. In the workshops teachers acquire knowledge and skills necessary to implement activity-based physics learning. The knowledge and skills included MBL basics and how to integrate it into the curriculum, as well as pedagogical content knowledge essential for activity-based learning. The exemplary lesson materials that were used in the workshops also served as examples for the development of lesson plans by the teachers.

In the workshops, teachers took on the role of science students, in which they were provided with opportunities to (1) reflect on their personal knowledge and prior experiences; (2) participated in interactive, hands-on and minds-on activities; (3) ask questions, solve problems, and use new knowledge; and (4) communicate and work with others in cooperative teams. In this way the exemplary lesson materials were effectively introduced, and teachers strengthened their content and pedagogical knowledge and skills. The in-
service arrangement had three cycles. Each cycle was formatively evaluated. The results of each were used to improve the subsequent exemplary lesson materials and the workshops.

Four teachers that took part in the in-service arrangement implemented the knowledge and skills they had acquired in their own classrooms. They used MBL in their lessons, using lesson plans they had developed themselves during the workshops.

The evaluation study focused on the impact of the in-service arrangement on classroom practice and student outcomes. Data were collected through analysis of teacher lesson plans, classroom observation, questionnaires for teachers and students, analysis of student lab reports and homework assignments and reflective interviews with teachers.

**RESULTS**

The teachers' reactions to the in-service arrangement were positive. They were satisfied with both the content covered in the workshops as well as the process as a whole.

The results also indicated that the teachers acquired new knowledge and skills on MBL and the new pedagogical approach in teaching physics. The teachers felt equipped with new knowledge and skills to develop MBL-supported lessons, and they developed lesson plans of fairly satisfactory quality. This was seen as indicators of some progress towards activity-based teaching.

Classroom observations indicated that teachers were able to translate the new knowledge and skills into their classroom context. Though their performances were not yet perfect, the indication was that they were moving towards a more student-centred approach. With more practice and a bit of support from experts, a substantial change may be expected.

Student outcomes were judged based on classroom products and students' opinions and perceptions on MBL and the new approach to teaching. The outcomes indicated that students were positive in all aspects and the quality of their products was also encouraging.
CONCLUSIONS

This study originated from the need to design an intervention that can help close the gap between traditional teaching practices and activity-based physics teaching approach, supported by MBL technology, for Tanzanian secondary education. This was a difficult and complex process as it involves change in teachers' beliefs, in the school learning infrastructure, and administrative support system. To achieve this goal, the central research question was: What are the characteristics of an in-service strategy that can contribute to the preparation of teachers for the implementation of MBL technology in an activity-based physics classroom?

The following characteristics appeared to be essential in preparing teachers for such implementation:

- Flexible time for teachers to attend to in-service education, preventing clashes with their teaching schedules.
- Intensive and sustained in-service activities over longer periods of time lead to success in teacher learning and eventually good classroom practices.
- The workshops offered new and interesting knowledge and skills, preparing teachers to face the challenges in the real classroom situation. Moreover, the workshops stimulated teachers working collaboratively on concrete teaching tasks.
- The exemplary lesson materials, enabling teachers to reflect on their learning, discuss their views with the researcher and suggest changes on the materials to make teaching more effective, was seen as another contributing factor.
NEDERLANDSE SAMENVATTING
Ondersteuning van leraren voor het gebruik van MBL in activerend natuurkunde-onderwijs in Tanzania

CONTEXT

In Tanzania beschouwt men onderwijs in natuurwetenschap en techniek als een belangrijke bijdrage aan de sociale en economische ontwikkeling van het land. Echter, het 'science'-onderwijs in de schoolpraktijk is slechts een flauwe afspiegeling van wat wetenschappers doen. Processen als het identificeren van problemen, manipuleren van variabelen en ontwerpen van experimenten zijn nog nauwelijks aan de orde. Daarnaast hanteren de meest docenten veeleer een traditionele overdrachtsstijl dan een interactieve didactiek.

De overheid heeft recentelijk het curriculum voor het voortgezet onderwijs gemoderniseerd. Een van de nieuwe onderdelen betreft 'computer studies'. Die toevoeging had vele implicaties, onder meer de introductie van computerapparatuur in de scholen en de scholing van docenten over integratie van computergebruik in het curriculum. Nog slechts een gering aantal scholen beschikt inmiddels over adequate hardware en software, maar ook daar is sprake van onderbenutting in het onderwijsleerproces, vooral vanwege onvoldoende geschoolde docenten.

Dit onderzoek was gericht op het ontwerpen en beproeven van ideeën en materialen voor computergebruik ter verbetering van de kwaliteit van het science-leren volgens een interactieve didactiek.
CONCEPTUEEL RAAMWERK

Recente ontwikkelingen op het terrein van cognitie en kennisverwerving leiden tot een nieuw begrip hoe mensen leren. Onderzoek wijst op enkele belangrijke didactische implicaties:
Docenten dienen actief en systematisch aandacht te besteden aan de voorkennis van hun leerlingen.
Kernleerstof dient grondig onderwezen te worden, met inbegrip van veel voorbeelden die relevant zijn voor de te leren begrippen.
Onderwijzen van metacognitieve vaardigheden dient geïntegreerd in het curriculum plaats te vinden.

Teneinde deze benadering te realiseren, lijkt een activerende aanpak van science-leren veelbelovend. Dat veronderstelt instructiemethoden met een accent op leren-door-doen in een leeromgeving waarin leerlingen actief zelf science-processen kunnen ervaren.
Voor de meeste (Tanzaniaanse) leraren veronderstelt zo'n aanpak aanzienlijke veranderingen in hun vakdidactisch repertoire. Dit onderzoek is gericht op het ontwerpen en beproeven van een daartoe geschikt nascholingsarrangement.
**VRAAGSTELLING EN ONDERZOEKSOPZET**

De hoofdvraag luidde:

Welke zijn de kenmerken van een nascholingsarrangement dat bijdraagt aan de implementatie van door MBL ondersteunde lesactiviteiten in de natuurkundeklas?

Er zijn drie deelvragen geformuleerd:

Welke kenmerken van een nascholingsstrategie dragen bij aan de voorbereiding van leraren voor het gebruik van MBL-technologie in de natuurkunde-les?

Hoe dienen MBL-ondersteunde lessen gestructureerd te worden om leraren te assisteren bij de implementatie van activerende lessen in de Tanzaniaanse context?

Wat is de invloed van het ontworpen nascholingsarrangement op het lesverloop en op de motivatie van de leerlingen m.b.t. natuurkunde-onderwijs?

Ter beantwoording van deze vragen is een ontwerpgerichte onderzoeksbenadering gehanteerd waarbinnen enkele kleinschalige, opeenvolgende voorbeelden van interventies ontwikkeld en geëvalueerd zijn. In die benadering was het ook goed mogelijk de locale implementatiecondities in acht te nemen en in het bijzonder om tegemoet te komen aan de dagelijkse praktische problemen van de leraren in zo'n veranderingsproces. Bovendien droeg het ontwikkelingsonderzoek bij aan de professionele groei van de verschillende deelnemers aan het proces.

Het onderzoek is gestructureerd in vier fasen: vooronderzoek; ontwerp & ontwikkeling; implementatie; evaluatie.

Het nascholingsarrangement bestond uit een combinatie van workshops en voorbeeld-lesmaterialen. De workshops waren gericht op het verwerven door de docenten van noodzakelijke kennis en vaardigheden m.b.t. activerende natuurkundedidactiek en MBL. De docenten kregen daarbij ruime gelegenheid: (1) te reflecteren op hun persoonlijke (voor)kennis en ervaringen, (2) te participeren in interactieve 'hands-on/minds-on' activiteiten, (3) vragen te stellen, problemen op te lossen, en nieuwe kennis toe te passen, (4) te communiceren en samen te werken in teams. De tijdens de workshops geïntroduceerde lesmaterialen droegen bij aan de vakdidactische kennis en vaardigheden en dienden tevens als voorbeelden voor de ontwikkeling van lesplannen door de docenten zelf. Het arrangement is ontwikkeld in drie cycli waarbinnen telkens formatieve evaluatie plaatsvond.
Vier nageschoolde docenten implementeerden de kennis en vaardigheden uiteindelijk ook in hun eigen klaspraktijk. Zij gebruikten MBL in hun lessen aan de hand van lesmateriaal dat zij zelf tijdens de workshops ontwikkeld hadden. Het evaluatiedeel van het onderzoek was gericht op de invloed van het nascholingsarrangement op de lespraktijk en de leerlingopbrengsten. Gegevens zijn verzameld d.m.v.: analyse van de door de docenten opgestelde lesplannen; lesobservaties; vragenlijsten voor docenten en leerlingen; analyse van practicumverslagen en huiswerkopdrachten van leerlingen; en reflectieve interviews met docenten.

RESULTATEN EN CONCLUSIES

De reactie van de docenten op het nascholingsarrangement was positief, zowel m.b.t. de aangereikte inhoud als het algehele proces. De resultaten wezen ook uit dat de docenten er behoorlijk in geslaagd waren de nodige nieuwe kennis en vaardigheden op te doen m.b.t. de beoogde natuurkundedidactiek en MBL-benutting. Zij voelden zich daarmee goed toegerust om lesplannen te ontwikkelen, die van een bevredigende kwaliteit bleken. Uit de lesobservaties bleek dat de leraren ook redelijk in staat waren de nieuwe kennis en vaardigheden in hun lespraktijk toe te passen. Hoewel die praktijken nog verre van volmaakt waren, was er sprake van een duidelijke verschuiving in de richting van een meer activerende didactiek. De leerlingopbrengsten waren ook positief, zowel qua uitgevoerd en opgeleverd werk als qua houding m.b.t. MBL en die nieuwe didactiek.

