OPTIMISING THE USE OF TRAC PACs IN SCIENCE EDUCATION IN SOUTH AFRICAN SCHOOLS

Trevor Bernard Daniels

BSc, BEd, HDE

Thesis submitted in fulfilment of the requirements for the degree Master of Education at Stellenbosch University.

Supervisor: Dr. A.S. Jordaan

Stellenbosch

November 2006

DECLARATION

I, the undersigned, hereby declare that this thesis is my own original work. I have not submitted it previously for any other degree or examination in any other university.

____________________________ ______________________

Trevor Bernard Daniels Date

ABSTRACT

The TRAC PAC is a micro computer-based laboratory that allows learners to collect real-time data about a particular event and then displays the information graphically. It was brought to South Africa from the United States of America in an attempt to increase the low number of learners from previously disadvantaged communities entering the Science, Engineering and Technology fields.

Anecdotal evidence has shown that the TRAC PAC has not been optimally utilised in classrooms. Subsequently a TRAC laboratory was established at Stellenbosch University and hence this study, which focused on identifying factors that would contribute towards the optimal use of the TRAC PAC.

A qualitative case study research method was used, which relied on different techniques to gather data on how the TRAC PAC is used in classrooms and at the TRAC laboratory. The analysis of this data was largely an intuitive process; it relied on the development of categories which provided insights on the advantages and disadvantages of using the TRAC PAC. The thesis concludes with a number of recommendations that can lead to the optimal use of the TRAC PAC.

One of the findings of this study was that even grade 12 Physical Science learners lacked certain basic skills such as the ability to take accurate measurements. Addressing this lack amongst South African learners is also a priority of the National Education Department, following its adoption of an outcomes-based education approach. The design of a detailed, well structured series of activities that addresses the required educational outcomes should result in the optimal use of the TRAC PAC.

OPSOMMING

Die TRAC PAC is 'n mikro-rekenaargebaseerde laboratorium wat leerders in staat stel om werklike data oor 'n bepaalde gebeurtenis intyds in te samel en die inligting daarvan grafies voor te stel. Dit is vanaf die Verenigde State van Amerika (VSA) na Suid Afrika gebring in 'n poging om die aantal leerders uit voorheen benadeelde gemeenskappe wat Wetenskap, Ingenieurswese en Tegnologie bestudeer, te verhoog.

Informele gesprekke het getoon dat die TRAC PAC nie optimaal in klaskamers benut is nie. Gevolglik is 'n TRAC laboratorium by die Universiteit Stellenbosch gevestig en dit het tot hierdie studie aanleiding gegee wat daarop gerig was om faktore te identifiseer wat kon bydra tot die optimale benutting van die TRAC PAC.

'n Kwalitatiewe gevallestudie is as navorsingsmetode gebruik. Daar is gesteun op verskillende tegnieke om data te versamel oor die wyse waarop die TRAC PAC in die klaskamer en by die TRAC laboratorium gebruik word. Die ontleding van hierdie data was grotendeels 'n intuïtiewe proses wat gegrond was op die ontwikkeling van kategorieë. Hierdie kategorieë het insig verskaf in die voordele en nadele verbonde aan die gebruik van die TRAC PAC. Aanbevelings wat hieruit voortkom, kan myns insiens lei tot die optimale benutting van die TRAC PAC.

Een van die bevindings van die studie was dat selfs graad 12 Natuur en Skeikunde leerders 'n gebrek het aan sekere basiese vaardighede soos die vermoë om akkurate afmetings te doen. Dit is ook die prioriteit van die Nasionale Onderwysdepartement om hierdie vaardighede by Suid-Afrikaanse leerders te ontwikkel - vandaar die verandering na uitkomsgebaseerde onderrig. Gevolglik glo ek dat TRAC PAC optimaal benut sal word mits TRAC SA 'n gedetailleerde, goed gestruktureerde reeks aktiwiteite ontwikkel wat die uitkomstes aanspreek soos deur die Nasionale Onderwysdepartement vereis.

DEDICATION

This study is dedicated to:

Julian - *My son*

and

Joan - *My wife*

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to:

My supervisor, Dr. A.S. Jordaan for the ongoing assistance and wisdom provided throughout this study.

Dr. W.R. Duff-Riddell for critical comments provided in his role as co-supervisor of this study.

Christa Philander (nèe Davids) for assistance provided in the collection of data.

TRAC SA for providing the resources required to complete this study.

The National Research Foundation, which funded the research.

All teachers and learners who participated in the study.

The Western Cape Education Department for granting permission to conduct this research at schools.

Peter Mullineux for proof-reading this thesis.

My family and friends for their support and patience.

My mother and father for their unwavering love and support.

PRAISE THE LORD

ABBREVIATIONS

C2005	Curriculum 2005
CASS	Continuous Assessment
CO	Critical Outcome
DO	Developmental Outcome
DOE	Department of Education
EMDC	Educational Management and Developmental Centre
FET	Further Education and Training
GET	General Education and Training
ICT	Information and Communication Technology
ITT	Institute for Transport Technology
MBL	Microcomputer Based Laboratory
NCS	National Curriculum Statement
NQF	National Qualifications Framework
OBE	Outcome Based Education
RNCS	Revised National Curriculum Statement
SAILI	Scientific and Industrial Leadership Initiative
SAQA	South African Qualifications Authority

SET	Science, Engineering and Technology
TRAC PAC	Transport Research Activity Centre
TRAC SA	Transportation and Civil Engineering of South Africa
UCT	University of Cape Town
US	University of Stellenbosch
UWC	University of the Western Cape
WCED	Western Cape Education Department

CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

LIST OF PICTURES

CHAPTER 1

THE PURPOSE OF THIS STUDY

1.1 INTRODUCTION

In 1994, Transportation and Civil Engineering of South Africa (TRAC SA) introduced the transport research activities centre (TRAC PAC) into South African schools[1]. At this stage, South Africa had just completed its first democratic elections and changes were inevitable. One of these changes involved a change in the education system through the implementation of curriculum 2005 (C2005) in 1998 in grade one. The adapted version of C2005, now called the National Curriculum Statement (NCS), will be implemented in grade 10 in 2006.

The TRAC PAC is an educational microcomputer-based laboratory (MBL) aimed at assisting teachers and learners with mathematics and physical science. Anecdotal evidence claims that the introduction of the TRAC PAC into South African schools has not had the desired effect.

This research intends identifying the strengths and weaknesses of the TRAC PAC in a South African context, and recommending what could ensure its optimal use.

1.2 DEFINITION OF THE TERM 'OPTIMAL'

The Encarta Concise English Dictionary (2001:1021) defines optimal as "*most desirable or favourable*" and The Concise Oxford Dictionary (1982: 716) defines optimal as "*best or most favourable*".

For the purpose of this research ‘optimal’ should be interpreted as meaning "*those actions that will benefit teaching and learning in the most favourable manner*".

1.3 MOTIVATION FOR THIS STUDY

Professor F. Hugo, the Director of the Institute for Transport Technology (ITT) at Stellenbosch University, introduced the TRAC PAC into South Africa in 1994. He was instrumental in getting the first TRAC regional centre opened outside of the United States of America (USA).

As a member of the education committee of the Transportation Research Board (a division of the National Science Foundation in the USA), he attended a presentation by one of the members on TRAC in the early 1990s.

> "It immediately prompted my mind and what I really do as part of my lifestyle up there is to continually explore and see what I can actually capture and bring across and build into this nation. It prompted me to say that this is something that we should get involved in" (Interview with Hugo, 15 June1999).

In 1994, TRAC USA allowed TRAC SA to be "… the first country outside the USA to participate in the TRAC programme" (TRAC Annual Report, 1997:2). Initially

[1] Refer to interview conducted with Prof. Hugo to verify date when TRAC was introduced into South

TRAC SA started off with one TRAC PAC which eventually grew to one hundred and five sponsored TRAC PACs in 1998 (TRAC Annual Report, 1998:3). Of these one hundred and five TRAC PACs, seventy-nine were operational in South Africa. Of these seventy-nine TRAC PACs, fifty-four were placed at secondary schools and twenty-five at tertiary institutions (TRAC Annual Report, 1999:7). The TRAC PAC was then loaned to one particular school for three years, after they had supplied a written motivation. Thereafter, the TRAC PAC was donated to the school, as they had satisfied the requirements of TRAC SA (TRAC Annual Report, 1997:4).

Schools from previously disadvantaged communities were given preference over other schools when deciding which schools were to receive TRAC PACs. As stated in the aims and objectives of TRAC SA, they wanted "... to increase the number of qualified pupils, particularly among historically disadvantaged communities, applying to study in SET fields..." (TRAC Annual Report, 1997:5).

The TRAC PACs were imported directly from the USA and placed in South African schools, accompanied by forty-two structured experiments designed for the USA schooling system, which differed significantly from the South African schooling system. TRAC SA then consulted teachers who were in possession of the TRAC PAC. Feedback received from thirty-eight teachers, indicated the following strengths of the TRAC programme (TRAC Annual Report, 1997:21-22):

- "...the greatest strength of the pack (sic) lies in its ability to plot real time graphs using sensor equipment".
- "Many teachers also indicated that the pack (sic) stimulated pupils’ interest in science".
- Using the TRAC PACs resulted in "An increase in pupil computer literacy..."
- "...the programme’s suitability to Outcomes Based Education (sic)" was seen as a strength because of the education department's shift towards outcomes-based education.

The teachers identified the following weaknesses of the TRAC programme:

Africa. Appendix O.

- Only one TRAC PAC per school "... limited their pupils' access to the programme during class time".

- Teachers indicated that it was difficult to use the TRAC PAC effectively in their classrooms due to the time needed to complete activities while using the TRAC PAC. The time awarded at their schools for the subject Physical Science was usually less than the amount of time they required to use the TRAC PAC effectively.

- Teachers were using the materials designed for the USA education system. These activities did not reflect the needs of the SA education system. This meant that teachers had to develop syllabus-related activities on their own. Teachers argued that they did not have the time for this, and wanted TRAC SA to develop syllabus relevant activities.

> "Due to rationalisation in education, the teacher-pupil ratio has been increased. Teachers do not have the time to give individual attention to pupils and enrichment activities are secondary to the need to work through the basic syllabus. To become an important part of normal classroom activities, the TRAC PAC must provide more syllabus relevant activities" (TRAC Annual Report, 1999:10).

- Schools also indicated that they experienced "... technical problems with their computer hardware".

- Teachers had difficulty using the TRAC programme because it used the MS-DOS version. As a result, teachers stated "...the pack (sic) was user unfriendly". This aspect was addressed by TRAC SA. The upgrades from MS-DOS to Windows 3.1 to Windows 95 and Windows 2000 were implemented successfully. The TRAC PAC is now user friendly.

- The secure storage of TRAC PACs placed at schools situated in previously disadvantaged communities could not be guaranteed due to the high rate of theft in the areas. Therefore, most schools had to make the necessary arrangements to ensure that the TRAC PACs were very securely stored in

> rooms "... with alarms and burglar bars". This became a problem for many teachers because it meant that they had to carry the TRAC PAC from the secured room "...to the science lab and then having to set the pac (sic) up makes its regular inclusion in class activities tedious and impractical for teachers".

The teachers recommended that "... centres consisting of a concentration of packs (sic) and full-time TRAC instructors..." should be set up to address the weaknesses mentioned above.

As a result, a pilot TRAC laboratory was established at the University of Stellenbosch, and new material relevant to the South African syllabus was developed to be used with the TRAC PAC (TRAC Annual Report, 1997:2 and 12; 1999:11). A TRAC research team was set up of which I was a member. The research team then developed draft versions of eight new TRAC activities (TRAC Annual Report, 1999:10).

1.4 RESEARCH QUESTIONS

The purpose of conducting this research is to provide answers to the following two questions:

- What were the practical realities experienced by teachers and learners when using the TRAC PACs at schools and at the TRAC laboratory?

- What were the learners' experiences while participating in activities using a TRAC PAC, and how well did they perform in class after these experiences?

The outcome of this research is to provide recommendations that will ensure that the TRAC PAC is utilised optimally.

1.5 DEMARCATIONS OF THIS RESEARCH PROJECT

This research project took place within the following boundaries:

- Only high schools from previously disadvantaged communities participated.
- Only high schools from the Western Cape participated.
- Eight high schools visited the TRAC laboratory.
- The classrooms of only two high schools were visited.
- The research only focused on Physical Science and not on Mathematics.
- The data collected was based on only one interaction between the TRAC PAC and the learners or teachers from each of the schools.

This research does not intend to do the following:

- Provide activities that will guarantee the optimal use of the TRAC PAC.
- Provide assessment instruments as required by the education department.
- Verify the recommendations offered.

1.6 RESEARCH DESIGN

Finding answers to the research questions involved both a practical study and a literature review. The literature review helped me to gain fresh insights into problems and possible solutions experienced by other researchers in the field, and to establish to what extent similar studies had been conducted. Specialist researchers in the field of MBLs such as Thornton and Sokoloff (1997:340-347 and 1998:338-352) have documented that learners' understanding of science concepts improves when using

MBLs. This conclusion was based upon the "… analysis of pre and post-test data…"(Thornton and Sokoloff, 1996:16).

It was not the intention of this research to determine whether learners' understanding of science concepts improved or not. Rather, it was my intention to determine the factors that would most likely contribute towards the optimal use of the TRAC PAC within the South African educational context. I hypothesized that once these factors were identified and implemented they would ensure that the TRAC PAC was utilized optimally within our schools to benefit learners studying Physical Science. To determine these factors, I had to identify a particular research method that would provide answers to my research questions. This implied that I had to collect data on how the TRAC PAC was being used in the classroom and in the TRAC laboratory. Pre and post-test data was therefore not going to provide me with the necessary answers.

A qualitative case study[2] was the research method that I used to collect and analyse the data. In this instance, the 'case' was the interaction of learners (and teachers to a lesser degree) with the TRAC PAC in different environments, i.e. the TRAC laboratory and their own classroom. The following data collection techniques[3] were used:

- Observation. Both observer and observer-as-participant techniques were used.

- Interviews. A combination of semi-structured and unstructured interviews was used.

- Questionnaires. These were designed for the teachers and learners, consisting mainly of "…selection-type …and supply-type items" (Fraenkel and Wallen, 1993:113).