Ten aanzien van de hoofdvraag van het onderzoek kan geconcludeerd worden dat de volgende kenmerken van belang blijken voor het toerusten van docenten voor een activerende didactiek met MBL-benutting in natuurkunde-onderwijs: Intensieve, doch flexibele (om botsing met lesrooster te voorkomen) en over langere tijdsperioden uitgestrekte nascholingsactiviteiten zijn bevorderlijk voor het succes van het docent-leren en de uiteindelijke klaspraktijken. De workshops bieden nieuwe en als interessant en relevant ervaren kennis en vaardigheden, die de docenten adequaat voorbereiden op de uitdagingen in de reële klaspraktijk. Bovendien stimuleren de workshops de docenten tot samenwerking rond concrete taken. De voorbeeld-lesmateriaal dragen bij aan reflectie op het eigen leerproces en aan discussie over verbeteringen van de onderwijsaanpak.
# APPENDIX A1

## Checklist for first workshop

**Checklist of the first workshop**

Name of participant …………………………………………………………………..

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>YES</th>
<th>NO</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the participant feel the material is appropriate for A-level?</td>
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<tr>
<td>Does the participant think the approach is suitable?</td>
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<tr>
<td>Did the participant use materials as expected?</td>
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<tr>
<td>Did the participant feel time for activities sufficient?</td>
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<tr>
<td>Did participant handle MBL properly?</td>
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<tr>
<td>Participant satisfied with teaching method?</td>
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<tr>
<td>Are all logistics in place?</td>
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<tr>
<td>Was the level of difficulty to participant correct?</td>
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<tr>
<td>Are the needs of the intended curriculum met sufficiently?</td>
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<tr>
<td>Is there any planned activity not done?</td>
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<tr>
<td>Did the participant made any positive comment about lesson design and lesson materials?</td>
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<tr>
<td>Any special thing the participant like about the lessons?</td>
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<tr>
<td>Did the participant talk well about the thinking problems?</td>
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<tr>
<td>Any positive comments about the reflections?</td>
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<tr>
<td>Did the differences in the lessons concern participant?</td>
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<tr>
<td>Did the participant enjoy the MBL-supported lessons?</td>
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<tr>
<td>Did the participant had any difficulty with the lessons?</td>
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<tr>
<td>Any comment made to improve the lessons?</td>
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<tr>
<td>Any indications of gain in conceptual understanding?</td>
<td></td>
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</tr>
<tr>
<td>Is there indications of acquisition of analytical skills or skills in problem solving?</td>
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</tbody>
</table>
APPENDIX A2
Workshop questionnaire I: (for the first workshop)

FORMATIVE EVALUATION OF THE FIRST WORKSHOP ACTIVITIES

1. What is your general comment about the lesson activities?

2. What was good about the activities?
   What was not so good?
   Any suggestion for improving what was not so good.

3. How do you judge the level of difficulty of exercises at the end of the lesson?
   If each activity in a lesson was to take one hour to complete, do you think the pace will
   cause difficulties to students?
   Did you find the reference readings useful in facilitating the learning?

4. What is the most significant thing you learned in this training workshop?
   Was there any question which was uppermost in your mind at the end of activity?

5. Please put down your suggestions about the following:
   In the next version of the lessons materials I would like you to do more in/on.
   In the next version of the lessons materials I would like you to do less in/on.
   I would like you to include the following in the teacher guide material.

6. To be specific, what were the weakness of the workshop in terms of:
   - Lesson materials used;
   - Teaching method/approach used;
   - Time allocated for different activities in a lesson;
   - Reference reading materials;
   - Others.

7. Give your recommendations in any area which you think needs correction and more
   emphasis in the whole workshop experience.
APPENDIX A3
Workshop questionnaire II: (for the second workshop)

Second workshop questionnaire

1. The lessons are designed such that they begin with a problem related to nature or everyday life. Do you think this pose any difficulty to your teaching?

2. In all lesson activities, students are supposed to actively be engaged in the learning process. In your view, is this difficulty to facilitate? If yes what are the difficulties?

3. The lesson activities force students to concentrate on the collection and use of evidence as a basis for their scientific learning. Do you think this is useful in understanding? What problems do you foresee which students might face in so doing in your class?

4. Writing and talking clarify students' thinking. For this reason, the lesson activities insist on clear expression, being in discussion groups or in the written lab reports. How difficulty/easy do you find the implementation of that idea in classroom setting?

5. Group learning approach is emphasised in the activities but the implementation of group work/discussion is very different from what students are used to (mostly, lectures). What difficulties do you envision in implementing and monitoring learning in such groups?

6. The thinking problems have as one of its intentions, to connect whatever evidence students found in the activities with their science knowledge domain. Do you think this can be successful? If not why, and what can be done to make it successful?

7. Memorisation of technical vocabulary is de-emphasised and instead, understanding is given upper hand. What are your reactions on this? Is this reflected in the activities? Do you think such approach may affects remembering of important scientific facts?

8. The integration of experiments with lecture approach, which we intend to follow in the activities, is a huge departure from traditional approach of teaching physics in secondary schools. Do you see any advantage? What problems will students face in adapting to new format?

9. MBL is one of the teaching tools employed in the new teaching approach, what advantage did you experience with MBL. What are disadvantages?

10. As the new teaching approach is different from traditional approach, what difficulties you presume you may face in using it in your future teaching?

11. What did you like about the activities?

12. What you dislike about the activities?

13. What is missing in the activities which you would like included?

14. Any general comment about the lesson design and future classroom implementation?
**APPENDIX A4**

Workshop questionnaire III: (for the third workshop)

Checklist for peer teaching (third workshop)

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>Yes</th>
<th>No</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lesson plan done according to the design</td>
<td></td>
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</tr>
<tr>
<td>The resource materials used effectively</td>
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<tr>
<td>The instructing teacher discuss the design of activities with peers</td>
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<tr>
<td>Peer teachers simulate how to carry out the lesson activities in groups</td>
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<tr>
<td>The instructing teacher simulate coaching the peers in activities</td>
<td></td>
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<td></td>
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<tr>
<td>The instructing teacher stimulate peers to associate graphs with phenomena studied</td>
<td></td>
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<td></td>
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<tr>
<td>The instructing teacher relate experimental results to theoretical framework</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The instructing teacher discuss physical rules derived from activities</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>There were difficulties in simulating the creation of group learning environment</td>
<td></td>
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<tr>
<td>There were difficulties in simulated supervision of group discussions</td>
<td></td>
<td></td>
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<tr>
<td>The instructing teacher found the group learning to be more labour intensive as an instructor</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The peer teachers are excited about active learning from start</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The workshop participants used what they learned</td>
<td></td>
<td></td>
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<tr>
<td>The participants liked the idea of group learning</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Problems cropped up in data collection process</td>
<td></td>
<td></td>
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</tbody>
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## QUESTIONS

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>Yes</th>
<th>No</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre- lab simulated?</td>
<td></td>
<td></td>
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<tr>
<td>Formative assessment simulated?</td>
<td></td>
<td></td>
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<tr>
<td>Drawing conclusion simulated?</td>
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<tr>
<td>There were common complains from peers about the approach</td>
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<tr>
<td>There were specific problems the participants face in handling MBL equipment</td>
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<tr>
<td>All participants indicate high expectations from learning with MBL</td>
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<tr>
<td>The instructing peer encounters many problems</td>
<td></td>
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<tr>
<td>Participants saw themselves as community of explorers in the classroom</td>
<td></td>
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<tr>
<td>The active learning seems to promote learning in the classroom</td>
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<tr>
<td>Classroom management is difficult</td>
<td></td>
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<tr>
<td>Assessment was implemented as integral part of instruction</td>
<td></td>
<td></td>
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<tr>
<td>Information from assessment proved to be useful in presenting the lesson</td>
<td></td>
<td></td>
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</tbody>
</table>
# APPENDIX A5

## Physics lesson plan evaluation sheet

<table>
<thead>
<tr>
<th>Focus</th>
<th>Yes/No/partly</th>
<th>Notes and Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there reference to the physics national curriculum?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is it clear what scientific knowledge and understanding the students will gain from this lesson?</td>
<td></td>
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<tr>
<td>Is it clear what science skills are being developed?</td>
<td></td>
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<tr>
<td>Has safety been considered?</td>
<td></td>
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<tr>
<td>Can the learning outcomes realistically be achieved in one lesson?</td>
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<tr>
<td>Does the plan show that the student's science knowledge and understanding are correct?</td>
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<tr>
<td>Will this be an interesting lesson, relevant to the pupils and set in an appropriate context?</td>
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<tr>
<td>Is there an opportunity to discover what the students already know at the start of the lesson?</td>
<td></td>
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<tr>
<td>Is it clear how the class will be organized for practical work, e.g. whole class, grouping etc.?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is it clear what the teacher will be doing at various stages of the lessons?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is it clear what the students will be doing at various stages of lesson?</td>
<td></td>
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<tr>
<td>Does the lesson have a clear beginning, middle and end? Are these realistically timed?</td>
<td></td>
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<tr>
<td>Are appropriate questions and scientific vocabulary planned for?</td>
<td></td>
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<tr>
<td>Is it clear how students will communicate their findings?</td>
<td></td>
<td></td>
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<tr>
<td>Does the lesson cater for a full range of abilities where necessary?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is it clear what resources are to be used and how they are to be organized?</td>
<td></td>
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</tr>
<tr>
<td>Is it clear what will be assessed and how this links with the stated learning outcomes?</td>
<td></td>
<td></td>
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<tr>
<td>Does the lesson match the level described?</td>
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</tbody>
</table>
APPENDIX A6
Final version of exemplary student lesson material

LESSON 6: MAGNETIC FIELDS
Magnetism plays a large part of our modern world's technology. Magnets are used today to store data for computers, to image parts of the body, and to explore the mysteries of the human brain. Magnetism also allows us to explore the structure of the Universe, the atomic structure of materials, and the quark structure of elementary particles.
The magnetic interaction can best be described using the concept of a field. For this reason, your experiences exploring the electric field concept in the previous lesson are also applicable in this lesson.
In this set of laboratory problems, you will map magnetic fields from different sources, explore factors that affect the magnetic field inside the coil of wires and study how the field varies in different parts of the coil. You will also determine (µ₀), the permeability constant of the coil. The activities are very similar to the activities dealing with electric fields.