- Worksheets. These were designed by the research team and were related to the 1996 syllabus of the Western Cape Education Department and hence the National Education Department.

[2] Refer to section 3.2.2 for a more detailed discussion on qualitative case studies.
[3] Refer to section 3.3 for a more detailed discussion on data collection techniques.

- Paper-and-pencil tests. These were designed by the researcher to determine whether learners were able to transfer skills and knowledge gained after using the TRAC PAC.

This data was then analysed through the identification of categories[4], which was largely an intuitive process. The categories then provided me with insight into the practical realities experienced by teachers and learners, as well as learners' experiences and performance when using the TRAC PAC either at their own school or at the TRAC laboratory. These insights enabled me to provide TRAC SA with recommendations for the optimal use of the TRAC PAC.

1.7 OVERVIEW

The literature review in Chapter Two provides the reader with background information on the status of science education in South Africa. This is highly relevant, given that the TRAC PAC, an American innovation, was brought into South African schools. The development of the TRAC PAC was based on the requirements of the American educational system and not those of the South African educational system. Therefore, it was important to determine whether TRAC PAC would address the needs of the learners in the South African educational system.

Computers found their way into science classrooms due to pressure from society and not because of educational demands[5]. Now that they were present in our schools, I reviewed some of the reasons why the computer had not had the desired educational effects in Western countries. I also analysed the problems experienced by schools in the Western Cape of South Africa, which have started to use computers in their schools.

---

[4] Refer to section 6.2 for a more detailed discussion on the analysis of data.
[5] Refer to section 2.4.1.

The TRAC PAC included a computer and software with wider applications than just data collection. Therefore, I explored the different uses of computers in science education to give the reader an understanding of other possibilities for the optimal use of the TRAC PAC. I focussed on the following common computer applications i.e. spreadsheets, Internet, word processor and MBLs. It was not my intention to highlight all possible applications, but merely to stimulate the reader's interest.

Chapter Three describes the research methodology, techniques, setting and sample used. The qualitative case study research method is defined and it provides the theoretical framework for this study. A characteristic of this research is that it only involved Physical Science learners and teachers from high schools situated in previously disadvantaged communities. This was done to align the research with the aims and objectives of TRAC SA as stated in their annual report (1997:5 and 17). Therefore, this research was conducted at two high schools that had their own TRAC PAC, and at the TRAC laboratory, where eight different high schools participated in the study. In total, 217 learners participated in this research.

Chapter Four describes the data collected at the TRAC laboratory. One hundred and four grade eleven learners completed an activity called reference points and directions[6] and sixty-nine grade twelve learners completed three different activities[7], two of which dealt with Newton's second law of motion and the third with free fall.

Chapter Five describes the data collected at the two participating high schools. Forty-four grade eleven learners completed the activity on reference points and directions.

Chapter Six provides an analysis of the collected data. This analysis was based on the identification of categories. These categories allowed me to identify certain clusters of answers that were repeated either within the same data collection technique or across different data collection techniques. These categories were then grouped into advantages, disadvantages and factors that hampered the optimal use of the TRAC PAC. The latter provided answers to my two research questions. The chapter concludes with a list of recommendations for the optimal use of the TRAC PAC.

[6] Refer to appendix D
[7] Refer to appendices E, F and G.

CHAPTER 2

LITERATURE REVIEW AND ITS IMPLICATIONS FOR THIS STUDY

The aims of this literature review were two-fold. Firstly, I wanted to ascertain what research had already been completed. The completed research would inform me of the potential problems that I might encounter as well as possible answers to my research questions. Secondly, I wanted to provide the reader with the broad context within which this study was undertaken.

The dawn of the 21st century marked a new phase in the South African education system. The implementation of the National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training (hereafter referred to as the National Strategy), Curriculum 2005 (C2005), Outcomes-Based Education (OBE) and the Revised National Curriculum Statement (RNCS) all indicated the energy and vitality with which the government aimed to prepare children for the future.

Changing an education system was, however, not sufficient to effect the implementation of the needed changes. In this chapter I explore, *inter alia*, the nature of these changes, the reasons why they were necessary and how they impacted on TRAC SA.

2.1 SCIENCE EDUCATION IN CRISIS IN SOUTH AFRICA

Many people will have different opinions about the state of science education in South Africa. I agree with Steyn and Wilkinson (1998:203) who state that, in the past, the South African education system "… experienced a crisis" and with Vieyra (1993:10) who is of the opinion that "... science education in South Africa is in a sorry state". The reasons for this view will follow.

Van der Linde, van der Wal and Wilkinson (1994:48) believe that our education system is not preparing enough learners for science related professions. There are simply not enough learners passing the subject at the end of grade twelve. Michael Khan, a former professor of Science, Mathematics and Technology Education at the University of Cape Town (UCT) and an advisor to former Minister of Education, Kader Asmal, also shares this view. In an article that appeared in the *Cape Argus* (6 May 1999) he wrote that the ratio of passes of black: white higher grade learners is 1:50. This was confirmed in an analysis of the year 2000 Senior Certificate results which indicated that 20 243 African learners wrote Mathematics on the higher grade, out of a total of 489 900 learners that wrote the matriculation examinations. Yet only 3 128 of these African learners passed the examination (DOE, 2001 A:12). The following table, adapted from the Department of Education (DOE) National Strategy document (2001:8), reflects the low numbers of learners in South Africa completing Mathematics and Physical Science on the higher grade in grade twelve.

	Mathematics HG				**Physical Science HG**			
	1997	1998	1999	2000	1997	1998	1999	2000
Total no. of learners that wrote grade 12	559000	552000	511000	489900	559000	552000	511000	489900
No. of learners that wrote the subject	68500	60300	50100	38500	76100	73300	66500	55700
No. of learners that passed the subject	22800	20300	19900	19300	27000	26700	24200	23300
Percentage of learners who passed the subject	33,3 %	33,7 %	39,7 %	50,1 %	35,5 %	36,4 %	36,4 %	41,8 %
Percentage of total learners that passed the subject	4,1 %	3,7 %	3,9 %	3,9 %	4,8 %	4,8 %	4,7 %	4,7 %

Table 1: The national pass percentage in Physical Science and Mathematics higher grade from 1997 – 2000 (Adapted from the Department of Education: National Strategy, 2001:8).

From this table one can see that the percentage of learners who passed Mathematics higher grade increased from 33,3 percent to 50,1 percent, and the percentage of learners who passed Physical Science higher grade increased from 35,5 percent to 41,8 percent over the four year period from 1997 to 2000. One can also see that, on average, only 4 percent of all grade twelve learners passed Mathematics on the higher grade and only 5 percent of all grade twelve learners passed Physical Science on the higher grade from 1997 to 2000.

When the South African learners participated in the Third International Mathematics and Science Study (TIMMS), the results clearly indicated that "South Africa obtained a significantly lower average score (352 points) than the other participating countries for which the international average score was 500 on a scale of 800 points" (Howie & Hughes, 1998:47). A similar result was also obtained when South African learners participated in the Scientific and Technological Literacy Survey conducted by the Foundation for Research and Development. The results of this survey indicated that

South African learners fared just as dismally (Ogunniyi, 1999:2). It is therefore evident that our learners are not able to compete with other learners on a global scale.

Another problem facing science education in South Africa is that many grade nine learners are not choosing Physical Science as a subject when they proceed to grade ten. A reason for this is that learners regard it as "difficult" (Mehl, 1991:13 and van der Linde *et al*. 1994:49). Rollnick (in Naidoo & Savage, 1998:86) also supports the view that learners fear and avoid science as a subject at school. Mehl goes further by stating that learners regard the subject as difficult because they lack the necessary cognitive skills required to understand and supply the scientific principles correctly. "It is clearly not an automatic part of their cognitive repertoire. This is hardly surprising given the tradition of rote learning to which they have been exposed". A study conducted by Ogunniyi from 1996 to 1998, in which six thousand grade seven, eight and nine learners from sixty primary and forty secondary schools in the Western Cape participated, found that there is a low level of interest shown amongst learners towards science and technology and concluded that it should therefore not be surprising that learners perform poorly in science related topics (Ogunniyi, 1999:253). This argument is not only confined to South African learners but is also evident in first world countries. Sillitto and MacKinnon (2000:326) and Thornton (in Chaisson and Kim, 1999:164) have documented that learners in their studies also regard science to be "…difficult, boring and overly concerned with detail".

Compounding the crisis in science education is the fact that South Africa is currently experiencing a drastic shortage of qualified Mathematics and Science teachers (DOE, 2001 A:19). Bisseker, in the *Financial Mail*, and Weiss in the *Cape Argus*, reported that at the end of the 1999 academic year, the three universities in the Western Cape (The University of Cape Town, the University of the Western Cape and Stellenbosch University) would, between them, only produce five students qualified to teach Physical Science up to grade twelve.

The qualifications of mathematics and science teachers are also cause for concern. In 1997, Edusource published a report that found that only 50 percent of teachers teaching mathematics at schools specialised in mathematics for their qualification, while only 42 percent of teachers were qualified to teach science (DOE, 2001 A:12). The Dinaledi Project, was an initiative launched by the DOE "... to raise participation and performance of historically disadvantaged learners in senior Certificate (sic) mathematics and physical science" in one hundred and two schools across the country (DOE, n.d. A: 8). In a document published by the DOE on the Dinaledi project, it was reported that 58,3 percent of Physical Science teachers and 64,6 percent of Mathematics teachers in these schools only had grade twelve as an academic qualification (DOE, n.d. B: 6 and 9).

Rollnick (in Naidoo and Savage, 1998:85) is of the opinion that public examinations dictate to teachers what should be taught in the classroom. The examinations are mainly content-driven and as a result drill-and-practice teaching methods dominate in the classrooms. Vieyra (1993:1) quotes the following from the National Education Policy Investigation (NEPI): "Although memory retention is an important learning skill, it is overemphasised in the current curriculum, while critical thinking, reasoning, reflection, and other conceptual skills are largely neglected". Steyn and Wilkinson support the view that the crisis in education in South Africa is characterised by a vociferous examination system with a major emphasis on rote learning and unimaginative teaching methods, among other reasons (1998:203).

Science teachers have reported the lack of resources and their inability to present the subject practically as reasons for problems in science education (van der Linde *et al*. 1994:49). Of the one hundred and two Dinaledi schools, it is reported that 52,5 percent do not have Physical Science laboratories (DOE, n.d. B: 16). Naik (in Lynch 1994:12) confirms that apparatus in the science laboratory in many black schools varies from very little to an adequate supply. Apparatus may never be unpacked, or it may be locked away for fear of vandalism. Whilst obviously a very real problem, lack of resources is generally only a convenient excuse as many well resourced schools do no practical work either (Naik in Lynch, 1994:6).

Ogunniyi (in van der Linde *et al*. 1994:49) contends that it is a combination of factors and not one factor alone that contributes to the poor state of science education in South Africa. "Despite various curriculum innovations, progress has been hampered by poor teacher preparation, a rapid rate of teacher transfer, a shortage of qualified science teachers, the use of archaic teaching methods and a lack of a reinforcing home and cultural background".

The reasons given above are not meant to be exhaustive but merely to provide an insight into the difficulties being experienced in science education in South Africa at present. I am convinced that the low numbers of learners passing mathematics and science on the higher grade, the poor performance of our learners in international tests, learners' perceptions of science as being a difficult subject, the low numbers of qualified science teachers, the overemphasis on passing the examinations and the availability and use of resources are just some of the reasons why science education in South Africa is in crisis.

One may pose the question, "Why all the fuss about science and mathematics"? According to Michael Khan "… science and mathematics education is the base upon which technology development rests. Without this base, countries lack skills needed for local advancement of technologies and remain perpetually dependant on outsiders" (*Sunday Times*, 2000:19). When the President of South Africa, Thabo Mbeki, asked former Minister of Education, Professor Kader Asmal, if the country was ready for the 21st century, the Minister stated that the number of learners entering further and higher education institutes to complete their studies on information and science-based professions was dwindling. He believed that this had serious implications for our national future in the 21st century (DOE, 2000 A:13).

During an interview[8] with Professor Hugo, the director of TRAC SA, I asked him to describe the general status of our science and mathematics education. His response: "…I am really disturbed and appalled at some of the things I have been hearing, seeing and experiencing..." informs me that the director of TRAC SA is also concerned about the current state of science and mathematics education in South Africa. Professor Hugo brought the TRAC PAC to South Africa because he "…thought this was one of the ways of bridging gaps…" in science and mathematics education.

In an attempt to provide answers and possible solutions to the many challenges facing science education in South Africa, changes to the educational system were brought about at a time when TRAC SA introduced the TRAC PAC into classrooms in South African schools.

I believed that TRAC SA should be made aware of the challenges which science education in South Africa was experiencing. For the TRAC PAC to be utilised optimally, it needed to contribute positively to these challenges. This could be achieved if the TRAC PAC was used to:

- assist learners to attain better results in the matriculation examination. It could possibly do this by encouraging matriculants to attend revision courses on concepts which proved difficult to teach at school but which were easy to teach with the TRAC PAC. This should greatly assist learners with their preparations for the matriculation examination and could lead to an improvement in the results of those learners.

- provide learners with the opportunities to acquire the necessary knowledge and skills to compete confidently against other learners on an international stage. This could be done by making the TRAC laboratory available to those learners who wished to complete a science investigation and participate in the annual Eskom Science Expo.

- make science relevant and exciting for learners which would motivate them to study the subject beyond grade nine. Besides providing learners with possible career options, the TRAC PAC together with the different computer applications such as the Internet could show learners how science was relevant to their everyday lives.

- provide science teachers with opportunities to improve their subject knowledge and teaching methodologies skills. The TRAC laboratory is an ideal venue to offer teachers 'refresher' courses in certain subject content areas. The implementation of the new curriculum in grades 10 to 12 from 2006 expects Physical Science teachers

[8] Refer to appendix O for the complete interview

to teach 'new content'. The TRAC PAC could provide teachers with an ideal opportunity to engage with the 'new content' in a non-threatening environment.

2.2 THE NEED FOR CHANGE

The difficulties which science education in South Africa is currently experiencing make change imperative. I will briefly set out my interpretation of the reasons for the changes introduced by the South African educational system. I regard the emergence of the Information Age, the importance of mathematics and science and the effects of culture on the curriculum as core issues that led to these changes. While a host of other issues could also have been named as reasons for the changes, this study is limited to these three issues, which are described and discussed more fully below.

2.2.1 The Information Age

Hawkridge, Jaworski and McMahon (1990:4), Herselman and Britton (2002:270-274), Howie and Hughes (1998:13), Lippert (1989:K1), Makhurane and Khan (in Naidoo & Savage, 1998:25-26), all acknowledge that the global economy is experiencing many challenges because of the emergence of the Information Age. This is best summarised by Hawkridge *et al*. (1990:4) who state that:

> "Information has always been a source of power and control, but never more so than in the modern world. It is used by individuals and governments to gain political and economic advantage. Industrial countries are seeking, through information technology based on computers and electronic

communications, to exert greater control over their competitors and over developing countries. To protect their own interests, all countries are obliged to respond, to a greater or lesser extent, by stepping up their capacity to access and process information".

It is evident from the above that the distribution of and access to information and communication technology (ICT) is unequal in society. Some people have access to ICT while others do not. The difference between these two groups of people is referred to as the 'digital divide' by Herselman and Britton (2002:271), who explain how this will impact on society. They argue that countries whose citizens do not have access to ICT will be at an increasing disadvantage when participating in an information-based global economy. This could result in a developing economy losing the opportunity to grow and risking an increase in social and economic anarchy. Those economies whose citizens have access to and use ICT effectively will on the other hand be in a better position to create wealth. This clearly risks creating a vast gap between the rich and the poor. This argument is also shared by Hawkridge *et al*. (1990:6) who believe that the technological gap between industrial and developing countries will widen if developing countries ignore ICT.

I think that Costa (in Crowther, 1997:7) is correct when he says that "... with knowledge doubling every 5 years - every 73 days by the year 2020- we can no longer anticipate future information requirements. We must teach our students how to access and use knowledge that is already present, to problem solve, and to understand inquiry skills so that new knowledge can be sought after and obtained".

To prepare our learners to participate actively in the Information Age and to prevent the 'digital divide' from widening, our educational system underwent a number of changes. An outcome of these changes is to provide all learners with equal opportunity to acquire the necessary knowledge and skills to utilise information effectively. The TRAC PAC has a role to play and it can definitely contribute by providing our learners with the knowledge and skills necessary to participate actively in the Information Age.

2.2.2 The importance of Mathematics and Science

Howie and Hughes (1998:13), Khan and Volmink (2000:2), Makhurane and Khan (in Naidoo and Savage, 1998: 27) have all documented the importance of mathematics and science. They report that if a country's citizens are mathematically and scientifically literate then they are able to participate actively and make valuable contributions to society.

> "As the twenty-first century approaches, the demand for mathematical, scientific and technological understanding and expertise will be greater than ever before. Students at the forefront of developments in the future will require very high levels of mathematical and scientific skills. These students will need to develop critical thinking, processing and interpreting skills far beyond those required a decade previously. As students leave school and enter higher education and the workplace, the above skills, in addition to competence in mathematics and science, will be crucial. With the need for populations to be better educated ... in a climate of shrinking national budgets, countries around the world have been looking for methods of making teaching and learning more effective" (Howie & Hughes, 1998:13).

The importance of learners developing mathematical and scientific skills at school is evident from this quotation. Will changing the education system bring about these skills in our learners? Only time will tell. I am confident that when learners use the TRAC PAC effectively, their mathematical and scientific skills will be greatly enhanced.

2.2.3 The influence of teaching methods

Ensuring that our learners acquire the skills mentioned in sections 2.2.1 and 2.2.2 means that our education system must ensure that this happens. Lippert (1989:K1) is of the opinion that our teaching methodologies and content are best suited to the Industrial Age and not the Information Age in which we now find ourselves. Boschee and Baron (1994:195) and Thornton (in Chaisson and Kim, 1999:163) agree that the teaching and learning methods used in schools which were designed for simpler times are no longer sufficient because these methods are unable to teach the majority of learners how to actively participate in their physical world. As our learners are prepared to participate in the economy of the 21st century, schools must prepare learners to master those skills required by them when they leave school. To do this

> "... authority-based teaching and learning must make way for investigative, learner-centred approaches. Teachers must become more open, receptive and reflective, learners more creative and critical ... Society cannot continue to afford the luxury of sending children to school to pursue knowledge simply for its own sake. The socio-economic and political realities on our continent are such that students must pursue knowledge for life" (Volmink in Naidoo & Savage, 1998:73-74).

I agree with Renate Lippert who suggests a possible solution: "The education system must be rebuilt to match the drastic changes needed in our economy if we are to prepare our students for productive lives in the 21st century" (Lippert, 1989:K1). Through changing the education system, teachers would be encouraged to actively attempt different teaching and learning strategies in their classrooms. I believe that the TRAC PAC can be used effectively to explore a variety of teaching and learning strategies that will benefit both teachers and learners.

2.2.4 The effect of culture on curriculum

In 1957 when the Soviet Union launched the first Sputnik, the United States of America (USA) was rudely awakened. Fearing that it was lagging behind the Soviet Union in terms of science and technology, funding was supplied by the National Science Foundation (NSF) to find ways in which the national science and mathematics curriculum in the USA would prepare its learners to compete with those of the Soviet Union. These changes were not limited to the USA only, but also spilled over into the United Kingdom (UK) and Africa (Khan & Volmink, 2000:13 and 16, Yoloye in Naidoo & Savage, 1998:4). The result of this action was that a number of conferences held on education in Africa took place in the early 1960's. Through these conferences many African countries became aware that science and technological development could lead to economic prosperity through education (Yoloye in Naidoo & Savage, 1998:1-2 and 4).

After African leaders, spurred on by the promise of economic growth and prosperity, brought about policy changes in education, curricula from Western countries were used in the African educational contexts. Bearing in mind that cultural values are entrenched in curricula (Nobles in Jeevanantham, 1999:52 and Rogan, 2000:123), this led to major problems. Rogan (2000:123) supplies the following two examples to illustrate that curricula and culture cannot be separated. In Western countries, curricula praise individuality, whereas African learners are encouraged to share. Where Western countries encourage learners to question authority, African learners are not expected to do this. As a result "even before independence most colonial powers had become aware that the wholesale transplantation of their system of education did not find a fertile soil in Africa" (Ogunniyi in Rogan, 2000:123).

Educational institutions do not only impart culturally influenced knowledge to learners but according to Aronowitz and Giroux (in Jeevanantham, 1999:51) they also fulfil certain social reproductive functions. They provide learners in different social classes with different skills and knowledge so that they will perform different roles in a tiered society which propagates and legalises general cultural patterns. Volmink (in Naidoo &

Savage, 1998:73-74) argues that the science that is currently being taught in our schools has been inherited, unquestioned, from our colonial past and as a result it has failed to address the developmental problems facing the continent. Therefore, Jeevanantham (1999:50) quite passionately argues: "Curricula currently in use in South African schools are irrelevant to the vast majority of the school going population because they reflect the life experiences, culture and traditions of a very small segment of society and exclude the same of the majority". As a result learners are 'failing' in a system in which they cannot 'cope', because it is foreign to them. To solve this problem, Magolda (in Jeevanantham, 1999:51-52) recommends that the curriculum should be relevant to the learners of Africa.

Not everyone will agree with the reasons given that the South African curriculum must change. Critics who are against changing the curriculum often provide the following reasons: "...that the ways of the past are tried and tested; that what has been done provided quality education; that the current programmes which are based on past practice deliver people with the skills that are needed in our society" (SAQA, 2000 A:26). What I am aware of is that far too many learners are ill-equipped to participate actively in South Africa today.

It was my opinion that the TRAC PAC, an American innovation, was struggling to find "…fertile soil in Africa". Through this research, it was important to identify those factors that would lead to the TRAC PAC finding fertile soil in South African classrooms.

To summarise, I believed that the TRAC PAC would be utilised optimally in South African schools if it was able to demonstrate that it could:

- provide learners with the necessary skills to participate actively in an Information Age. This was possible because the learners were engaging with ICT when they used the TRAC PAC.

- provide learners with the necessary mathematical and science skills that would enable them to be globally competitive. The learners were engaging with these skills when they used the TRAC PAC.

- provide teachers with different teaching strategies that would help their learners to acquire the knowledge and skills required for the Information Age. This was possible because learners had more than one opportunity to engage with a specific science concept while using the TRAC PAC.

- address the needs of the South African Education Department. It was possible for the TRAC PAC to accomplish this if TRAC SA aligned its activities with the new curriculum.

2.3 CHANGES TO THE SOUTH AFRICAN EDUCATION SYSTEM

Thus far, I have discussed the crisis in science education in South Africa and have outlined the skills that our learners need to master in order to be globally competitive. The DOE has changed the educational system by adopting an outcomes-based education (OBE) approach. What do these changes entail and can an American innovation, the TRAC PAC, be whole-heartedly imported into our schools? In order for the TRAC PAC to be utilised optimally within South African schools, the educational landscape needs to be clearly understood. With this in mind, the changes to the South African education system are briefly described here.

After the first democratic elections that took place in South Africa in 1994, "The political space …(was)… made for educational transformation in South Africa..." (Mason, 1999:140). The changes to the education system began immediately with the Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996) providing the foundation for curriculum transformation and development (DOE, 2002 A:6).

To bring about changes to the education system of South Africa, the DOE engaged in 'education reform' (SAQA, 2000 A:10). The acceptance of outcomes-based education as a means of bringing about education reform implies that systemic and curriculum change is fundamental to educational reform (SAQA, 2000 A:10; SAQA, 2000 B:6).

2.3.1 Systemic change

Systemic change refers to changes in the way that the education system is structured to ensure that educational change can take place. Systems, for example, that ensure:

- the establishment of Educational Management and Development Centres (EMDCs) in the Western Cape.
- that the previous fourteen racially divided educational departments be reduced to nine democratic provincial educational departments.
- that national standards are set and maintained when all matriculants write common examinations in 'gateway subjects' which are Mathematics, Languages, Physical Science, Biology and one other subject on a rotational basis (DOE, 2001 B:29).
- the establishment of the South African Qualifications Authority.
- the establishment of the National Qualifications Framework.

2.3.1.1 The South African Qualifications Authority (SAQA)

In October 1995, the South African Qualifications Authority Act was passed into law. The South African Qualifications Authority (SAQA) was established in 1996 and is responsible for overseeing the development and establishment of the National Qualifications Framework (NQF). "The role of SAQA is to establish standards, quality assurance systems and management information systems to support the NQF" (DOE, 2001 B:22). It is responsible for setting standards and quality of the outcomes and to ensure that the qualifications awarded by the NQF are globally acceptable (SAQA, 2000 B:3).

2.3.1.2 The National Qualifications Framework (NQF)

The NQF consists of qualifications at eight levels of education and training. The table below summarises the NQF for South Africa (SAQA, 2001 A:10-11).

NQF Level	**Band**	**Qualification Type**
8 7 6 5	Higher Education and Training	• Post-doctoral research degrees • Doctorates • Masters degrees • Professional Qualifications • Honours degrees • National first degrees • Higher diplomas • National diplomas • National certificates
Further Education and Training Certificate (FETC)		
4 3 2	Further Education and Training	National certificates
General Education and Training Certificate (GETC)		
1	General Education and Training	Grade 9 and ABET Level 4 National certificates

Table 2: The National Qualifications Framework.

For learners to receive an accredited qualification, approved by SAQA, they must have demonstrated the following critical outcomes and developmental outcomes (DOE, 2002 A:11). The critical outcomes expect the learner(s) to be able to:

1. identify and solve problems and make decisions using critical and creative thinking;

2. work effectively with others as members of a team, group, organisation and community;

3. organise and manage themselves and their activities responsibly and effectively;

4. collect, analyse, organise and critically evaluate information;

5. communicate effectively using visual, symbolic and/or language skills in various modes;

6. use Science and Technology effectively and critically showing responsibility towards the environment and health of others; and

7. demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

The developmental outcomes expect the learner(s) to be able to:

1. reflect on and explore a variety of strategies to learn more effectively;

2. participate as responsible citizens in the life of local, national and global communities;

3. be culturally and aesthetically sensitive across a range of social contexts;

4. explore education and career opportunities; and

5. develop entrepreneurial opportunities.

I believe that our learners can quite effectively develop these skills mentioned in the outcomes above when they interact with the TRAC PAC. A discussion on this issue will follow in chapter 6.

2.3.2 Curriculum Change

Outcomes-based education was introduced into the South African education system through a policy called Curriculum 2005 (C2005), and resulted in curriculum change. The emphasis of C2005 is to move away from the traditional aims-and-objectives approach to an outcomes-based approach (DOE, 2002 A:4). Through C2005, it is envisaged that our learners will move from a system which, to a large degree, focused on the rote memorisation of content knowledge to one in which learners are able to apply their knowledge to many critical problems that are currently facing our society (Rogan, 2000:118). Curriculum change also has to do with the strategies that can be followed to ensure that the learners achieve the required outcomes for their qualification. These include the curriculum, instruction and assessment (SAQA, 2001:1). The Minister of Education launched C2005 on 24 March 1997. The first phase of implementation of C2005 into schools took place in 1998 (Jansen, 1998:2).

2.3.2.1 Outcomes-Based Education (OBE)

Many different views on OBE exist. In this section of the literature review I hope to clarify precisely what OBE means. I think that this will provide some insight into how the TRAC PAC can be utilised optimally.

2.3.2.1.1 The history of OBE

Many researchers have different opinions on the origin of OBE. Jansen (1998:2) writes that:

> "OBE does not have any single historical legacy. Some trace its roots to behavioural psychology associated with B.F. Skinner, others to mastery learning as espoused by Benjamin Bloom, some associated OBE with the curriculum objectives of Ralph Tyler, yet another claim is that OBE derives from the competency education models associated with vocational education in the UK".

Khan and Volmink (2000:3-4) have found that some researchers argue that OBE can be traced back to an approach which requires learners to be responsible for their own learning. This approach is called the constructivist learning approach which is different to the behaviourist approach which believes that learning takes place when changes in the learner's behaviour are evident.