OBJECTIVES
After successfully completing this laboratory, you should be able to:
- Explain the differences and similarities between magnetic fields and electric fields.
- Describe the pattern of magnetic fields near various sources, such as permanent 'bar' magnets, straight current-carrying wires, and coils of wire.
- Establish the relationship between magnetic field and the current and the number of turns per meter in a coil.
- Explain how the magnetic field varies inside and outside a coil.

PREPARATION
Read Nelkon and Parker on magnetic field (page 319-325) and on magnetic field and interaction current (page 345-362) or Halliday, Resnick and Walker: Chapter 29, sections 1 - 3; Chapter 30, sections 1, 3, 5. Also review your notes from the previous lesson (Electric Fields).
Before coming to lesson you should be able to:
- Add fields using vector properties.
- Use the vector cross product.
- Write down the magnetic field due to current-carrying wire in which a current element is moving in a known direction.

EXPLORATORY PROBLEM #1: CURRENT CARRYING WIRE
Your friend Joe's parents, whose livelihood depends on dairy farming, have high voltage power lines across their farm. They have heard about magnetic field from the power lines from the veterinary officer and are concerned about the effect that the magnetic field might have on the health of their dairy cows always grazing nearby. They bought a device to measure the magnetic field. The instructions for the device state that it must be oriented perpendicular to the magnetic field. To measure the magnetic field correctly, they need to know its direction at points near a current carrying wire. They know you have taken physics, so they ask you for help. You decide to check your prediction about the magnetic field map with a magnetic compass before you make the trip to your friend's parents' farm.
Question: What is the map of the magnetic field from a current carrying wire?

EQUIPMENT
You will have a magnetic compass, a length of wire, a meter stick, and a DC power supply.
PREDICTIONS
Sketch your best guess of the map of the magnetic field near a current carrying wire when the wire is (a) stretched straight, and (b) formed into a loop.

EXPLORATION
In doing this problem, keep in mind that because of the small size of the compass needle, it aligns itself parallel to the local magnet field.

Attach several wires together to give a total length of at least half a meter. Is there any evidence of a magnetic field from a non current-carrying wire? To check this, stretch the wire vertically and move your compass around the centre of the wire. Does the compass always point in the same direction?

Connect the wire across the 5V terminals of the power supply and turn the power supply on. The circuit breaker built into the power supply minimizes the hazard of this short circuit. Stretch the wire vertically and move your compass around the wire. Start where you expect the magnetic field to be largest. Is there any evidence of a magnetic field from a current carrying wire? Watch the compass as you turn the current on and off. Does the compass always point in the same direction? How far from the wire can the compass be and still show a deflection? Develop a measurement plan.

Now make a single loop in the wire through which you can easily move the compass. Move the compass around the loop. How far away from the loop can you see a deflection? Is this distance larger along the axis of the loop or somewhere else?

MEASUREMENT
Use your measurement plan to create a map of the magnetic field around the stretched wire and the looped wire.

ANALYSIS
The direction of the magnetic field at a point near a current carrying wire can be found by using the 'right-hand rule' that is described in your text. How does the 'right-hand rule' compare to your measurements?

CONCLUSION
How did your predictions of the map of the magnetic field near current-carrying wires compare with your results? How do they compare with the 'right-hand rule'?

PROBLEM #2: THE MAGNETIC FIELD OF ONE COIL
You read in your text that a coil of wire carrying a current gives the same magnetic field as a bar magnet: a magnetic dipole field. This seems strange so you decide to check it using a large coil of wire and a Magnetic field sensor. You decide to measure the strength of the magnetic field as a function of position along the central axis of the coil. As a qualitative check you also use the Magnetic field sensor to make a map of the magnetic field everywhere near the current carrying coil.

Question: How does the magnitude of the magnetic field caused by a current carrying coil of wire vary as a function of position along its central axis? What is the map of the magnetic field near the coil?

EQUIPMENT
You will have a coil of 200 turns of wire, a DC power supply, a compass, a meter stick, a multimeter (DMM), a magnetic field sensor (Hall probe), and a computer data acquisition system.

PREDICTION
Compare the magnitude of the magnetic field as a function of distance along central axis of a coil of known radius and carrying a known electric current to that of a permanent bar magnet.
Also compare the field map of the current carrying coil with that of a bar magnet.

METHOD QUESTIONS
Draw the coil and label the current through it. Using the right hand rule, determine the direction of the magnetic field along the central axis of the coil. Using this information, which symmetry axis of a magnetic dipole corresponds to this central axis?

EXPLORATION
Connect a large coil to the power supply using the 5V adjustable voltage. Using your
Final version of exemplary student lesson material

compass, make a qualitative map of the magnetic field produced. To get the most obvious effect on the compass, should the central axis of the coil be oriented N-S or EW? Using your compass an indicator, adjust the current up and down to determine the sensitivity of the magnetic field to the current. For a reasonable current in the coil, use the compass to determine how far a measurable magnetic field along the axis of the coil extends. Also check out the magnetic field outside the coil. Is it large or small? Compared to what?
Try reversing the current through the coil. What happens to the magnetic field at each point?

Connect the magnetic field sensor accordingly. Explore the strength of the magnetic field in the plane of the coil. Is the field stronger inside or outside the coil? Where is the field the strongest inside the coil? Decide whether you should set the amplifier to high or low sensitivity.
How far from the centre of the coil along the axis can you measure the field? Is it the same on both sides of the coil? How can you tell by your magnetic field reading if you are on the axis? How far from the axis can you move the Magnetic field sensor without introducing additional uncertainty to your measurement?
Write down a measurement plan.

MEASUREMENT
Based on your exploration, choose a scale for your graph of magnetic field strength as a function of position that will include all of the points that you will measure.
Use the Magnetic field sensor to measure the magnitude and direction of the magnetic field as a function of position along the axis of the coil. Measure the field on both sides of the coil. Be sure your Magnetic field sensor is calibrated and has the correct orientation to accurately measure the magnetic field.
Use the Magnetic field sensor to complete the field map for the coil.
Use the multimeter to measure the current in the coil. Try measuring the field along the axis at several different currents.
Don't forget to measure the diameter of the coil and record the number of turns. What considerations need to be made when measuring the diameter?

ANALYSIS
Graph the magnetic field of the coil along its axis as a function of position.

CONCLUSION
Is the graph of magnetic field strength as a function of position along the central axis similar to that for a bar magnet? Does the magnetic field map for a current-carrying coil have the same pattern as for a bar magnet? Do you believe that this coil gives a magnetic dipole field? Is this true everywhere? Why or why not?
How does the magnetic field strength of a current-carrying coil depend on the current? What measurements justify your statement?

PROBLEM #3: DETERMINING THE MAGNETIC FIELD OF A COIL
You have a temporary job in a microelectronics laboratory and need to cut and shape a silicon wafer to a very high precision of a few microns. Your team decides to investigate using an ion beam to do this accurate cutting. You know that an ion is just an atom with some of its electrons stripped off, so you know you can direct it with a magnetic field. One of the members of your group suggests that a coil of wire can be used to produce a magnetic field, which can be varied by changing the current through it.
You have been assigned to calculate the magnetic field along the axis of the coil as a function of its current, number of turns, radius, and the distance along the axis from the centre of the coil. To make sure you are correct, you decide to compare your calculation to measurements.
Question: How does the magnitude of the magnetic field of a current-carrying coil of wire depend on the position along the central axis, the radius of the coil, the number of turns of the coil, and the current through the coil?

EQUIPMENT
You will have a large, 200 turn coil of wire, a power supply, a digital Multimeter (DMM), a compass, a meter stick, a Magnetic field sensor, and a computer data acquisition system.

PREDICTION
Calculate the magnitude of the magnetic field as a function of the position along the
central axis of a coil of known radius, the number of turns of wire, and the electric current in the coil. Use this expression to graph the magnetic field strength as a function of position along the central axis of the coil.

METHOD QUESTIONS
1. Make a sketch of a coil of radius R. Define a coordinate axis, label the relevant quantities, and indicate the direction of the current through the coil. Select a point along the axis at which you will calculate the magnetic field.
2. Select a small element of current along the coil, which will cause a small fraction of this magnetic field. Label the length of that current element. Draw a position vector from that current element to the selected point along the axis of the coil. Use the Biot-Savart law to draw a vector representing the direction of the small part of the magnetic field from your current element at the position of interest. Determine the components of this vector along the axes of your coordinate system. Are there any symmetries that rule out one or more components of the magnetic field at the point of interest?
3. Use the Biot-Savart law to calculate the small part of the desired component of the magnetic field, at the selected point, from the small element of current. Now add up (using an integral) all of the small fractions of that component of the magnetic field from all of the small elements of current around the coil. Determine the magnitude of the magnetic field at that point along the axis for one loop of wire, writing your answer as a function of the distance along the axis of the coil. What will be the effect of N identical loops on the magnitude of the magnetic field?
4. Graph the magnitude of magnetic field strength as a function of the position along the central axis of the coil of wire.