King and Evans (in Waghid, 2001:127) trace OBE to the American education system in the 1960's when competency-based education and mastery learning was used to define a learner's performance.

This indicates to us that researchers have always asked what approach will best ensure that learners are successful at school. Our approaches to education have progressed over time from behaviourism through objectivism and now we are at outcomes-based education. Only time will tell whether we have succeeded with outcomes-based education.

2.3.2.1.2 The South African version of OBE

Why did the DOE in South Africa decide to adopt outcomes-based education? According to the DOE:

> "The South African version of outcomes-based education is aimed at stimulating the minds of young people so that they are able to participate fully in economic and social life. It is intended to ensure that all learners are able to develop and achieve to their maximum ability and are equipped for lifelong learning" (DOE, 2002 A:12).

The acceptance of outcomes-based education by the DOE is grounded in William Spady's definition of OBE. In this thesis, this definition will be adopted. Spady defines OBE as:

> "...clearly focussing and organising everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organising curriculum, instruction, and assessment to make sure this learning ultimately happens" (SAQA, 2000 A:10-11; SAQA, 2000 B:1).

Different researchers provide different reasons why South Africa has adopted outcomes-based education. According to Mason (1999:1), OBE was introduced in South Africa because it is intended to address the legacy of apartheid education by ensuring that all learners, irrespective of colour, acquire the necessary skills that will enable them to participate effectively in a competitive global economy. Jeevanantham (1999:53) believes that outcomes-based education in South Africa was introduced to assess black learners for the skills, attitudes, values and competences that they are able to demonstrate. I agree with Jeevanantham because I think that learners cannot be taught certain skills and knowledge without teaching them the appropriate attitudes and values as well. For example, I would teach a learner how to solve a problem. I would then want to determine whether the learner is capable of applying the skills learned to a new problem. If the learner simply copies the answer from another learner, then this would indicate to me that the learner has not developed the appropriate values because the learner is in fact 'stealing' the answer from another learner. Therefore, I think that the learners' attitudes and values should also be developed together with skills. Jansen (1998:6) is, however, sceptical as to the reasons why outcomes-based education was introduced into South Africa. He is of the opinion that OBE is merely a political tool introduced by the Education Department to indicate that transformation is taking place when in fact very little evidence of transformation exists.

Whether one agrees or disagrees with the arguments presented above, what is quite clear to me is that OBE is now part of the educational landscape. Everyone involved in education in South Africa (including TRAC SA) has the responsibility to ensure that our learners acquire the necessary knowledge and skills needed when they enter the workplace.

A Principles of OBE

There are four principles that guide the implementation of OBE in South Africa (SAQA, 2000 B:5). These principles are also relevant to the TRAC PAC, and will be discussed briefly.

1. *Clarity of focus on the learning outcomes*. This means that learners must demonstrate the outcomes stipulated by the education department. Using the National Curriculum Statement (NCS) grades 10 –12 for Physical Science (DOE, 2003:19) as an example, learners are expected to 'interpret data to draw conclusions'. A teacher could provide the learners with the following table to determine whether the learners are able to master the outcome.

Force (N)	acceleration ($m.s^{-2}$)
20	4
30	6
40	8
50	10

Table 3: Force and acceleration readings taken during Newton's second law of motion experiment.

Using this information, the learners must then interpret the information in the table and draw a conclusion by stating the relationship between force and acceleration.

The relevance of this principle to this research is that it highlights the point that all activities that are designed to be used with the TRAC PAC must align with the outcomes set out by the DOE. This will ensure that the activities are relevant and accepted by all.

2. *Design down / build back approach*. This means that one must start with the outcome, teach towards it, and assess the outcome. In the example given above, the learners are expected to 'interpret data to draw conclusions'. Therefore, the ability of the learners to both interpret the data in the table and to draw the correct conclusions from it is what the teacher should assess.

   To determine whether the TRAC PAC has been successful in addressing the outcome, stipulated in the activity, one must measure the success of the activity based on the learners' ability to complete the outcome.

3. *High expectations*. This means that everyone expects high standards of quality of work done by learners when they demonstrate their ability to master the outcomes. The teacher should not accept mediocrity from learners.

   TRAC SA should also have high expectations from learners who use their material. TRAC SA would contribute positively towards this principle if it were able to measure whether learners have in fact satisfied the high expectations set for them.

4. *Expanded opportunity*. This means that the teacher needs to give learners the time, space and opportunities to master the outcomes. The following continues from the example given in 1 above. After the teacher has assessed the outcome, and found that the learners could not master the outcome, the teacher is expected to create another opportunity for the learners to master the outcome. The teacher could then provide the learners with the following table:

Mass (kg)	Acceleration ($m.s^{-2}$)
2	5
3	3,33
4	2,5
5	2

Table 4: Mass and acceleration readings taken during Newton's second law of motion experiment.

Using this information, the learners interpret the data in the table and draw a conclusion by stating the relationship between mass and acceleration. The learners have another opportunity to demonstrate whether they are able to master this outcome or not and will thereby show their ability to apply new knowledge.

The TRAC PAC definitely has an advantage when one considers this principle. It allows learners multiple opportunities to engage with an outcome in science which they might find difficult.

To conclude, I believe that the TRAC PAC would be utilised optimally when all materials are designed according to these four principles.

B The advantages of OBE

In Johnson City, New York, the outcomes-driven developmental model, which was created more than 20 years ago, is an example of a success story.

> "OBE is the simplest idea in the world and it should have stayed simple. Know what you want kids to learn and work backward. Let what you want kids to learn drive behavior. How simple can you get? …classrooms in Johnson City are inviting, teachers have been empowered to use the best research available, students are respected and no one is allowed to advance with a grade under 80 … Johnson City, with one of the highest poverty rates … in New York's Southern Tier, …more students are completing algebra, fewer are dropping out and vandalism costs have dropped …" (Chion-Kenney, 1994:16).

Kudlas (1994:32-33) highlights many positive aspects of OBE. I will focus on two. Firstly, through OBE, with the emphasis on mastering outcomes, learners will also develop problem solving skills instead of merely memorising a number of science facts. Secondly, more learners can successfully attain outcomes if their learning styles are appropriately addressed. The traditional lecture and test process is not the only learning and assessment strategy that teachers can use to determine whether a learner has achieved an outcome or not. Teachers must try other learning styles and techniques such as multiple intelligences and co-operative learning together with the traditional lecture and test process, until the learner has successfully demonstrated the ability to master the learning outcomes. Through this process, learners will take control of their own learning instead of expecting the teacher to motivate them to learn.

I believe that the TRAC PAC has the potential to facilitate quite effectively the learning of the required knowledge and skills required from our learners.

C Arguments against OBE

In theory, it seems as if OBE could solve the many challenges facing education in South Africa. However, this has not been the case thus far. Ever since Curriculum 2005 was formally implemented in grade 1 in 1998 in South African schools, many have documented their disapproval of the system.

A critic of OBE in South Africa is Jonathan Jansen (1998:1-8). In his article "Curriculum reform in South Africa; A critical analysis of outcomes-based education" he scathingly attacks OBE and tells us why he thinks that 'OBE will fail'. I will highlight two of his criticisms of OBE.

He believes that the introduction of OBE into the South African education system is offered as a solution to economic revival. He thinks that this is not true because no evidence exists in curriculum change literature which suggests that changing the school curriculum will result in changes in national economies. Another reason offered by Jansen is that it is "...based on flawed assumptions about what happens inside schools, how classrooms are organised and what kinds of teachers exist within the system". He adds that teachers are not encouraged to participate in discussion with others so that they can make sense of OBE policy and what is expected from them. Rogan (2000:119 & 121) supports Jansen’s view that OBE is a problem in South Africa because the once-off training workshops that teachers receive, do not address their needs. In addition, they must keep accurate records of the outcomes that their learners have mastered. This he feels will only increase the administrative loads placed on teachers as they will not receive additional support.

Rogan (2000:119 and 121) has also identified similar problems to those mentioned by Jansen. However, he takes his argument further by describing the 'Verspoor Model'. In this model a school is categorised using the following criteria: teacher background and professionalism, the curriculum, school organisation, and school and teacher development. Based on these criteria a school is classified as: Stage 1 - Unskilled, Stage

2 - Mechanical, Stage 3 - Routine and Stage 4 - Professional. He believes that for OBE to be successfully implemented in South Africa, schools should be at stage 4. However, this is not the case since our schools fit all four stages.

This criticism against OBE can be summarised as follows: The teachers in South African schools are ill-equipped to implement OBE. I think that the ideal opportunity exists for TRAC SA to use the 'Verspoor Model' and to focus on teacher training activities that cater for teachers who find themselves in one of the four stages. This focussed approach would provide the correct guidance and assistance to all teachers. In this way, TRAC SA would contribute positively towards the successful implementation of OBE by assisting teachers where necessary.

D Difficulties experienced with the implementation of OBE

When the DOE brought about changes to the education system, it did this through the publication of various Papers, Acts and Bills. Mason (1999:3) argues that no matter how good these policies are, evidence gathered from research show that problems always arise in the implementation of policy (Mason, 1999:3).

In February 2000, the Minister of Education commissioned a review of C2005 (DOE, 2001 B:27). This committee reviewed C2005 and its implementation and not outcomes-based education (DOE, 2001 A:5). They recommended that strengthening the curriculum required streamlining its design features and simplifying its language through the production of an amended National Curriculum Statement. "The revised NCS is thus not a new curriculum but a streamlining and strengthening of C2005. It keeps intact the principles, purposes and thrust of Curriculum 2005 and affirms the commitment to outcomes-based education" (DOE, 2001 A:6).

Kader Asmal acknowledged that the criticisms against OBE in South Africa are as a result of difficulties experienced with the implementation of OBE. He was, however, confident that these issues had been addressed because "Administrative and support systems are stronger, general understanding of the underlying curriculum principles is better, and the National Curriculum Statement is being strengthened" (DOE, 2001 B:28).

The TRAC PAC could be utilised optimally in South African schools if it is able to assist teachers with the implementation of outcomes-based education.

E Possible solutions to the problems of implementation of OBE and its impact on the optimal use of the TRAC PAC

Educational researchers offer their informed opinions on what the education specialists should be doing to ensure the successful implementation of OBE. In line with this practice, I offer the following recommendations which I believe can be addressed by TRAC SA. These recommendations could address those issues which hamper the successful implementation of OBE.

- Develop teacher training as well as learner material that will receive accreditation from SAQA.

- The TRAC PAC has the necessary features that enable it to showcase a variety teaching and learning strategies. For example, learners could quite easily work in groups or they could use the TRAC PAC individually. Therefore, through well structured workshops, TRAC SA could demonstrate to teachers how to apply these different strategies (Steyn and Wilkinson, 1998:206-207).

- The activities developed by TRAC SA to be used with the TRAC PAC must be designed according to the four principles of OBE which were discussed earlier in this chapter.

- Through its website, TRAC SA is creating the space to allow teachers the opportunity to continually reflect and critique OBE. In so doing, teachers will begin to make sense of OBE and this will assist them in seeking solutions to the successful implementation of OBE in their classrooms (Waghid, 2001:132). However, the success of this website to allow teachers the opportunity to reflect and critique OBE depends largely on TRAC SA's ability to encourage teachers to participate in these discussions.

- The TRAC laboratory at Stellenbosch University is ideally located to allow all role players to pool their resources and experience to "... create test-beds where the implementation of Curriculum 2005 could be developed and researched" (Rogan, 2000:118-125). TRAC SA should therefore invite teachers to gather at the laboratory on a regular basis to design new activities and test them in their classrooms.

- In the General Education and Training (GET) phase (grades 7 to 9) as well as in the Further Education and Training (FET) band (grades 10-12), new content has been introduced into the curriculum. In GET this new content covers the theme 'Earth and Beyond', while in the FET this new content includes amongst others, electronics, plastics and atmospheric chemistry. Many teachers have not received any formal training on this new content and therefore do not have the necessary knowledge to teach their learners effectively. I believe that TRAC SA is capable of providing this service to teachers.

- The TRAC laboratory, with its computers, could be used to provide teacher workshops on the effective use of ICT to help teachers to manage their administrative duties at schools. This will go a long way towards assisting the teachers to lessen their administrative workload so that they can spend their time constructively with their learners.

In conclusion, I wish to state that I agree with Mason (1999:142-143). I believe that the role of the teacher is crucial to the successful implementation of OBE in South Africa. Teachers need to understand that there are no quick fix solutions and that they will have to find the best available strategies to make OBE successful. TRAC SA can definitely assist the teachers in making this a reality.

2.4 COMPUTERS IN EDUCATION

Since the TRAC PAC is a computer based application capable of collecting data in real time in the science classroom, it is necessary to provide a brief overview of computers in education. This will help to determine those factors that could lead to the optimal use of the TRAC PAC. In this section, I share my interpretation of why computers were introduced into education and discuss possible reasons why this move was problematic.

2.4.1 The introduction of computers into education

Duguet (1990:165) argues that it was not educational demands, but rather societal pressures that forced computers into schools. Hawkridge (1990:2-3) and Hawkridge *et al.* (1990:16-21) describe four popular rationales for the introduction of computers into schools. These rationales are briefly:

- Social Rationale: It is accepted that all citizens must be computer literate in order for them to participate in a global village that is becoming increasingly dependent on computer technology.

- Vocational Rationale: It is believed that if citizens know how to programme a computer, then it will make them employable and this will contribute to economic prosperity.

- Pedagogical Rationale: Computers are used to improve the quality of teaching and learning.

- Catalytic Rationale: It is hoped that computers will bring about change in the way teachers teach and learners learn.

2.4.2 Problems experienced with the introduction of computers into education

Various researchers (Redish, Saul and Steinberg, 2001:1; Rodriques, 1997:35; Wilcox and Jensen, 1997:258) ask why the introduction of computers into schools has not had the desired effect of solving many of our educational problems despite the staggering promises of its perceived benefits to education.

One of the lessons to be learned from the introduction of computers into schools can be taken from the Dutch government which had supplied all its schools with hardware, software and had presented compulsory teacher training workshops by 1992. Even though schools had access to computers, Brummelhuis and Plomp (1993:338; 1994:291) found that the computers were not used frequently and that their usage in schools depended largely on the initiative of individual teachers. In a research project funded by Pennsylvania State System of Higher Education in which 486 secondary schools participated, Lehman (1994: 416) documented that: "In 81% of the schools, microcomputers are used with students twice a month or less". I believe that there is a lesson that TRAC SA can learn from this. Simply supplying teachers with a TRAC PAC is no guarantee that it will be used effectively.

Brummelhuis and Plomp (1993:339); Lawler, Rossett and Hoffman (1998:33) and Lehman (1994:419) have found that teachers want to know how to integrate the computer into the existing curriculum. Morse (1991:2) reports that: "70% of teachers wished to know more about using computers to deliver science instruction". The problem which Lawler *et al*. (1998:30) and Lehman (1994:419) have identified in this respect is that the amount of time teachers require to develop lessons, utilising the computer, is just too much for many who are already overburdened with huge workloads (Lippert, 1989:K1). The problem is further compounded by the lack of experienced science teachers who can share their methodology with other teachers (Lehman 1994:418). As a result, those teachers that do not have the experience in utilising the computer effectively tend to treat the computer as an 'add-on' and not as a resource which could enrich their teaching (Lippert, 1989:K1).

Taking this point further, Kearsley (1998:47) and Lehman (1994:413) have reported that the lack of adequate training is the main reason for the low level of computer usage in schools. The problem arises when trainers of new products offer 'once off' workshops to teachers and then expect teachers to change their traditional teaching methodology immediately to suit the methodology required for implementation of the product. This has proven to be ineffective (Borchers, Shroyer and Enochs, 1992:385). This is further supported by Lehman (1994:413) who found that the ENLIST Micros project was initiated because some teachers realised that they needed continual support on the implementation of computers in their classrooms. Krajcik, Arbor and Layman (2001:2) reinforce the view that teachers will rather use traditional teaching methodology than teach their learners new strategies such as expecting them to making predictions, analysing data and drawing conclusions. For teachers to use computers over the traditional teaching methodology requires that teachers must feel confident and competent before replacing their traditional style of teaching with something new (Brummelhuis & Plomp, 1994:298). Lehman (1994:416-417) has reported that it takes teachers five to six years of using computers before they attempt non-traditional methods.

The lack of high quality software is another reason attributed to the poor response of teachers to the use of computers in their classrooms. Brummelhuis & Plomp (1993:334); Bross (1986:17) and Duguet (1990:169) have found that only ten to twenty per cent of all software designed for the classroom is of high quality.

I agree with Escalada, Baptiste, Zollman and Rebello (1997:27-28) and Krajcik *et al.* (2001:3-4) who have reported that placing a computer (or a TRAC PAC) at a school will not guarantee that it will contribute positively towards the learning process. It is actually a combination of factors that contributes towards the learning process and not merely the use of a computer. The adoption and implementation of the following factors would go a long way towards contributing to the optimal use of the TRAC PAC in South African schools. These factors include: the development of activities that engage a learner in a problem, multiple instructional strategies, the interactions between learners and the teacher or facilitator, determining before-hand learners' prior knowledge, utilising whole class discussion, hard work and self-esteem.

It is widely acknowledged that teachers have a key role to play in ensuring that their learners' benefit from any new innovation brought to their classroom. Yet, Blignaut (1997:10) has found that:

> "Many innovations have failed because the central role of teachers in the educational development process was not taken into account. When a teacher is not convinced that an innovation will benefit students and classroom practice, it is doubtful that any effort will succeed".

Savage (in the work of Naidoo & Savage, 1998:48-51) hints at a possible solution. To ensure that any innovation (TRAC PAC) succeeds, TRAC SA should consult with teachers and they should participate in the discussions about the changes that need to be brought about in their classrooms. This will greatly improve the chances of the TRAC PAC succeeding.

2.5 THE INTRODUCTION OF COMPUTERS INTO WESTERN CAPE SCHOOLS

The introduction of computers into the schools of the Western Cape Province in South Africa, was planned for some time by the Western Cape Education Department (WCED). In a report to the Executive Director: Education, Cape Education Department, 1990, it was stated that the: "... integration of computers into the curriculum is correct, but we must move as rapidly as possible and need to work within the scope of current staff complement and limited funds" (Williamson and Waker, 1990:1).

Considering all the problems currently being experienced in science education in South Africa as highlighted in section 2.1 above, the question to be asked is, "Do we really need computer-based education in South Africa"? Mehl, Director of the Gold Fields Resource centre at UWC from 1983 until 1990, answers, "Yes, desperately, yesterday" (Mehl, 1991:11). Why does he think so? At his centre, computers were used to help matriculants from disadvantaged communities to pass the Mathematics and Physical Science examinations successfully. The many lessons learned during this period convinced him that computers have a role to play in science education in South Africa. The positive lessons learned from this project were:

- Computers can assist learners from previously disadvantaged communities because they provide an environment where learners can learn from each other.
- Learners adjust easily to using computers.
- It was easy to address difficulties which learners were experiencing with subject content.

However, he argues that the use of computers in science and mathematics education is not easy. The difficulties experienced included amongst others:

- It was difficult to develop a model that teachers could use which would integrate the use of the computer into the normal classroom activities.
- Very poorly designed software for South Africa's context or a complete lack thereof, can negatively affect learners' and teachers' enthusiasm for sustained use of the computer. This implies that teachers will have to become involved in the writing of local software, which is very time consuming because it takes up to 500 hours of programming to prepare one hour of activity for a learner to use (Retief, 1989:151).

Another trend developing in the Western Cape is that schools are using their own funds to change existing classrooms into computer laboratories. Schools do this because parents demand that they want to prepare their children for life after school, and fear that their children will get left behind because a neighbouring school has a computer laboratory

(Coetzee, 1999:2). After much observation of the practices at many schools in the Western Cape that have computer laboratories, Coetzee, an Information Technology advisor for the WCED, concluded that many computer laboratories are merely expensive window dressing exercises to impress parents and the community (Millennium Minds Conference, Westerford High School, September 1999). He is of the opinion that this inevitably leads to problems because no proper thought and planning goes into this process. It is simply assumed by parents and governing bodies that if their learners learn how to use a computer then they will automatically understand the content and concepts taught by their teachers. Coetzee thinks that this is a problem. After a while, learners show no interest in using the computer laboratories. In many cases, more hardware and software is purchased or an outside consultant is approached to take over the computer laboratory. The reasons given by Coetzee (1999:10-13) why many computer laboratories at schools fail, include among others the following:

- Teachers merely teach learners how the computer works and not how the learners can use it to help them understand the content and concepts better.

- Teachers tend not use the computer as an integral part of a lesson when teaching.

- Teachers who use a computer laboratory often forget to teach as they assume that the computer will be able to teach their learners. They do not realise that "computers are merely tools to be used ... to enhance the learning process".

- Schools do not spend the same amount of money on technical backup or support as they spend on hardware and software. As a result of insufficient funds spent on support, it takes a long time to fix computer problems when they do arise, and this leads to the computer laboratory being under-utilised.

I think that many schools do not do the necessary research and planning before they decide to open a computer laboratory facility. I hope that these lessons will be shared with schools who decide to introduce the TRAC PAC into their schools so that the mistakes of the past are not repeated. This will prevent a situation from arising where the TRAC PAC suddenly becomes a white elephant in many science classrooms.

2.6 DIFFERENT USES OF COMPUTERS IN SCIENCE EDUCATION

The TRAC PAC is an example of a microcomputer-based laboratory (MBL), but it is not limited to performing only this function. It is first and foremost a computer, and with the correct computer programmes, is capable of performing many other functions. Initially, when computers were introduced into science education, it was mainly used for drill and practice activities (Lippert, 1989:K5). However, the speed and skill with which computers can execute tasks have increased dramatically. As a result, many researchers have identified that computers can and do have different roles to play in science education. In this section, I will highlight some of the most common uses of computers in science education. It is not my intention to describe all the possible uses of computers in science education, but merely to provide an insight into the possibilities of using the TRAC PAC optimally.

2.6.1 Spreadsheets

Spreadsheet software is readily available to all learners in most schools and learners are becoming more and more familiar with its uses (Carson, 1997:69). The spreadsheet is a computer application that is capable of tabulating results, performing calculations based on formula entered into the programme, and producing graphs and charts based on the information entered into the programme. This allows the learner to develop his or her interpretation and communication skills (Carson, 1997:69; Severn, 1999:361). Amend, Tucker, Larsen and Furstenau (1990:102), Carson (1997:79) and Silva (1994:352) all agree that using spreadsheet applications in the science classroom "... give(s) the students more time to think about their data, rather than doing excessive number crunching and hand plotting of graphs ... which can so often get in the way of understanding ... the tedium is taken out; the thinking is put in". Therefore, learners are encouraged to spend more time analysing the data collected, so that a deeper understanding of the science concepts takes place.

Amend, *et al*. (1990:111), Carson (1997:69), Kellogg (1993:21-22) and Scaife and Wellington (1993:82) identify the following additional advantages when using spreadsheets in science education. It allows learners to work co-operatively by encouraging them to work together as a small group of learners. Using the spreadsheet motivates learners and at the same time allows them to develop the necessary skills that can be used for any subject as well as in an environment outside the school.

The most common use of the spreadsheet in science education is called simulation. Silva (1994:352) supplies a number of reasons why spreadsheet simulations are effective. It allows the learner to create an environment that is free from scientific apparatus such as batteries, wires, chemicals, etc. This is particularly useful in schools that do not have access to scientific equipment. This also allows the learner to test extreme conditions that normally would not be possible in a science laboratory. The learner is able to make predictions by changing a variable and then to test his/her answer. As a result simulation provides "... for cognitive conflicts between intuitive and scientific ideas ... and helps to overcome misconceptions".

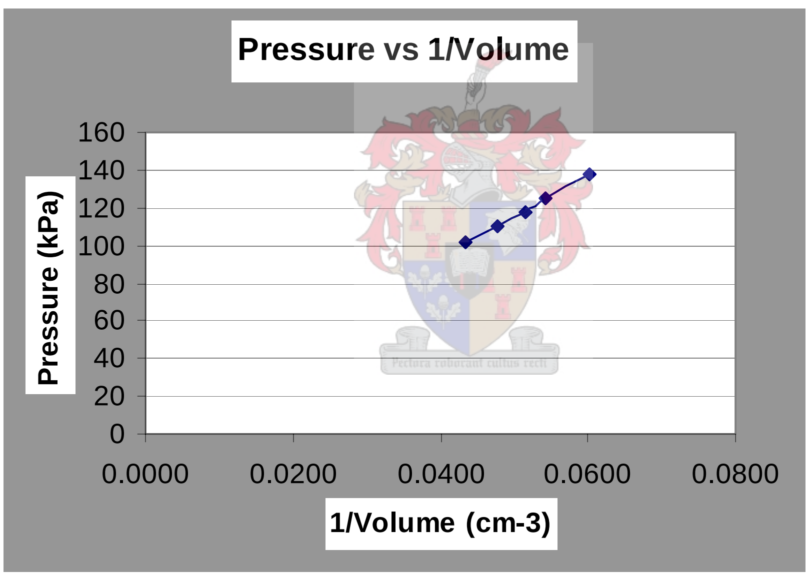
The following examples were modified from Amend *et al*. (1990:105-109) and Kellogg (1993:22-23). These two examples illustrate the spreadsheet simulations that can be applied in science education. For the purpose of these examples, Microsoft Excel 2000 has been used.

In the first example, on Boyle's Law, learners would have collected, or would have been given, pressure and volume readings. The results would then be tabulated into Excel as follows:

Volume(cm3)	1/V(cm-3)	Pressure(kPa)
16.6	0.0602	137.8
18.4	0.0543	125
19.4	0.0515	117.5
21	0.0476	109.8
23	0.0435	101.5

Table 5: Pressure, Volume and 1/Volume readings in Boyle's experiment.

Then using the chart wizard function key  on the tools bar, the computer will create the following graph.



Graph 1: Relationship between pressure and 1/volume in Boyle's experiment.

One advantage of this would be that the shape of the graph would immediately be evident. This would help the learner to understand the concept that pressure is inversely proportional to the volume of a gas (at a fixed temperature). The teacher could take this further, for example, by encouraging the learners to change the pressure and volume readings in the table above and to 'see' what shape graph appears. The teacher could then ask the learners to predict the shape of the graph when the pressure values are increased.

A second example that I will use to illustrate how spreadsheets can be used in science education, will focus on Ohm's Law. The potential difference across a cell is changed from 1,5 V to 3 V to 4,5 V and to 6V. At each change, the voltmeter reading across the resistor and the ammeter reading for the circuit are taken. The readings are tabulated and the spreadsheet programme draws a corresponding potential difference versus current graph.