EXPLORATION
Connect a large coil to the power supply using the 5V adjustable voltage. Using your compass, make a qualitative map of the magnetic field produced. To get the most obvious effect on the compass, should the central axis of the coil be oriented N-S or EW? Decide whether you should set the amplifier to high or low sensitivity. Using your compass an indicator, adjust the current up and down to determine the sensitivity of the magnetic field to the current. For a reasonable current in the coil, use the compass to determine how far a measurable magnetic field along the axis of the coil extends. Also check out the magnetic field outside the coil. Is it large or small? Compared to what? Try reversing the current through the coil. What happens to the magnetic field at each point?

MEASUREMENT
Based on your exploration, choose a scale for your graph of magnetic field strength against position that will include all of the points you will measure. Use the Magnetic field sensor to measure the magnitude and direction of the magnetic field as a function of position along the axis of the coil. Measure the field on both sides of the coil. Be sure your Magnetic field sensor is calibrated and has the correct orientation to accurately measure the magnetic field. Use the Magnetic field sensor to complete the field map for the coil. Use the Multimeter to measure the current in the coil. Try measuring the field along the axis at several different currents. Don't forget to measure the diameter of the coil and record the number of turns. What considerations need to be made when measuring the diameter?
ANALYSIS
Graph the measured magnetic field of the coil along its axis as a function of position and compare with your prediction.

CONCLUSION
Does the graph of magnetic field strength as a function of distance agree with your prediction? Is this true everywhere? Why or why not?

PROBLEM #4: MEASURING THE MAGNETIC FIELD OF TWO PARALLEL COILS
You have a part time job with a high tech company working in a laboratory developing large liquid crystal displays that could be used for laptop computer monitors. The alignment of the liquid crystals is very sensitive to magnetic fields. It is important that the material sample be in a fairly uniform magnetic field for some crystal alignment tests. The laboratory has two nearly identical large coils of wire mounted so that the distance between them equals their radii. You have been asked to determine the magnetic field between them to see if it is suitable for the test.

Question: For two large, parallel coils, what is the magnetic field on the axis, as a function of the distance from the middle of the two coils?

EQUIPMENT
Connect two large coils to a power supply so that each coil has the same current.
Each coil has 200 turns. You will have a Multimeter, a compass, a meter stick, and a Magnetic field sensor. A computer is used for data acquisition.

PREDICTION
Calculate the magnitude of the magnetic field for two coils as a function of the position along their central axis, for the special case where the distance between the coils is the same as the radius of the coils. Use this expression to graph the magnetic field strength versus position along the axis.

METHOD QUESTIONS
1. Draw a picture of the situation showing the direction of the current through each coil of wire. Establish a single convenient coordinate system for both coils. Label all of the relevant quantities.
2. Select a point along the axis of the two coils at which you will determine an equation for the magnetic field. In the previous problem, you calculated the magnetic field caused by one coil as a function of the position along its axis. To solve this problem, add the magnetic field from each coil at the selected point along the axis. Remember to pay attention to the geometry of your drawing. The origin of your coordinate system for this problem cannot be at the centre of both coils at once. Also remember that the magnetic field is a vector.
3. Use your equation to graph the magnetic field strength as a function of position from the common origin along the central axis of the coils. Describe the qualitative behaviour of the magnetic field between the two coils. What about the region outside the coils?

EXPLORATION
Connect the large coils to the power supply with the current flowing in the opposite direction in both coils, using the 5V adjustable voltage. Using your compass, explore the magnetic field produced. Be sure to look both between the coils and outside the coils. Now connect the large coils to the power supply with the current flowing in the same direction in both coils, using the 5V adjustable voltage. Using your compass, explore the magnetic field produced. Be sure to look both between the coils and outside the coils. Based on your observations, should the currents be in the same direction or in opposite directions to give the most uniform magnetic field between the coils?
Connect the Magnetic field sensor accordingly. For the current configuration that gives the most uniform magnetic field between the coils, explore the strength of the magnetic field along the axis between the coils.
Follow the axis through the coils. Is the field stronger between or outside the coils? Where is the field strongest between the coils? The weakest?
See how the field varies when you are between the two coils but move off the axis. How far from the axis of the coils can you measure the field? Is it the same on both sides of the coils? Decide whether you should set the amplifier to high or low sensitivity. Write down a measurement plan.

**MEASUREMENT**

Based on your exploration, choose a scale for your graph of magnetic field strength against position that will include all of the points you will measure. Use the Magnetic field sensor to measure the magnitude of the magnetic field along the axis of the coils of wire. Be sure to measure the field on both sides of the coils. What are the units of your measured magnetic fields? How do these compare to the units of your prediction equations? Use the Multimeter to measure the current in the two coils. As a check, repeat these measurements with the other current configuration.

**ANALYSIS**

Graph the measured magnetic field of the coil along its axis as a function of position and compare to your prediction.

**CONCLUSION**

For two large, parallel coils, how does the magnetic field on the axis vary as a function of distance along the axis? Did your measured values agree with your predicted values? If not, why not? What are the limitations on the accuracy of your measurements and analysis? Does this two-coil configuration satisfy the requirement of giving a fairly uniform field? Over how large a region is the field constant to within 20%? This very useful geometric configuration of two coils (distance between them equals their radius) is called a Helmholtz coil.

**REFLECTIONS**

1. In what ways are magnetic interactions similar to electric interactions?
2. In what ways are magnetic interactions different from electric interactions?
3. Can you show that magnetic interactions are not the result of electric interactions? Explain.
4. Is magnetic field the same as electric field?
5. Do you suppose there is magnetic charge, like electric charge, that can be passed from one object to another? Explain why or why not.
6. Do you suppose the geographic South Pole of the Earth is also a magnetic South pole or is it a magnetic North pole? Explain why you think so.

**EXERCISE**

1. While studying intensely for your physics final exams you decide to take a break and listen to your radio. As you unwind it, your thoughts drift to newspaper stories about the dangers of household magnetic fields on the body. You examine your radio wires and find that most of them are coaxial cable, a thin conducting wire at the center surrounded by an insulator, which is in turn surrounded by a conducting shell. The inner wire and the conducting shell are both part of the circuit with the same current (I) passing through both, but in opposite directions. As a way to practice for your physics final exam you decide to calculate the magnetic field in the insulator, and outside the coaxial cable as a function of the current and the distance from the center of the cable. As an additional challenge to yourself, you calculate what the magnetic field would be (as a function of the current and the distance from the center of the cable) inside the outer conducting shell of the coaxial cable. For this you assume that the inner radius of the conducting shell is R1 and the outer radius is R2. What are the values of the magnetic field you obtain.
2. In the past there have been some experiments with DC power transmission. A large high voltage DC two-wire power line may carry a current of 10,000 amps and voltage of 200,000 Volts. Estimate the magnetic field that would be measured standing at the base of a tower holding up such a line.
APPENDIX A7
Final version of exemplary teacher guide

Lesson 6: Magnetic fields from electric current

What the lesson is about
This lesson is an exploration by students of magnetic fields created by electric current. The lesson has four related activities, which can be done in two consecutive lab sessions. The main aims of the lesson are to deepen students’ understanding of magnetic fields and help to correct possible misconceptions. This lesson is a continuation of electric fields we covered in the previous lesson.

What we intend to achieve in this lesson
By the end of the lesson, students are expected to be able to:
- Explain the differences and similarities between magnetic fields and electric field.
- Describe the pattern of magnetic fields near various sources such as permanent magnets, straight current-carrying wires and coils of wire.
- Determine the relationship between magnetic fields and current, the number of coils per meter and its permeability to the surroundings.

Relevant pages on the students’ textbooks
Chapter of Nelkon and Parker, sections, or chapter 29, sections 1-3 and chapter 30 sections 1, 3, 5 of Halliday, Resnick and Walker.

Lesson Plan and Timing

| Start of lesson | 20 |
| Body of lesson  | 115|
| Conclusion      | 20 |
| Total time      | 155|

Lesson Preparation

√ To be done before the class
- Read the relevant pages of the students’ textbook for this topic.
- Revisit the possible misconceptions students might have, to focus and streamline the lesson accordingly. The following is an example of commonly held alternative conceptions about magnetic fields by students.
  1. Only magnets produce magnetic fields.
  2. A magnetic field is a pattern of lines (not a field of force) that surrounds a magnet.
  3. In a magnet, the magnetic field lines exist only outside the magnet.
  4. Flux is the same as field lines.
  5. Flux is actually the flow of the magnetic field.
  6. Magnetic fields are the same as electric fields.
  7. Magnetic fields from magnets are not caused by moving charges.
Note in teaching this lesson, you shall take account of these alternative conceptions, and:
- Recognize that alternative conceptions are strongly held.
- Try to probe for student's misconceptions through questions.
- Ask students to explain their conceptions clearly.
- Provide contradictions to students' misconceptions through questions, and dialog.
- Encourage discussion, urging students to apply physical concepts in their reasoning.
- Encourage the replacement of the misconception with new concepts through questions, thought experiments, hypothetical situations with and without the underlying physical law, experiments designed to test hypotheses.
- Re-evaluate students' understanding by posing conceptual questions.