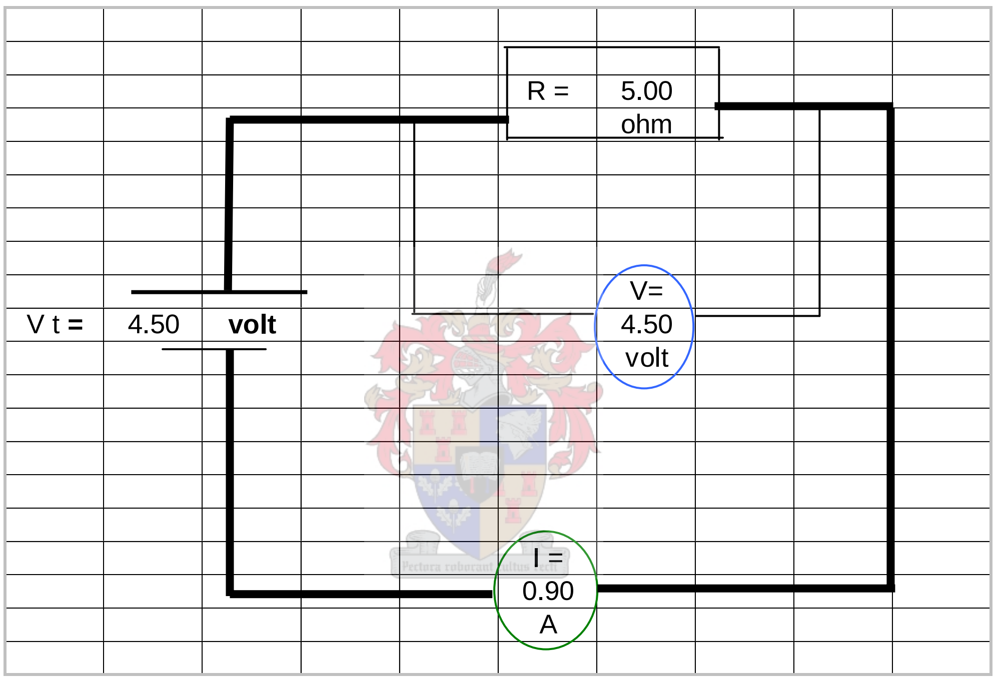
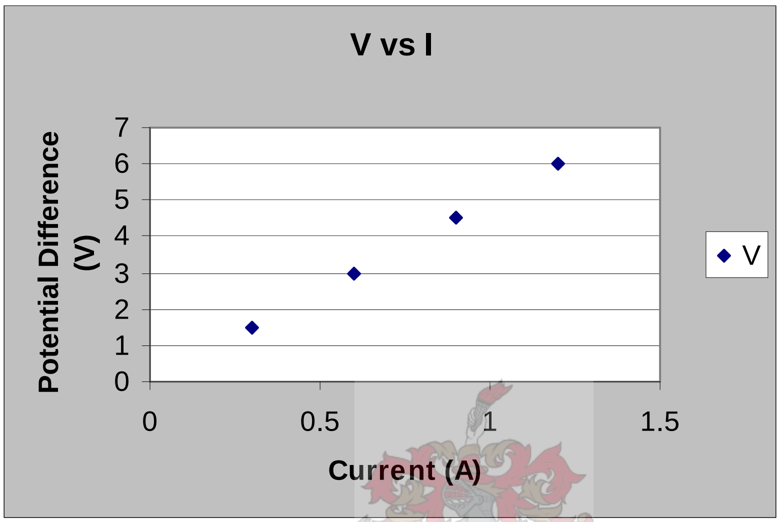


Figure 1: A simulated DC circuit using Microsoft Excel 2000.

I	V
0.3	1.5
0.6	3
0.9	4.5
1.2	6

Table 6: Results of voltmeter and ammeter readings of DC circuit.

The learner will then be able to draw a graph using the chart wizard function key  that appears on the toolbar and the corresponding pressure versus current graph can be drawn.



Graph 2: Relationship between Potential Difference and Current.

A learner could now test these laws by "... trying to predict what will happen as a consequence of changing the value of one parameter" (Silva, 1994:351). Silva believes that the learner would now be motivated to find out more and as a result would be engaged in his or her own learning.

The use of the spreadsheet also has advantages for the teacher. Carson (1997:69) and Scaife and Wellington (1993:82) argue that the use of spreadsheets will improve teacher understanding of, and teacher confidence in, computer technology. For example, teachers could use the spreadsheet to keep assessment records or an inventory of apparatus in the laboratory. As a result, teachers who have been cautious of computers may find that simple spreadsheets are much easier to use than they had initially thought. This will improve the teacher's confidence in the use of computers in the classroom.

I think it is important to state that I agree with Kellogg (1993:23) and Silva (1994:345), that using spreadsheet simulation in the science classroom should not replace actual hands-on experiences. The spreadsheet simulation is merely a tool that teachers can use to facilitate effective learning. The teacher must use his or her professional judgement to decide when to use a spreadsheet simulation so as to encourage the learners to get involved in classroom discussions and to analyse data critically.

2.6.2 The Internet

Pfaffenberger (in Hackbath, 1997:60) defines the Internet as "(a) system of linked computer networks, worldwide in scope, that facilitates data communication services such as remote login, file transfer, electronic mail, and distributed newsgroups". When a number of Internet servers are linked together, this is referred to as the World Wide Web (WWW) (Hackbath, 1997:60).

As mentioned earlier[9], Duguet (1990) argued that computers were introduced into education as a result of societal pressures. The same is happening with the Internet. The Internet was never intended for use in education. Descy (1997:48) argues that the Internet was not intended for the general public at all. In fact, the Internet was developed by the U.S. Department of Defence (DoD) in 1969 "... to move information between DoD and military researchers".

The Internet is fast becoming the 'must have' educational technology. "The ultimate technology, panacea, ... for ... educational technology is now the Internet..." (Kaufman, 1998:63). As a result almost everyone is rushing out to get connected to the Internet which has resulted in a dramatic increase in its use (Bertot, McClure, Moen & Rubin in Schulze, 2000:248). Even schools have not fallen behind in the quest to gain access to the Internet. According to Descy (1997:48), schools all over the world are scurrying around

[9] Refer to section 2.4.1

to give their learners access to the Internet. Maddux and LaMont Johnson (1997:5) and statistics published by the U.S. Department of Education (2000:1) have documented the growing number of people connected to the Internet. The National Centre for Education Statistics in U.S. has found that "...99 percent of full-time regular public school teachers reported that they had access to computers or the internet (sic) somewhere in their schools" (U.S. Department of Education, 2000:1). As a result, teachers of every philosophical persuasion are being pushed into adapting their lesson plans so as to include activities from the Internet (Hackbath, 1997:60).

A reason given for learners' needing to have access to the Internet is that it opens up the world to them (Descy, 1997:48). Failing to be connected to the Internet can have serious consequences for those learners who are not able to gain access to it. Descy (1997:48), Hargis (2000:2) and Jackson and Bazley (1997:43) all agree that "... the gap between the haves and the have nots ... will widen ... from a crevice to an abyss", and that learners who do not have access to the Internet are likely to be seriously disadvantaged.

Other than fearing being left behind, researchers are in agreement that there are educational benefits for learners who use the Internet. Hackbarth (1997:61) and Hargis (2000:1) have found that the Internet has a 'motivational influence' on learners and that they pursue the Internet with eager anticipation and amazement. Hargis goes further to explain that the Internet also encourages the learner to participate actively in inquiry-based activities as well as in co-operative learning environments.

Santos and de Oliveira (1999:4-5) quite passionately argue that learners need to develop their critical thinking skills if they are to be successful in their future careers because we are currently in a rapidly changing technological society that requires these skills of the learners. Owston (in Santos and de Oliveira, 1999:7) argues that learners would also need to master additional skills such as problem solving and written communication, which can be developed through the use of the Internet. Nadelson (1997:3) and Hackbarth (1997:60-61) believe that the communication skills of learners will be improved through the use of the Internet because they can publish their work on the Internet and as a result share their work with anyone anywhere in the world. They will also be able to communicate with people of different countries and participate in projects with these people.

Jackson and Bazley (1997:41-42) state that the Internet is a powerful educational resource because learners have immediate access to information and knowledge. In many countries, including South Africa, not all learners have easy access to information. The Internet is capable of bringing previously unavailable learning material to these learners (Hargis, 2000:1-2). The use of the Internet also promises to provide low cost education to the majority of people (Hackbarth, 1997:60-61; Hargis, 2000:1-2). It is believed that because the Internet will be easily accessible, this will give learners the freedom to choose how, when and where they will learn. This will then create a cheaper alternative to formal education. Not everyone is convinced. At an UNESCO workshop, O'Shea and Scanlon (in Scanlon, 1997:85) expressed the view that they "... are deeply sceptical of economic cost saving arguments for the introduction of ... technologies into education".

When it comes to using the Internet with learners in a classroom environment, other problems become evident. Scanlon (1997:82-85); Smart (in Schulze, 2000:248) and Fouché (in Schulze, 2000:248) have identified that not many learners can access the Internet at the same time as this increases the time taken to download material from the Internet. To combat this it means that the bandwidth needs to be increased and this increases the costs associated with using the Internet.

Kaufman (1998:63) refers to lessons of past technologies that were introduced into the education system. These technological innovations were also heralded to be the saving grace of all the educational problems. Because these technologies had failed to revolutionise education, Kaufman is not convinced that the Internet will make a huge impact either.

> "Once again we are confusing the mode and methods – the means- of delivery (telephones, overhead projectors, teaching machines, TV, computers, the Web) with the consequences – the ends- to be achieved. We can assume that ... we can take the same stuff (unchanged courses and learning experiences)

and deliver it with the newest and flashiest methods around and the results will automatically be worthy. Guess again!"

Why has the Internet failed to meet the expectations of the education system? According to Maddux (1998:24) and Jackson *et al*. (1997:42) even though "...[the Internet] is potentially the most powerful aid to the educational process yet developed, ... its use for educational purposes still needs to be structured and managed". Friedman's reason for this (in Schulze, 2000:248) is because materials used on the Internet are poorly developed and are outdated.

Scanlon (1997:82-85) offers another reason why the potential of the Internet has not been realised. The Internet must become an integral part of the curriculum for it to be truly effective, but integration is not easy because it is time consuming and resource intensive. Goggin (in Schulze, 2000:248) agrees that for teachers to develop materials for the web, in order to integrate this technology with their curricula, demands huge amounts of their time and effort.

Assuming a teacher is capable of successfully integrating the Internet into the curriculum, another challenge needs to be addressed. O'Shea and Scanlon (in Scanlon, 1997:85) believe that "(t)he role of the teacher will change as the ... forms of technology integration take place". This means that our teachers would have to lose the cloak of figure of authority, one that knows all the answers, and should rather become a facilitator. This complies with one of the roles that teachers should fulfil as required by the National Curriculum Statement, namely 'teachers as mediators of learning' (DOE, 2002:9). As a facilitator, the teacher would provide the learners with the tools that will enable them to understand what they learn instead of making them gatherers of incoherent information in the hope that learning will take place (Rose in Alexander and Robertson, 1997:29). Alexander *et al*. (1997:29) therefore recommend that teachers should take learners beyond memorisation of content and superficial levels of understanding to levels that emphasise critical-thinking and problem-solving skills, in their lessons. Teachers should be wary that when they integrate this new technology into their curriculum, that this does not simply imitate old methods of instruction or be seen as an addition to the current model of teaching because learners will soon lose interest.

Woolsey and Bellamy (in Scanlon, 1997:83) ask: "Will staff be prepared to change the way they teach"? Santos and de Oliveira (1999:4-5) do not think so because schools are effective in transmitting knowledge and are not effective as skills development institutions. Besides this, Fallon (in Schulze, 2000:248) has found that teachers are resistant to using the Internet in their classrooms. This is another factor that may hamper the successful implementation of the Internet into the education system. To overcome this, teachers will have to receive sustained training and support (Alexander *et al*. 1997:29).

Doherty (1998:61) believes that the Internet is a dynamic technology that should not present information in a static way, such as a textbook format. It should rather be used in such a way that it will create an interactive learning experience for the learner (Borsook and Higginbotham-Wheat in Schulze, 2000:249). Santos and de Oliveira (1999:9-10) advise that:

> "... in order to establish a real interaction environment, ... activities must be planned and created to promote deliberately, explicitly and systematically, real interaction between students via internet that enables students to solve problems in a collaborative way and develop critical thinking skills connected with interaction".

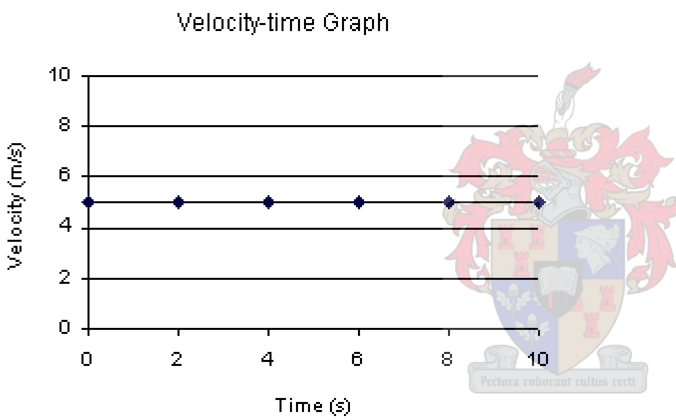
Hargis (2000:1-2) has found that learners can learn successfully via the Internet if they are able to take charge of their own learning. However, this will be negated if the learner does not receive appropriate support. This re-emphasises the important role that teachers play. High quality self-assessment with appropriate feedback is vitally important to involve learners actively in the construction of their knowledge.

The following two examples are activities taken from the Internet, which I think encourages the development of these skills in learners who use these websites.

In the first example, which is a section taken from the website, http://library.thinkquest.org/10796/ch2/ch2.htm (Oenoki, 1997), learners are allowed to interact with the material. A question is posed at the end of the section and the learner can answer the question. The advantage of this is that the learner is given immediate feedback. The shortfall of this is that the learner will not be able to identify the mistake made should the answer be incorrect. This example is only meant to illustrate that the Internet can encourage learners to learn at their own pace and that it is possible to give immediate feedback to the learner.

Section 4. Velocity-time Graph

A **velocity-time graph** shows the relationship between velocity and time. For example, if a car moves at constant velocity of 5 m/s for 10 seconds, you can draw a velocity-time graph that looks like this:



The area below the line represents the displacement the object traveled since it can be calculated by xy, or (time * velocity) which equals (sic) to displacement.

QUESTION: Calculate the distance traveled by the car.

m

In the second example, which is a section taken off another website http://www.can-do.com/uci/lessons98/Periodic.html (Swain, 1998) learners are given a research assignment where they have to choose an element that appears on the Periodic Table. Using the Internet as a source of information, they are expected to present their findings based on assessment guidelines given by the teacher. An assessment rubric is also included, clearly informing the learner what the teacher expects.

Your task:

A. Choose an element you want to research and follow the assignment guidelines. (grading rubric is included)
B. Use at least three sources from the internet to obtain your information.
C. Present your project on poster board (assignment guidelines for specific instructions are below)

Assignment Guidelines:

1. Use poster board or foam board to illustrate the element.
2. Neatness includes using a ruler to draw straight lines and using computer print programs or stencils to produce clean clear printing.
3. Make a key indicating the nucleus, orbitals, protons, neutrons, and electrons.
4. Include physical properties of the element (description of what the element looks like, density, melting point, state of matter, metal, non-metal, metalloid, crystalline structure, hardness...etc...)
5. Include chemical properties of the element (description of how the element reacts with other elements such as: whether an element is corrosive, combustible, or flammable)
6. Include the element's group number and family name
7. All the isotopes for that element will be illustrated. Show the number of protons, neutrons, electrons, orbitals, and isotope formulas for each illustration. (look at chart in textbook or internet to find isotopes)
8. Make a Lewis drawing with an explanation of what this drawing tells the person reading the chart.
9. Name some commonly identified molecules with this element in it. Give historical information:
   Who discovered it?
   Where was it discovered?
   When was it discovered?
   What are it's uses? (sic)
   When was it discovered?

Procedure (Use the web sites in section below to complete the following 7 steps)

1. Select an internet link (by clicking the mouse)
2. Select the element that you want to research (by clicking the mouse on the box which provides detailed information of the element you are researching)
3. From this menu of information record specific data for each component on your structured chart.
4. Select two more internet links and repeat steps two and three.

5. Summarize the information collected from the three resources.
6. Organize your work according to the assignment guidlines on the structured chart.
7. Construct the illustrated chart as shown in the format.

Click on two or more of the links below to complete steps 1-7

http://www.chem4kids.com/elements/index.html
http://www.shef.ac.uk/~chem/web-elements/B/key.html
http://tqd.advanced.org/3310/higraphics/textbook/u04tofc.html
http://chemlab.pc.maricopa.edu/periodic/periodic.html

Rubric for Grading

Content
40 pts possible

Diagram of the atom (Bohr model)

Key for identifing the model

Lewis drawing of atom with explanation of what this shows you

Isotope drawings for the element you are researching
(indicating protons, nuetrons (sic), electrons and isotope formulas)

Artisitc (sic)
20pts possible ______

Colour

Labeled/Titles

Neat Prsentation (sic) (printing, computer printed, stenciling, straight lines)

Material Organized

Accuracy
20 pts possible ______

Historical Data
20pts possible ______

Family name and group number Physical Properties (such as: state of matter, density, melting point, metal, non-metal, metalloic, characteristics...) Chemical Properties (How does it react with other substances? corrosive, flammable, reactive, non- reactive) Report on information one of the choices below: Choice A: Who discovered it, When was it discovered, What is it used for? (or) Choice B: Identify some common molecules with this element in it. **Total number of points ________** **100** **Grade = ______**

These two examples demonstrate that it is possible for a teacher to allow for learning to take place through the use of the Internet. I am not suggesting that teachers should leave the learners to fend for themselves, but rather that teachers should control the environment in which learning can take place effectively. What is evident to me is that the learner is able to interact with material that is presented in a variety of different formats, which in my opinion can only benefit the learner. The added benefit of using the Internet is that in some cases, depending on the quality of the material presented on the website, learners are able to receive immediate feedback.

2.6.3 Word processors

Very little research has been done on the use of word processors in science (Scaife *et al*, 1997:76). This is somewhat ironic since most learners' first encounter with computers is through the use of word processors.

Tebbutt (1997:91) states that although the word processor is the most widely available computer application, its use in science lessons is routine and non-challenging. Tebbutt believes that using the word processor contributes greatly to the development of the learner's communication skills. These skills are important since "(w)riting is the means by which pupils learn much of their science, and by which they usually demonstrate their knowledge and skills". Potts (in Tebbutt, 1997:91) identifies three different skills that can be enhanced in learners through the use of word processors in science education. They are presentation, productivity and cognitive skills. Learners could demonstrate their presentation skills when they write up their reports on practical work done in class. At the same time their communication skills would improve with the assistance of the spell checker. As a result their writing skills would be developed further.

Scaife *et al*. (1993:75) reports that no evidence exists which support the concern of some people who argue that the handwriting skills of learners who use a word processor, are stunted. Clough (in Scaife *et al*, 1997:76) has documented the following positive effects demonstrated by his learners when they wrote up their science investigations: The learners were motivated, displayed greater attention to detail and the quality of their write-up improved dramatically.

2.6.4 Microcomputer-based Laboratories (MBLs)

Tinker and his colleagues at TERC (Technical Educational Research Centres) experimented with applications of microcomputers in the laboratory in the late 1970's

(Nakhleh, 1994:369; Tinker, 1981:94). They believed that by the time their learners would enter the job market, microcomputers would be present and that their learners would have to know how to apply computers in their work environment (Tinker, 1981:94). As a result of their work, many educational researchers regard Tinker and his colleagues as the pioneers in the application of microcomputer-based laboratories in science education (Lehman & Campbell, 1991:4; Nakhleh, 1994:369).

Microcomputer-based laboratories (MBLs) are defined as devices that collect and store data, with various sensors, and convert that data into graphs in real time (Lapp & Cyrus, 2000:505; Nakhleh, 1994:368; Tinker, 1987:469).

Picture 1: A microcomputer-based laboratory (TRAC SA, 2004).

The MBL consists of different sensors that are connected to a computer through a digital interface. The interface is able to convert the signal, which it receives from the sensor, to a signal that can be interpreted by the computer. Different sensors exist which are able to measure different physical quantities such as displacement, velocity, acceleration and temperature. In the case of the TRAC PAC, the motion sensor only measures displacement with respect to time. This sensor measures the displacement with respect to time by sending out high-frequency pulses, which strikes an object and is reflected towards the sensor. The computer then measures the time between the transmitted and received pulses, and calculates the displacement and derives the velocity and acceleration of the object causing the reflection. This data gathered by the computer is then displayed immediately as a graph on the computer screen and can be saved on the computer so that the learners can analyse the data at a later stage (Thornton & Sokoloff, 1990:858-859).

Motion Sensor

A device that measures the distance to the closest object. This is accomplished by emitting pulses and measuring the time for these pulses to be reflected.

Force Probe

A device capable of measuring the magnitude of an applied force.

Microphone

This device is capable of converting sound into an electrical signal so that it can be used by a computer for calculations.

Sound Level Meter

This device measures the amplitude or intensity of the surrounding sound (This does not connect to the computer).

Digital Interface

This box provides the functionality of converting the signals from the sensors to a format that can be used by the computer.

Picture 2: Different types of sensors used in MBLs (TRAC SA, 2004).

Thornton and Sokoloff (1990:858) are convinced that MBLs are easy to use, even by those who have never worked with a computer before. Besides the ease with which learners can use MBLs, many other researchers have documented the positive effects associated with the use of MBLs in science education. Bross (1986:17), Krajcik *et al*. (2001:2), Lam (1995:2), Lapp & Cyrus (2000:505-507), Nakhleh (1994: 369), and Tinker (1987:473) all provide evidence to confirm that learners display positive attitudes when using MBLs. Their findings indicate that the learners' scientific process skills, self esteem, learner achievement and cognitive development are all enhanced as a result of using MBLs. Through the collection of raw data and the instantaneous generation of real time graphs, the learner is able to understand real life phenomena and is able to link concrete reality with the abstract. The graphical results displayed on the screen, shift the emphasis away from calculation techniques towards interpretation of data so that more effective learning takes place. The tedious, time consuming manual plotting of graphs is eliminated as the learners become actively engaged in analysing the data. Those who argue that the manual plotting of graphs is essential will realise that their argument contradicts that of Barton (1998:367), whose research lead him to conclude that he saw "…no benefit to pupils to plot graphs manually"[10]. McFarlane, Friedler, Warwick and Chaplain (1995: 477) find that the positive effect associated with the use of MBLs is not only confined to high school learners. The reading and interpretation of temperature vs time graphs in 7-8 year old learners are also greatly enhanced when using MBLs. The fact that the graph is displayed instantaneously, contributes positively to the learners'

[10] I do not agree with Barton's conclusion.

understanding of the concepts being learned. Brasell is quoted by many (Lapp & Cyrus, 2000:505; Helgeson, 1988:3 and Solomon, Bevan, Frost, Reynolds, Summers and Zimmerman, 1991:345) in noting that even a 20-30 second delay between the completion of the actual event and the generation of the graph is detrimental to the cognitive development of science concepts.

Russell, Lucas and McRobbie (1999:5) refer to the predict-observe-explain (POE) strategy that has been used successfully by learners to construct understanding of physical phenomena. Krajcik *et al*. (2001:3) and Riche and Dawe (2001:6) have found that learners' concept development is greatly enhanced when learners are required to make predictions prior to becoming engaged in an MBL activity.

Therefore, MBLs, in theory, should be an excellent resource to be used by teachers to improve the understanding of science concepts by their learners.

Duguet (1990:172) and Lapp and Cyrus (2000:509) recommend that further research is needed so everyone can understand the pedagogical advantages of MBLs. This will inform others of possible solutions to problems that are inevitable with the use of microcomputers in science education. This will ensure that we all know how best to use microcomputers for better learning and prevent situations from arising where microcomputers in education become a burden to teachers and an obstacle to learning. Hlynka and Mason (1998:48) advise us " ...to stop for a moment in the mad dash to get the latest educational tool which is bigger, better, and faster than the last one. Instead we should step back and look critically at what we are doing". Maybe what they are trying to say is that learners should not use computer data gathering equipment until they at least know how to use a meter stick (Snyder, 1990:171).

Through this research I wanted to determine the optimal use of the TRAC PAC (an example of a MBL) in science education in Western Cape schools. I am hopeful that this will provide solutions to the problems experienced with the use of the TRAC PAC and thereby contribute to a better understanding of the educational benefits of microcomputer-based laboratories.

CHAPTER 3

RESEARCH METHODOLOGY, TECHNIQUES, SETTING AND SAMPLE

3.1 INTRODUCTION

As discussed in Chapter One, the research done by TRAC SA showed that the TRAC PAC was not being utilised optimally at schools. There was also a need to investigate what happened when learners visited the TRAC laboratory. As a result, two questions arose, which I attempted to answer.

- What were the practical realities experienced by teachers and learners when using the TRAC PACs at schools and at the TRAC laboratory?

- What were the learners' experiences while participating in activities using a TRAC PAC, and how well did they perform in class after these experiences?

The aim of the research was to gather information to determine the effectiveness of the TRAC PACs at the TRAC laboratory and at the schools. It was important to document what actually happened when a group of learners visited the TRAC laboratory for the first time and completed an activity worksheet designed by the TRAC research team. This was done in order to identify the strengths and weaknesses of the TRAC PAC at the laboratory so that it could be used optimally in future. I also wanted to document how the

TRAC PAC was being used in school classrooms, so that the shortcomings could be highlighted. This would help teachers to improve their use of the TRAC PAC.

The research methodology that I used to answer these questions will be discussed in this chapter.

3.2 RESEARCH METHODOLOGY

3.2.1 Qualitative and Quantitative Research Methodologies

The aim of this research was to find answers to the research questions stated in the introduction to this chapter[11]. To do this, I needed to gather data which would help me to answer the specific research questions. Leedy (1993:139) quite clearly stipulates: "the nature of the data and the problem for research… will prescribe what research methodology to use". Therefore, the type of data to be collected and the research problem highlighted above, determined the specific research method that I needed to follow.

The literature review informed me that there are two main ways of collecting data. These are broadly categorised as quantitative and qualitative research methodology. According to Leedy (1993:142), qualitative research can de defined as being "... concerned with human beings: interpersonal relationships, personal values, meanings, beliefs, thoughts and feelings. The qualitative researcher attempts to attain rich, real, deep, and valid data and, from a rational standpoint, the approach is inductive". The quantitative researcher on the other hand tends to "...manipulate variables and control natural phenomena. They construct hypotheses and 'test' them against the hard facts of reality" (Leedy, 1993:143).

[11] Refer to section 3.1

Qualitative research is a relatively new method of research. It rose to prominence in the 1960's (Leedy, 1993:139). At that stage quantitative research was considered to be the only method that could be employed to provide reliable data about a specific event. According to Leedy (1993:140), many believed that: "If it's not experimental, empirical or statistical, it's not research". Therefore, many academic researchers frowned upon qualitative research methodology. Even though there is much debate on which research method is more reliable, it is not my intention to discuss this issue. I believe that each method has value for the researcher. This is highlighted in the table, taken from Fraenkel and Wallen (1993:380) that appears below.

Quantitative Methodologies	Qualitative Methodologies
Preference for precise hypotheses stated at the outset	Preference for hypotheses that emerge as study develops
Preference for precise definitions stated at the outset	Preference for definitions in context or as study progresses
Data reduced to numerical scores	Preference for narrative description
Much attention to assessing and improving reliability of scores obtained from instruments	Preference for assuming that reliability of inferences is adequate
Assessment of validity through a variety of procedures with reliance on statistical indices	Assessment of validity through cross-checking sources of information (triangulation)
Preference for random techniques for obtaining meaningful samples	Preference for expert informant (purposive) samples
Preference for precise description of procedures	Preference for narrative/literary description of procedures
Preference for design or statistical control of extraneous variables	Preference for logical analysis in controlling or accounting for extraneous variables
Preference for specific design control for procedural bias	Primary reliance on researcher to deal with procedural bias
Preference for statistical summary of results	Preference for narrative summary of results
Preference for breaking down of complex phenomena into specific parts for analysis	Preference for holistic description of complex phenomena
Willingness to manipulate aspects, situations, or conditions in studying complex phenomena	Unwillingness to tamper with naturally occurring phenomena

Table 7: Characteristics of Quantitative and Qualitative Research Methodologies [Fraenkel & Wallen, 1993:380].

Fraenkel and Wallen (1993:380) believe that research in education should be a mixture of quantitative and qualitative methods. This idea is also shared by Goodwin and Goodwin (in Leedy, 1993:143) who say that academic discourse agrees that each method has merit and that there is a tendency to combine these approaches in a single study. Kidder and Fine (in Merriman, 1988:2) note that there "...is nothing mysterious about combining quantitative and qualitative measures. This is, in fact, a form of triangulation that enhances the validity and reliability of one's study".

3.2.2 Qualitative Case Study

I chose to use the qualitative case study approach because I believe that my research satisfies the following criteria identified by Merriam (1988:9):

A **The research was guided by the nature of the research question:** How was the TRAC PAC being used in the classroom and in the TRAC laboratory? This enabled me to identify factors that promote the optimal use of the TRAC PAC.

B **The research was governed by the amount of control**. In my research, I had limited control over what happened in the classrooms and in the TRAC laboratory.

C **The desired end product steered my research**. I did not want to manipulate variables but merely aimed to provide a detailed description of the use of the TRAC PAC in the TRAC laboratory and in the classrooms.