- Set a time aside before the lesson start and try out the activities yourself.
- Prepare the classroom by checking that proper equipment is on student tables and on the front table of yours. On the blackboards, provide space for each group to present its predictions.

\[ \text{Material} \]
Windows PC with Coach Lab11 Interface and Coach 5 software, meter stick, DC power supply, multimeter; Magnetic Field Sensor (Hall probe), cardboard spacers, Coiled wire (Slinky), connecting wires, tape and cardboard.

\[ \text{What to expect and tips} \]
- Students may have difficulties with measurement. They may have wrong conception that measurement is only linear; any quantity can be measured accurately as long as they are using computer; some concepts such as magnetic fields cannot be measured because of their inaccessibility; the five senses are infallible; and measurement of an object can be accomplished only through touching.
- Student may have problems concerning correct interpretation of symbolic language of mathematics, eg. Biot-Savart derivations.
- Besides, some students may have problem with scaling properly the x-y axes of the graphs in their computers.
- Be patient. Group work takes more time; you will have less time to cover things. There will be students who are not on task. The main thing is not to be discouraged when you try something and does not work the way you planned.

\[ \text{Execution of lesson} \]
\[ \text{Start of lesson} \]
Briefly revise what you covered in the previous lessons through asking some questions. Ask student what, why and how type of questions related to the lesson that helps to diagnose possible alternative ideas mentioned earlier, e.g. What is magnetic field, what causes magnetic fields, how can we prove it exist? Listen to their ideas and write them down on the black board. Some answers will indicate conceptual problems. No matter how severe students' conceptual problems seem to be, how unprepared students seem to be, do not lecture to students at the start of lab. They have an opportunity to see the theory of physics in your non-lab part of lesson and textbooks, but lab gives them an opportunity to find out for themselves whether they are right about the way the world works. Let the students know the focus of the lesson early. Each activity must be successfully completed before students proceed to the next one. Do not forget to remind them of safety precautionary measures at the end of this section.

\[ \text{Body of the lesson} \]
See that students are in groups and they start the lab with discussion of the predictions. To keep the students from starting the activity before they discuss their predictions, set aside a small but necessary piece of equipment (say, Hall probe) in your front table. Pass this out to groups only after the predictions and discussion is complete. Many students can come up with correct answers or reasonable looking graphs for strange reasons that do not follow the accepted laws.
of physics. Point out the discrepancies. If you do not discuss these reasons, your students will never realize later that their reasoning is incorrect. Do not tell the students if their predictions are correct! This would spoil the whole purpose of the labs.

Once the groups have settled into their task, spend about five minutes circulating and observing all groups. Try not to explain anything (except trivial clarification) until you have observed all groups at least once. This will allow you to determine if a whole-class intervention is necessary to clarify the task (e.g., Be sure to calibrate the Hall Probe correctly according to information available on the help menu).

While groups are working, spend a significant amount of your time monitoring (observing and listening to group members) the class in order to see:

- What they do and do not understand, and
- What problems they have working together collaboratively.

Armed with that kind of information, you can intervene more efficiently and effectively. Mind not to get trapped into going from group to group explaining the task/physics or answering questions. Also watch out not to begin intervening too soon, for it won't fair to the last groups. By the time you recognize that all groups may have the same difficulty, the last groups will have wasted considerable time.

**Monitoring**

- Establish a circulation pattern around the room. Stop and observe each group to see how easily they are solving the experimental problem and how well they are working together. Don't spend a long time with any one group. Keep distance from students' line of sight so they don't focus on you.
- Make notes about student difficulties with the task and with group functioning so you know what successful moves to make.
- If several groups are having the same difficulty, you may want to stop the whole class and clarify the task or make additional comments that will help the students get back on the right track (e.g., I noticed that you are all you have set the sensitivity of Hall probe not correctly... Remember to computer display the data as you commanded it....). Another strategy is to stop the class and have one group (or several groups) show the rest of the class how they decided to make a certain measurement or carry out a particular analysis. You can then spend a few minutes discussing how that measurement or analysis could be done most effectively.

**Intervening**

- From your observations (circulation pattern), decide which group (if any) is obviously struggling and needs attention most urgently. Return to that group, watch for a moment and then join the group at eye level. One way to intervene is to point out the problem and ask the appropriate group what can be done about it. This establishes your role as one of coach rather than answer-giver. Another way to intervene is to ask the students in those groups (a) What are you doing? (b) Why are you doing it? and (c) How will that help you? Try to give just enough help to get the group on course, then leave.
- One way to coach is to first diagnose the type of problem (e.g., managerial, came to decision too quickly without considering all the options, can't agree on what procedure to use, etc.) Then ask: “Who is the manager (or group leader, or checker)? What should you be doing to help resolve this problem?” If the student doesn't have any suggestions, then you could model several possibilities e.g. assume they failed to map the of the coil, ask them to think of the coil as a permanent magnet.
- If you observe a group in which one student does not seem to be involved in the discussion and decisions, ask that student to explain what the group is doing and why. This emphasizes the fact that all group members need to be able to explain each step in solving the experimental problem.
If a group asks you a question, try to turn the question back to the group to solve. Again, try to give just enough help to get the group started, then leave.

Conclusion of the lesson
Select one person from each group to put their results or data on the board, so all students can see what each group did. It is sometimes effective to occasionally select a student who has not participated in the labs as much as you would like. This reinforces the fact that all group members need to know and be able to explain what their group did.

A whole-class discussion will commonly be used to help students consolidate their ideas and make sense out of what has been going on in the lab. The whole class discussions serve several purposes:
- To summarize what students have learned;
- To help students find out what other students learned from the same problem;
- To produce discrepancies which stimulate further discussion, thinking, or investigations; and
- To provide a transition to the next activity in the lesson.

These discussions should always be based on the groups, with individuals’ only acting as representatives of a group. This avoids putting one student ‘on the spot.’ The trick is to conduct a discussion about the results without (a) telling the students the ‘right’ answer or becoming the final ‘authority’ for the right answers, and (b) without focusing on the ‘wrong’ results of one group and making them feel stupid or resentful. To avoid these pitfalls, you could try starting with general, open-ended questions such as:
- How are these results the same?
- How are these results different?
Then you can become more specific:
- What could be some reasons for them to be different?
- Are the differences important?
- Do these differences indicate a real difference in the physics, or are they a matter of judgment (e.g., decisions about starting times and positions for a graph).

Always encourage an individual to get help from other group members if he or she is ‘stuck.’ Encourage groups to talk to each other by redirecting the discussion back to the groups. For example, if a group reports a certain result or conclusion, ask the rest of the class to comment: "What do the rest of you think about that?" This helps avoid the problem of you becoming the final ‘authority’ for the right answer.

Students should be able to explain to their classmates how they collected and analysed their data in order to come up with the answer to the experimental problem. If their predictions were very different, ask students to think about and discuss why they might have thought differently before and after the lab.

You can also let the students discuss how the groups were functioning. Students need to hear difficulties other groups are having, discuss different ways to solve these difficulties, and receive feedback from you.
- Randomly call on one member of each group to report either
  - one way they interacted well together, or
  - one difficulty they encountered working together, or
  - one way they could interact better next time.
- Add your own feedback from observing your groups (e.g., "I noticed that many groups are coming to an agreement too quickly, without considering all the possibilities. What might you do in your groups to avoid this?")

If you have a group that is experiencing great difficulties, remember that it is better that they spend the whole lesson on the first activity, and learn it, than that they work quickly and do not learn.
If it is the last activity of the lesson, conclude by assigning students homework with clear direction of what is expected of them.

REFLECTION
In reflection section assess the student understanding of the highlighted points for each question:
1. The students could show similarity from the perspective that opposite pole attracts and same poles repels.
2. The students mention among others, magnetic interactions do not depend on charged particles.
3. Yes it can be shown, e.g. if the charged particles involved in the electric interactions are stationary, no magnetic field and eventually interactions are possible.
4. They are both force fields but originate from different sources.
5. No. Magnetic poles are different from electric charges. Positive and negative charges can be separated and isolated but not the poles of magnet. Cutting a magnet into half will produce two new magnetic, each with its own north and south poles. Magnetism is electric in origin and is a secondary property of electricity.
6. No. The fact that the South Pole of a bar magnet is attracted towards Earth's South Pole means that earth's South Pole actually behaves like the North Pole of a magnet. Similarly, Earth's' North Pole behaves like the South Pole of a magnet.

EXERCISE
The answers to the questions involve application of Ampere law and the rule to determine the magnetic field produced by a long, straight wire. For question one use, it is assumed the students can perform Amperes' closed integral to determine the magnetic field. The second question assumes the base of a tower is at distance r, and magnetic field B is calculated by using formula $B = \frac{\mu_0 I}{2\pi r}$, where I is current through the wire.
APPELLIX B1
Teacher questionnaire

Teachers Questionnaire

School: ______________________________________________________________________
Teachers' name _______________________________________________________________

For each of the following questions please tick the rectangular box that best describes how you feel about a particular statement. The information is confidential, and there is no right and wrong answer.

SD- Strongly Disagree D- Disagree N- No Opinion A- Agree SA- Strongly Agree

1. I was provided with adequate training to use MBL system
   SD D N A SA
2. MBL is an excellent tool for individualization of student laboratory work
   SD D N A SA
3. MBL provides more effective instruction than traditional lab instructions
   SD D N A SA
4. The preparation of MBL lessons takes a lot of time
   SD D N A SA
5. MBL is easy to use for students
   SD D N A SA
6. The MBL-based lessons I used need improvement
   SD D N A SA
7. MBL is an effective teaching tool
   SD D N A SA
8. Students' level of physics comprehension is greatly enhanced using MBL
   SD D N A SA
9. MBL develop a high level of thinking skills
   SD D N A SA
10. My students were very motivated during the MBL-based lessons
    SD D N A SA
11. My students felt unsure during MBL-based lessons
    SD D N A SA
12. MBL is a necessary tool for physics lab instruction
    SD D N A SA
13. Supplementary materials are necessary to enhance physics instruction with MBL
    SD D N A SA
14. The use of ICT (such as MBL) should be a requirement of the physics curriculum
    SD D N A SA
15. MBL based lessons can easily be integrated in the current physics curriculum
    SD D N A SA
16. MBL should not be used in schools
    SD D N A SA
17. MBL activities relates to the real world
    SD D N A SA
18. Students retain physics concepts when MBL is used
    SD D N A SA
19. MBL could provide the following educational benefits for my students
    SD D N A SA
20. Name 5 personal priorities you want to address in improving your skills as a teacher
    SD D N A SA
21. Additional Comments:
    SD D N A SA
APPENDIX B2
Lesson plan summary

Lesson Plan summary (part 1)

The following characteristic features are eminent in the lessons. They are also expected in lessons developed by teachers.

i. They are centered on microcomputer-based laboratories (MBL) thinking, aiming at enabling students taking cognitive advantages inherent in MBL.

ii. The activities advance critical thinking and problem-solving skills of the students.

iii. The assignments promote the idea of students reflecting on the activities after completion and also try to apply the learned concepts/principles in a different context.

iv. The activities encourage collaborative learning as students carry out the activities in groups of three or four.

The laboratory activities are open-ended, problem-based lessons. The lessons do not have step-by-step instructions. Instead, each laboratory consists of a set of problems that students solve before coming to the laboratory by making an organized set of decisions (a problem solving strategy) based on their initial knowledge. The instructions are designed to help students examine their thoughts about physics. The labs give students opportunity to compare their ideas about what 'should' happen with what really happens. The labs are of little value in helping students learn physics unless students take time to predict what will happen before they do something. While in the lab, students take their time and try to answer all the questions in the lesson. In particular, the exploration questions are important to answer before they make measurements.

Lesson organization
The lessons are organized in a sequential order presented in the following sections.

Introduction
A brief introduction of the lesson is necessary. This gives a general overview of the problem to be solved. It may include some definitions of concepts, tell students the specific concepts, principles, and other ideas that will be raised and addressed during the activity, or if the problem may require a battery of experiments, an overview to clarify why those experiments and so on. For example:

You are familiar with many objects that vibrate or oscillate. For example, a tuning fork, the balance wheel of a mechanical watch, a pendulum, a plastic ruler held firmly over the edge of a table and gently struck, the strings of a guitar or piano. Spiders detect prey by the vibrations of their webs, cars oscillate up and down when they hit a bump, and buildings and bridges vibrate when heavy trucks pass or the wind is strong. Electrical oscillations occur in radios and TV sets. At the atomic level, atoms vibrate within molecules, and the molecules of a solid oscillate about their equilibrium positions. .... In this activity, you will study the oscillatory motion of springs that are.
Objectives
Objectives of the lab work are clearly stated at the beginning so that student is aware what will be achieved at the end of the lesson. For example,

After successfully completing this laboratory, you should be able to:
- Provide a qualitative explanation of why the mass-and-spring system oscillates using the concepts of restoring force and inertial mass.
- Identify the physical parameters, which influence the period (or frequency) of the motion and describe this influence quantitatively. ... Etc.

Preparation
Reference readings, Chapters or sections of certain textbook where students can gather prior knowledge, mathematical skills and any necessary prerequisite are mentioned in this section. For example

Read, Nelkon and Parker or any other Physics textbook that covers mechanical oscillations. Before coming to lab you should be able to:
- Define and use the sine, cosine and tangent functions.
- Recognised the difference between amplitude, frequency, and period.
- Determine the spring constant for a spring using Hookes law and its period.

Problem Statement
Why are we doing this lab problem? How is it related to the real world? In the lab instructions, the first paragraphs describe a possible situation that raises the problem students are about to solve. This emphasizes the application of physics in solving real-world problems. For example

You are selecting lightweight springs for a large antique clock, and you need to determine the spring constant of the springs.

What is the spring constant of the spring?

The question, framed in a box and preceded by a question mark, defines the experimental problem students are trying to solve. Students have to keep the question in mind as they work through the problem.

Equipment
To make a prediction about what students expect to happen, they need to have a general understanding of the apparatus they will use before they begin. This section contains a brief description of the apparatus and the kind of measurements students can make to solve the laboratory problem. The details should become clear to students as they use the equipment. For example

You will hang a spring attached to a force sensor from a ring stand and use a distance sensor to measure how far the spring stretches. You also have a mass holder, an assortment of masses, a triple-beam balance, an IP-Coach interface and Coach 5 software.

Prediction
Everyone has his or her own 'personal theories' about the way the world works. One purpose of the lab is to help students clarify their conceptions of the physical world by testing the predictions of their personal theory against what really happens. For this reason, students always predict what will happen before collecting and analyzing the data. Their predictions have to be completed and written in their lab journal before they come to lab. The 'Method Questions' in the next section are designed to help students to determine their prediction and should also be completed before they come to lab. Although the prediction question is given before the method
questions, students should complete the method questions before making the prediction. The prediction question is given first so student can know his/her goal. Then student spend the first few minutes at the beginning of the lab session comparing prediction with those of their group partners. Discuss the reasons for any differences in opinion. It is not necessary that their predictions are correct, but it is necessary that student understand the basis of their prediction. E.g.

1. Predict quantitatively the spring constant of a spring from measurements of the displacement of different masses hung on the spring.
2. Predict quantitatively the spring constant of a spring from measurements of the period of oscillation of a mass attached to the spring.

Method questions
Method Questions are a series of questions intended to help student solve the experimental problem. They either help student make the prediction or help then plan how to analyze data. Method Questions should be answered and written in students' lab journal before they come to lab. E.g.

Suppose you hang several different known masses on a spring and measure the vertical displacement of each mass by distance sensor.
1. Make two sketches of the situation, one before you attach a mass to a spring, and one after a mass is suspended from the spring and is at rest. Draw a co-ordinate system and label the equilibrium position (where the spring is un-stretched), the stretched position, the suspended mass, and the spring constant. Assume the springs are mass less.

Exploration
This section is extremely important—many instructions will not make sense, or students may be lead astray, if they do not take the time to carefully explore the experimental plan. In this section students practice with the apparatus before they make time consuming measurements which may not be valid. This is where students carefully observe the behavior of the physical system, before they begin making measurements. Students will also need to explore the range over which the apparatus is reliable. Most apparatus has a range in which its operation is simple and straightforward. This is its range of reliability. Outside of that range, complicated corrections need to be applied. Students should record their observations in their lab journal. If a student observes that the apparatus does not function properly for the range of quantities she/he was considering measuring, they can modify the experimental plan before they have wasted time taking an invalid set of measurements. The result of the exploration should be a plan for doing the measurements that student need. Students record measurement plan in the journal, e.g.

Select a series of masses that give a usable range of displacements. (Note: The assumption of mass less springs holds when the suspended mass used to stretch the springs is about 500 grams.) Decide on a recording scheme that allows you to measure consistently the displacement of each mass. Decide how many and which measurements you will need to make to determine the spring constant.

Measurements
After students have predicted the result of the measurement and have explored how the apparatus behaves, they are ready to make careful measurements. To avoid wasting time and effort, students make the minimal measurements necessary to convince themselves and others that they have solved the laboratory problem, e.g.

Make the measurements that you decided you needed to determine the spring constant. Analyse your data as you go along so you can decide how many measurements you need to make to determine the spring constant accurately and reliably.
Analysis
Data by itself is of very limited use. Most interesting quantities are those derived from the data, not direct measurements themselves. Students’ predictions may be qualitatively correct but quantitatively very wrong. To see this they must process the data. Students are advised always to complete data processing (analysis) before they take the next set of data. If something is going wrong, they shouldn’t waste time taking a lot of useless data. After analyzing the first data, they may need to modify measurement plan and re-do the measurements. If they do, they should record the changes in plan in their journal. E.g.

Use IP-Coach system to draw a graph of displacement versus mass for the mass-spring system. From the slope of this graph, calculate the value of the spring constant, including the uncertainty.

Conclusions
After have analyzed the data, students are ready to answer the experimental problem. They state the result in the most general terms supported by analysis, but must compare the results to prediction. E.g.

How do the two values of the spring constant compare? Which method has the highest precision? Which method is quicker? Which method do you feel is the most reliable? Justify your answers. Did your measured values agree with your initial predictions? Why or why not? What are the limitations on the accuracy of your measurements and analysis?

Reflection. After finishing the Main Activity, students re-examine their answers to look for patterns. They are also asked to generalize, abstract, and relate concepts to the situations they have studied. For example

- What factors determine the magnitude of the spring force?
- Imagine hanging an object from a rope, and then hanging it from a spring. Is there any difference between a very stiff spring and a rope? Comment on the similarities.

Exercise
These exercises are to help student think deeply about the activity and in some cases the exercise may involve students applying the learned concept to a different context, so as to provide a more context rich environment. The idea is also to try to make the questions as much as possible relevant to life of students and hard enough to require group work e.g.

1. The diagram below shows an oscillating mass/spring system at times 0, T/4, T/2, 3T/4, and T, where T is the period of oscillation. For each of these times, write an expression for the displacement (x), the velocity (v), the acceleration (a), the kinetic energy (KE), and the potential energy (PE) in terms of the amplitude of the oscillations (A), the angular velocity (ω), and the spring constant (k).
## APPENDIX B3
### Curriculum profile

Teacher name: .................................................................

### INTRODUCTION TO LESSON

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>IND.</th>
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</thead>
<tbody>
<tr>
<td>1. Teacher appears organised and ready to start</td>
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<td>P ...........</td>
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<tr>
<td>2. Teacher checks homework (exercise, &amp; reflection)</td>
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<tr>
<td>3. Teacher asks/answers homework questions</td>
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<td>4. Teacher discusses and reviews homework</td>
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<td>P ...........</td>
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<tr>
<td>5. Teacher introduces new activity</td>
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<td>P ...........</td>
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<tr>
<td>6. Teacher asks prompting and probing questions to introduce the activity</td>
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<td>P ...........</td>
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<tr>
<td>7. Teachers takes opportunity to discover what students already know at start of activity</td>
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<td></td>
<td>F ...........</td>
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<tr>
<td>8. Teacher uses learner's ideas to illustrate activity</td>
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<td>F ...........</td>
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<tr>
<td>9. Teacher relates activity to previous/future activities</td>
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<tr>
<td>10. Teacher establish the relevance of the activity to learners' daily lives'</td>
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<td>P ...........</td>
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<tr>
<td>11. Teacher makes clear what science knowledge and skills are developed</td>
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<td>P ...........</td>
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<tr>
<td>12. Teacher makes clear how the class will be organised of the activity e.g. grouping.</td>
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<td>P ...........</td>
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<tr>
<td>13. Teacher clarifies what students will be doing in various stages of the lesson e.g. prediction</td>
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<td>P ...........</td>
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<tr>
<td>14. Teacher clarifies what resources are to be used and how they are to be organised.</td>
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<tr>
<td>15. Teacher clarifies what will be assessed and how this links with the stated objectives</td>
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<tr>
<td>16. Teacher poses question that are challenging and debatable</td>
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<td>F ...........</td>
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<tr>
<td>17. Teacher stresses safety instruction (where applicable)</td>
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<tr>
<td>18. Teacher tells students what the objectives are for the activity</td>
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<td>P ...........</td>
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### BODY OF LESSON

#### A. Basic teaching skills and classroom management

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>IND.</th>
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</thead>
<tbody>
<tr>
<td>1. Teacher has essential materials ready and organised</td>
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<tr>
<td>2. Teacher makes sure that materials are easily accessible to learners</td>
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<td>P ...........</td>
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<tr>
<td>3. Teacher explains how to use materials and equipment</td>
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<td>P ...........</td>
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<tr>
<td>4. Teacher stimulates less motivated groups</td>
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<td></td>
<td>C ...........</td>
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<tr>
<td>5. Teacher responds positively to learners’ questions/answers</td>
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<td>F ...........</td>
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</tbody>
</table>
6. Teacher maintains a positive learning environment during activity

7. Teacher helps student to investigate, to construct meaning

8. Teacher ensures students stick to procedure, strategies or process that ensure inquiry

9. Teacher promotes thinking and problem solving skills

10. Teacher enables students access to information crucial to inquiry

**B. Learner-centred orientation**

1. Teacher groups learners for activity

2. Teacher assigns appropriate number of learners to each group

3. Teacher considers the member composition of each group

4. Teacher assigns various group roles to members

5. Teacher gives practical instructions to the groups

6. Teacher allows students 'room to choose' their own approach

7. Teacher observes how learners choose to approach activity

8. Teacher makes sure learners execute activity and use materials or equipment correctly

9. Teacher interacts with students during activities

10. Teacher interacts equally with all groups

11. Teacher assists learners when necessary (but not immediately)

12. Teacher guides learners (via questioning, referral, etc.)

13. Teacher allows learners to draw own conclusions in groups

14. Teacher encourages learners to ask questions

15. Teacher gives answers to learners too quickly

16. Teacher tries to understand learner problems/questions

17. Teacher readily grasps handles learners problems/questions

18. Teacher discusses results/problems with particular group

19. Teacher asking questions to probe reasoning and understanding

20. Teacher looking closely at the evidence from class work

21. Teacher gives positive feedback and does not make comparison of students

**C. Subject Matter**

1. Teacher gives clear, correct and complete information to the groups

2. Teacher relates information to other past/future activities

3. Teacher guides students' learning in order to get to the core of the content

**CONCLUSION OF LESSON**

**A. Basic teaching skills**

1. Conclusions are drawn from activity

2. Teacher summarises the findings of the activity

3. Teacher discusses the methods used: correct and incorrect

4. Teacher asks learners questions and waits for a response

5. Teacher spends time discussing activity afterward

6. Teacher gives specific homework

7. Homework is given before the end of the lesson
8. Teacher ensures students' awareness of assignment
9. Teacher explains homework clearly
10. Teacher explains significance of the activity
11. Teacher provides opportunity for all students to demonstrate their learning presenting findings

B. Learner-centred orientation
1. Teacher asks each group to report their results to the class
2. Teacher asks groups for specific information/results
3. Teacher draws conclusions with the learners from the activity
4. Teacher responds to questions and answers
5. Teacher asks learners to report on their methods
6. Teacher guides learners to understand discrepancies in their results
7. Teacher asks students to explain their results

C. Subject Content
1. Teacher effectively and correctly addresses discrepancies in group results
2. Teacher does not provide theory for observed results
3. Teacher refers back to introductory part of the activity
4. Teacher provides general theoretical conclusions from activity
5. Teacher leads students to theory for the observed results through dialogue

Overall impression

C. Basic teaching skills
1. Teacher listens to learner's answers
2. Teacher responds positively to learner inquiry
3. Teacher uses teaching aids for further clarification
4. Teacher asks 'thought provoking' questions to learners
5. Teachers' expectations of learners' behaviour are clear
6. Teacher is well organised and prepared for activity
7. Teacher uses available time efficiently
8. Teacher appears to understand the objectives of the activity
9. Teacher makes use of classroom aids (e.g. Blackboard etc.)
10. Improvised methods are effective
11. The actualisation of the lesson understandable/ orderly

B. Learner-centred orientation
1. Teacher acknowledges learner's ideas (e.g. questions/answers)
2. Teacher uses/discusses learners ideas
3. Teacher summarises learners' ideas
4. Is the classroom atmosphere conducive to learning?
5. Classroom atmosphere seems to encourage learners to ask/answer questions
6. Are the materials produced by the learners displayed around the classroom?
Subject matter
1. Learners meets overall lesson objectives □ □ I .................
2. Teacher appears confident in lesson content □ □ I .................
3. Teacher notices and responds to incorrect learner answers □ □ F .................
4. Teacher seems to have a firm understanding of subject area □ □ I/A .................

General Observation
Number of students in class ........................................
Number of small groups ...........................................
Average number of members in a group ......................
Summary of the learner’s responses to the Activity:
What is the teachers’ questioning style?
How does the teacher respond to questions?
What is the classroom layout like?
Description of classroom environment.

Note: P= Pre-lab; I= Inquiry-oriented learning; A= Active learning; F= Formative assessment; C= Collaboration.
APPENDIX B4
Teacher reflective interview

Teachers' Interview Questions

1. What are your general observations of the MBL workshops you attended? What are the most important ideas you gained from the workshops experience? Do you have any new skills that improved your abilities to help students learn? Would you describe those skills please?

2. Do you think the school administration influence how you implemented MBL-based lessons in your classroom? What can be done to improve the situation? Have you ever visited one of the teacher resource centres? Do you think they can play a role in improving the situation

3. What do you think of the MBL activity-based lessons and how was the implementation in your classroom? Tell me more about what you mean when you say you were having problems/success with …

4. When you look back about using these new practices in your classroom, what are your greatest concerns?

5. How did you ensure individual accountability when students were working in collaborative groups?

6. What are you doing differently now from what you were doing before the workshops experiences?

Supplementary questions

1. Reflecting on the lessons and how you implemented them in your classroom, what are your views on student learning? With your experience with students, what difficulties do you perceive students had with the lessons? Do you think students like the lesson plan? Why and why not?

2. What do you think about group work? Was it successful in your classroom? Why and why not? Computers were not sufficient what are your views on using group work to solve the problem?

3. In your view did students receive enough support? What attributed to that? Some students thought computers were impersonal; do you think this has connection with your answer?

4. Assume MBL could fully be implemented in the school curriculum what difficulties can you foresee?

5. What difficulties did you experience in introducing MBL in your classroom? -Computers?, Student basic skills? Resources? Time?

6. Recalling how students were doing the activities, what advantages do you think students profited?
**APPENDIX B5**

Alpha reliability and discriminant validity of CCEI questionnaire

Alpha reliability and discriminant validity of the Computer Classroom Environment Inventory
(Maor & Fraser, 1996, p. 407)

<table>
<thead>
<tr>
<th></th>
<th>No. of items</th>
<th>Alpha reliability</th>
<th>Mean correlation with other scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td>6</td>
<td>0.77</td>
<td>0.37</td>
</tr>
<tr>
<td>Open-endedness</td>
<td>6</td>
<td>0.62</td>
<td>0.34</td>
</tr>
<tr>
<td>Organisation</td>
<td>6</td>
<td>0.69</td>
<td>0.47</td>
</tr>
<tr>
<td>Material environment</td>
<td>6</td>
<td>0.74</td>
<td>0.39</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6</td>
<td>0.91</td>
<td>0.45</td>
</tr>
</tbody>
</table>
APPENDIX B6
CCEI questionnaire

Computer Classroom Environment Inventory (CCEI) Student Questionnaire

DIRECTIONS

1. This questionnaire asks you to describe this classroom which you are in right now. There are no right or wrong answers. This is not a test. Your opinion is what is wanted.

2. On the next few pages you find 30 sentences. For each sentence, circle one number corresponding to your answer. For example:

   The work in this class is easy
   Never  |  Seldom  |  Sometimes  |  Often  |  Very often
   1      |   2     |       3    |       4  |      5

   - If you think that the work never is easy, circle the 1.
   - If you think that the work very often is easy, circle the 5.
   - Or you can choose the number 2, 3 or 4 if this seems like a more accurate answer.

3. If you want to change your answer, cross it out and circle a new number.

4. Please provide details in the box below.

   a. Students name: _________________________
   b. School: _________________________
   c. Grade/Level: _________________________
   d. Subject: _________________________
   e. Gender (please circle): Male or Female
   f. Teacher's name: _________________________

5. Now turn the page and please give an answer for every question.

   1. In these computer sessions, I find out the answers to questions by investigation.
      Never  |  Seldom  |  Sometimes  |  Often  |  Very often
      1      |   2     |       3    |       4  |      5

   2. I am able to pursue my own interests in this computer class.
      1      |   2     |       3    |       4  |      5

   3. I find that the computer sessions are well organised.
      1      |   2     |       3    |       4  |      5

   4. I find the computer programs to be user friendly.
      1      |   2     |       3    |       4  |      5
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Never</th>
<th>Seldom</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very often</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>After this class, I feel satisfied.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6.</td>
<td>In this class, I carry out computer investigations to test my ideas.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7.</td>
<td>In this computer class, I’m encouraged to design my own ways, of solving the problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8.</td>
<td>At the beginning of the computer sessions, I begin work without delay.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9.</td>
<td>The computers are in good working conditions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10.</td>
<td>In this class learning to use the computer is not enjoyable.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11.</td>
<td>I use the computer investigations to answer questions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12.</td>
<td>I am not allowed to make up any of my own projects in this class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13.</td>
<td>I am confused about what to do during these computer sessions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14.</td>
<td>The computers are not suitable for running the programs I use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15.</td>
<td>I am not happy what is done in this computer class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16.</td>
<td>I am asked to think about the data that supports my conclusions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17.</td>
<td>There is opportunity for me to collect different data and use different approaches for the same problem in this class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18.</td>
<td>There are times when I have to wait for the teacher to help me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19.</td>
<td>There are not enough computers for me to use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20.</td>
<td>The work with computers is boring in this class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21.</td>
<td>I carry out computer investigations to answer questions coming from new information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22.</td>
<td>In this class, I can go beyond the regular instruction and do some problems on my own.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23.</td>
<td>My work in this computer class is interrupted by students who have nothing to do.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>24.</td>
<td>The computer programs enable me to make effective use of the computer.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>25.</td>
<td>The work with computers in this class is enjoyable.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>26.</td>
<td>In this class, there is opportunity for me to carry out computer investigations to answer questions that puzzle me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>27.</td>
<td>In this class, the teacher decides the best way for me to proceed with my work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>28.</td>
<td>The activities in this computer session are carefully planned.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>29.</td>
<td>The computer programs run for me without problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>30.</td>
<td>The computer classes are a waste of time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
APPENDIX B7
MBL student attitude questionnaire

Microcomputer-Based Laboratory (MBL) Activity Survey for Students

Purpose of the Questionnaire
Dear student, we would like to know what do you think about the MBL activities which took place in your class recently. There are no right or wrong answers. Your opinion is what is wanted. Your answers will enable us to improve future science teaching.

Personal Information
Please provide information in the space below. Please be assured that your answers to this questionnaire will be treated confidentially.

<table>
<thead>
<tr>
<th>Name:</th>
<th>School:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form:</td>
<td>Sex: Male/Female</td>
</tr>
</tbody>
</table>

How to Answer
For each of the following questions please tick the rectangular box that best describes how you feel about a particular statement.

SD= Strongly Disagree, D= Disagree, N= Not sure, A= Agree, SA= Strongly Agree

<table>
<thead>
<tr>
<th>Did you feel that the MBL activities:</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>S</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Were linked into other parts of the course</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped you understand more about the topic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped you prepare for other parts of the course</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained some concepts that you had found difficulty with</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Made you feel like learning more about the subject</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scale: 1= very helpful, 2= helpful, 3= moderately helpful, 4= of little help, 5= not at all helpful?

<table>
<thead>
<tr>
<th>How useful have you found the following activities in helping you tackle the given problems</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher giving individual help</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doing predictions before the activity begins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To use MBL to collect data during experimentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To use MBL to analyse experimental data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To discus problems with partner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To discus problems with the whole class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To do the end of activity exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To consult the textbook</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher giving room for personal initiative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher not explaining everything in the activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Please list two things that you liked in the MBL-based lessons.

Please list two things that you disliked in the MBL-based lessons.

Beside the computer, how were these lessons different from your regular classes?

Please write any other comment or suggestions you may have about the whole experience.
APPENDIX B8

Student interview schedule

Student Interview Scheme

1. Of the activities you did last two weeks, which were your favourites and why?
2. How have the lessons you did last two weeks been different from your normal classes, if at all?
3. The practical lessons were structured differently compared to traditional practical lessons. Did you notice any advantage or disadvantage?
4. Do you think the whole class understood these lessons, or do you think that there was some confusion and if so where?
5. If you could have more of anything in your physics classes, what would that be?
6. If you could have less of anything in your physics classes, what would that be?
7. Can you think of anything new that you learned from these physics lessons?
8. Do you feel comfortable asking your teachers for extra help? Why, why not?
9. Do you have any comments; suggestions or other things you would like to say which you think might be useful?
APPENDIX C1
Photographs of measurements analysis and graphs from a student lab report

The following pictures are photocopies of measurements, analysis and graphs from a student lab report.

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>Oscillations</th>
<th>Time (s)</th>
<th>Predicted Period (s)</th>
<th>T^2 (s^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>20</td>
<td>18.13</td>
<td>0.92</td>
<td>0.82</td>
</tr>
<tr>
<td>110</td>
<td>20</td>
<td>18.97</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>130</td>
<td>20</td>
<td>19.97</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>150</td>
<td>20</td>
<td>20.09</td>
<td>1.00</td>
<td>1.01</td>
</tr>
<tr>
<td>170</td>
<td>20</td>
<td>21.07</td>
<td>1.05</td>
<td>1.11</td>
</tr>
<tr>
<td>190</td>
<td>20</td>
<td>22.04</td>
<td>1.14</td>
<td>1.35</td>
</tr>
</tbody>
</table>

Essential Measurements in a harmonic oscillation experiment

\[ T = 2\pi \sqrt{\frac{Mg}{k}} \]

\[ T^2 = \frac{4\pi^2 (Mg)}{k} \]

\[ M^2 = \frac{4\pi^2 M + 4\pi^2 g}{k} \]

\[ T^2 = \left(\frac{4\pi^2}{N}\right) M + \left(\frac{4\pi^2 g}{N}\right) \]

from our graph

\[ y = mx + c \]

\[ T^2 = (Mg)\bar{M} + c\left(\frac{4\pi^2 g}{N}\right) \]

\[ \frac{4\pi^2 g}{N} = \text{Slope} \]

Some algebraic and arithmetic students made to justify their conclusion.
The graph of data tabulated above
APPENDIX C2
Examples of homework and solutions

Examples of homework and some solutions

1. This data consists of the mass and distance measurements for the mass on a spring that you studied in your Harmonic Oscillations activity [Data omitted]. Calculate the applied force in Newtons and the distance in meters and copy the results to the program Graphical Analysis.
   a. Using Graphical Analysis and statistical analysis functions plot the regression line through the data. Find the slope and intercept of the line of best fit, together with their associated uncertainties.
      Compare the values you obtain from Graphical Analysis with those you calculated in the Harmonic Oscillation activity. Include both sets of values and discuss any discrepancy between them.
   b. From the value of the intercept and the slope obtained from Graphical Analysis, calculate the equilibrium displacement of the spring and the value of the spring constant used in the experiment, together with their associated uncertainties.
   c. From your analysis of the data calculate the distance of the spring from the top of the bench if a load of 6 N was applied to the end of the spring. What is the uncertainty in your calculated value of the distance?
      Include a printout of your graph showing the data, the best-fit line and the regression parameters in your solution.

2. The time for a single oscillation of a simple pendulum was measured 10 times. The results, in seconds, are given in the table:
   1.73 1.75 1.71 1.75 1.74 1.76 1.74 1.72 1.73 1.74
   a. Calculate the period of the pendulum and its uncertainty, which we will take as the standard deviation.
   b. Calculate the frequency and its uncertainty.
   c. Given that the length of the pendulum is 0.835 ± 0.005 m, calculate g and its uncertainty from these measurements.

A solution of problem number 2
a) \[ T = \frac{24}{10} \cdot T_1 = 1.2 \text{ s} \]
\[ \nu_f = \sqrt{\frac{12}{3} \left(\frac{T_1 - T}{T}ight)^2} = 0.014 \text{ s} \]
\[ T + \nu_f = 1.24 \pm 0.02 \text{ s} \]

b) \[ V_f = \frac{1}{T} = 0.525 \text{ m/s} \]
\[ \frac{V_f}{T} = \nu_f \rightarrow \frac{V_f}{T} = \nu_f = (0.5257) \frac{0.0145}{1.25} \]
\[ \nu_f = 0.004 \text{ m/s} \]
\[ \frac{V_f}{T} = 0.006 \text{ m/s} \]
\[ \frac{V_f}{T} = 0.525 \pm 0.005 \text{ m/s} \]

c) \[ L = 0.825 \pm 0.005 \text{ m} \]
\[ T = 2 \pi \sqrt{\frac{L}{g}} \rightarrow g = \frac{4 \pi^2 L}{T^2} = \frac{4 \pi^2 (0.825)}{(0.338)^2} = 10.5 \text{ m/s}^2 \]
\[ \nu_f = \frac{V_f}{T} \rightarrow \nu_f = \frac{\nu_T}{\frac{T}{L}} = \frac{0.0145}{1.25} \frac{0.525}{1.25} \]
\[ V_f = (10.526) \sqrt{(0.0145)^2 + (0.004)^2} \approx 0.135 \text{ m/s}^2 \]
\[ \nu_f = (10.526) \sqrt{(0.0145)^2 + (0.004)^2} = 0.135 \text{ m/s}^2 \]
\[ g = 10.5 \pm 0.2 \text{ m/s}^2 \]