D **The research was conducted within specific parameters**. The research was conducted in particular venues (the TRAC laboratory and classrooms) and the activities were clearly specified.

In addition to these criteria, I took my research one step further by using "...many cases to study the same phenomenon" (Merriman, 1988:174), although with different learners. Since my research satisfied the above criteria, I can argue that I conducted numerous qualitative case studies of the same event.

3.2.2.1 Characteristics of a Qualitative Case Study

The characteristics of a qualitative case study, according to Merriman (1988:11-15), are:

A **Particularistic**. This implies that when one uses case studies to gather data, one gives attention to a "...particular situation, event, program or phenomenon". My focus was on a specific group of learners, participating in a certain event (using the TRAC PAC) and I was able to take a holistic view of the event.

B **Descriptive**. This means that the final report must be "... a rich, thick description of the phenomenon under study". I attempted to explain the findings of the research descriptively rather than numerically, although some quantitative data was also used.

C **Heuristic**. "Previously unknown relationships and variables can be expected to emerge from case studies leading to a rethinking of the phenomenon being studied. Insights into how things get to be the way they are can be expected to result from case studies". It was my intention to highlight what actually happened when the TRAC PAC was used.

D. **Inductive**. From the examination of data gathered during the research, certain "...generalizations, concepts or hypotheses emerge…" The emphasis of inductive reasoning is to discover "... new relationships, concepts and understanding, rather than verification of predetermined hypotheses..." It was my intention to share the findings that emerged from the data with others.

3.2.2.2 Definition: Qualitative Case Study

My chosen research method was a qualitative case study, which Merriam (1988:16) defines as "... an intensive, holistic description and analysis of a single entity, phenomenon or social unit. They are particularistic, descriptive, and heuristic and rely heavily on inductive reasoning to handle multiple data sources". In this instance, the 'case' was the interaction of learners (and teachers to a lesser degree) with the TRAC PAC in different environments, i.e. the TRAC laboratory and their own classroom.

3.2.2.3 Validity and Reliability of Qualitative Case Studies

> "Because what is being studied in education is assumed to be in flux, multifaceted, and highly contextual, because information gathered is a function of who gives it and how skilled the researcher is at getting it, and because the emergent design of a qualitative case study precludes a priori controls, achieving reliability in the traditional sense is not only fanciful but impossible. Furthermore ... replication of a qualitative study will not yield the same results". Therefore, "... rather than demanding that outsiders get the same results, one wishes outsiders to concur that, given the data collected, the results make sense- they are consistent and dependable" (Merriam, 1988:171-172).

Merriam (1988:171) argues that it is difficult to separate validity and reliability when conducting research. This means that one cannot have validity without reliability and vice versa (Guba and Lincoln in Merriam, 1988:171). Ratcliff (in Merriam, 1988:167) contends that "…there is no universal way of guaranteeing validity; there are only ‘notions of validity’". Merriam therefore identifies six basic strategies that a qualitative case study researcher can employ to enhance the validity and subsequently reliability of his or her research. I attempted to address these issues in my research.

A **Triangulation**. Fraenkel and Wallen (1993:400) define triangulation as being a process that involves the use of a number of different data-gathering instruments to validate the research findings. Mathison (in Merriam, 1988:169) takes this further by pointing out that triangulation should not be considered to be "... a technological solution for ensuring validity..." but that it should rather rely "... on one's holistic understanding of the situation to construct plausible explanations about the phenomenon being studied". I addressed this issue by using a variety of data collection techniques. These included:

- observations,
- interviews,
- questionnaires,
- worksheets, and
- a paper-and-pencil test.

These will be discussed later[12].

B **Member checks**. Merriam (1988: 169) says that member checks occur when the researcher takes the data collected and his/her interpretations of the data "... back to the people from whom it was derived and asking them if the results are plausible". It was not possible for me to do comprehensive member checks. The reason for this was that the learners had left school and I was not able to contact them. Of the three teachers that were interviewed, two had left the teaching profession and the remaining teacher was satisfied with the interpretation of the interview. I did, however, consult with the TRAC facilitator, who was present during my tests at the TRAC laboratory, to verify the findings.

C **Long-term observation** improves the validity of the results of the research when the data is collected through "... repeated observation of the same phenomenon..." I believe that I was able to address this issue by observing the same activity being performed by different learners on different days.

D **Peer examination**. According to Merriam, this implies that the researcher should ask "... colleagues to comment on the findings as they emerge". I believe that this was accomplished through receiving feedback from my supervisor as well as receiving feedback from the presentation of these findings at the following conferences: The Education Association of South Africa (EASA) conference of 2003, the South African Association for Research in Mathematics, Science and Technology (SAARMSTE) conference of 2004 and the South African Association of Science and Technology Educators (SAASTE) conference of 2004.

E **A participatory mode of research** requires that the researcher should involve "... participants in all phases of research from conceptualizing the study to writing up the findings". This was made possible through engaging in discussions with my supervisor, the TRAC research team and to a certain extent the teachers and learners who participated in the research.

F **Researcher's bias**. When one collects data and analyses it, it must still be interpreted. This interpretation of data is dependent on the researcher's bias. It was not possible to be completely aware of all my biases while conducting this research. However, I was aware of the influence that the researcher's bias could have on my research. Fraenkel and Wallen (1993:402) state that all researchers have certain biases. "No one can be totally objective, as we are all influenced to some degree by our past experiences, which in turn affect how we see the world and the people within it". Since I did not stand to gain personally in any respect from this research, it was relatively easy to interpret the data in a reasonably objective manner.

In view of my efforts to implement the above-mentioned strategies, I believe that my findings are as valid and reliable as this type of study allows.

---

[12] Refer to section 3.3

3.3 DATA COLLECTION TECHNIQUES

Merriam (1988:10) states that case studies do "… not claim any particular methods for data collection or data analysis". I used a variety of techniques, which will be discussed briefly, to gather the data needed to answer my research questions. These resulted in both qualitative and quantitative data.

3.3.1 Observation

Observation of the interaction between learners, between learners and the TRAC PAC was done at the TRAC laboratory and at the two schools that I visited while conducting my research.

The literature reviewed suggests that observation as a data gathering tool in qualitative case study research is widely used (Fraenkel & Wallen, 1993:384; Leedy, 1993:185, Merriam, 1988: 87). My aim was to use this data to provide rich descriptions of the 'case' to be studied. In this instance it referred to the use of the TRAC PACs at the TRAC laboratory and at the schools.

However, critics of observation as a data gathering tool "... point to the highly subjective and therefore unreliable nature of human perception" (Merriam, 1988:88). Cohen and Manion (1994:110) indicate that the findings that are revealed through observation are criticised as being "...subjective, biased, impressionistic, idiosyncratic and lacking in the precise quantifiable measures that are the hallmark of survey research and experimentation".

Beside these issues, there is also the concern that the researcher cannot scrutinise everything (Merriam, 1998:90). Therefore, the researcher is concerned with: how much he or she should record of the observations, how often those recordings should take place, whether the researcher's presence will influence the actions of the learners under study and whether the researcher's observations will not be influenced by his or her own biases (Merriam, 1988:94-95; Cohen *et al*. 1994:112).

There are no clear-cut answers to address these concerns of researchers. In fact, Merriam (1988:97) concludes that "every researcher devises his or her own technique for remembering and recording specifics of an observation". Cohen *et al*. (1994:112) recommends using Lofland's suggestions when collecting data through observation. I implemented the following of these suggestions during my observations:

- I tried to record the notes as quickly as possible after the observations were made. This was possible because the TRAC facilitator was present to attend to any difficulties that might have arisen with the TRAC PAC in my absence.

- The notes that I made were purposefully detailed so that I could obtain a fair reflection of the 'case' long after the observations were made.

- Lofland does not mention this point, but I also used a video and audio recorder during the observations as suggested by Reid (in Merriam, 1988:88). This was particularly useful, because it supplied additional information regarding participation and facial expressions.

There were times during the observation when I acted exclusively as an observer. According to Merriam (1988:93) and Fraenkel and Wallen (1993:384) this is when the researcher "... observes the activities of a group without in any way becoming a participant in those activities". There were times when I had to intervene and assist the learners with the use of the TRAC PAC or assist them with understanding certain concepts of Physics. In these cases I acted as an observer-as-participant. According to Fraenkel *et al*. (1993:384), this is when the researcher informs everyone that he or she is a researcher, "…but makes no pretense of actually being a member of the group…" which is being observed.

There is no specific method that a researcher can follow which will guarantee that the observations are valid and reliable beyond all doubt. This is one of the major criticisms of observation techniques as mentioned earlier. However, notwithstanding all the concerns mentioned above, Diener and Crandall (in Merriam, 1988:182) offer the following advice: "There is simply no ethical alternative to being as nonbiased, accurate and honest as is humanly possible in all phases of research", and this is what I strove to achieve. Details of the observations taken during my study are given later.

3.3.2 Interviews

Immediately after the learners had completed the activity using the TRAC PAC, I asked the teacher, who had accompanied the learners to the TRAC laboratory, to identify learners whom I could interview. Merriam (1988:77) agrees that when one needs to identify candidates who could be interviewed, the researcher could "... begin with a key person who is considered knowledgeable ... and then ask that person for referrals". In total six learners and three teachers were interviewed independently at the TRAC laboratory, in a room adjacent to the laboratory. Interviews were also conducted with three learners and two teachers from the two high schools where the research was conducted. In all cases an audio recorder was used with the permission of the interviewees.

Patton (in Merriam, 1988:72) states that "...we interview people to find out from them those things we cannot observe directly". Interviews are a common method used mainly by qualitative researchers to gather data on their research question (Merriam, 1988:71). I therefore believed that it could form an effective part of my research methodology.

I chose a combination of semi-structured interviews and unstructured interviews. I decided to follow this strategy as I did not know enough about the TRAC laboratory at the time of the research in order to ask the appropriate questions (Merriam, 1988:74). I started with a few questions or raised topics that I wanted to explore. I did not write down the exact wording or the order of the questions before the time (Merriam, 1988:74). I then relied on my ability to further explore the answers that the interviewee provided.

Merriam (1988:75 and 78) argues that the type of questions asked and the interaction between the interviewer and the interviewee, will determine how successful the interview, as an instrument, will be to gather quality data. The interaction results in a mixture of the interviewer and interviewee's own biases that are brought together during the interview. This could distort the collected data. To combat this, Merriam (1988:75) argues that the interviewer could minimise his or her biases by "being neutral, nonjudgmental no matter how much a respondent's revelations violate the interviewers own standards". As regards the interviewee's biases, the researcher can compare the interviewee's responses with those given by other interviewees. Merriam (1988:84) tells us that the responses of an interviewee are merely their own perception of the situation and that "this personal perspective is what is sought in qualitative research".

When I interviewed the learners and teachers I was constantly aware of these issues. I tried to be as honest and nonjudgmental as possible. I also tried to ask the type of questions relevant to my research.

3.3.3 Questionnaires

Two different questionnaires were designed. One questionnaire was designed for the grade twelve Physical Science teachers whose learners participated in the research. The second questionnaire was designed for those grade eleven and twelve learners who participated in the research at the TRAC laboratory.

The motivation behind using questionnaires in this case study was to "...gather simple information on *what people do or have done*...and *what people know*" (Brown and Dowling, 1998:69).

The teacher questionnaire focused on two areas. Firstly, it wanted to find out specifically what Physical Science teachers did when completing practical activities in their classrooms and taking their learners on educational school outings. Secondly, I wanted to determine the level of the Physical Science teachers' computer literacy skills. Through this questionnaire, I wanted to gain some insight into what motivated a teacher to bring his or her learners to an educational centre such as the TRAC laboratory.

The design of the questionnaire consisted mainly of "...selection-type items ... and supply-type items" (Fraenkel and Wallen, 1993:113). An example of the selection-type items used in the teacher questionnaire is: *Which is the most common destination for school outings? Please tick (✔) the appropriate box.*

a) lecture ☐

b) revision classes ☐

c) practicals ☐

d) exhibitions ☐

e) other (please specify) .... ☐

An example of a supply-type item used in the teacher questionnaire is: *Would you use a computer in your physical science classroom?*

Yes .... No.............

Supply a reason ....

The learner questionnaire was designed to gather information about what the learners had done during their participation in the activities at the TRAC laboratory. The questionnaire consisted of supply-type items. An example of one found in the learner questionnaire is: *What role did you play in the group? Please tick (✔) the appropriate box. You may tick more than one box.*

a) Read instructions ☐

b) Set up apparatus ☐

c) Record observations ☐

d) Use the mouse to click "start" ☐

e) Other (please specify) ....
.... ☐

Those teachers who had accompanied their learners to the TRAC laboratory completed the questionnaire at the laboratory and handed it in to me once they had completed it. Those teachers who had not accompanied their learners to the laboratory were given the questionnaire when their learners were collected at school. The completed questionnaire was collected from them when their learners returned to school later that same day. The learners completed and submitted the questionnaire individually at the laboratory, after they had completed the activity (-ies) using the TRAC PAC.

The construction of these questionnaires was done in consultation with a lecturer in Physical Science Didactics at Stellenbosch University. This was done to ensure that the questionnaires contained questions that were fair, reliable and relevant to this study.

In essence, the information gathered from the questionnaires were used in conjunction with the data collected from using other techniques to provide detail on the optimal use of the TRAC PAC.

3.3.4 Worksheets

The TRAC research team compiled the worksheets that were completed by the grade eleven and grade twelve learners who participated in this research. These worksheets were compiled in response to teachers' demands for syllabus-related activities, as mentioned in Chapter One. These worksheets consisted of instructions for the learners to follow, when using the TRAC PAC, as well as a series of questions which were used to test learners' understanding of the science concepts that they were supposed to have mastered through the use of the TRAC PAC.

The grade eleven learners were given a worksheet called 'Activity One: Reference points and directions'[13]. The grade twelve learners were given three worksheets to complete. These were called:

1. Activity Two: The relationship between mass and acceleration[14]
2. Activity Three: The relationship between resultant force and acceleration[15]
3. Activity Five: Free fall[16].

I collected all the worksheets completed by the learners and marked them using a memorandum. The responses to these worksheets will be discussed later[17].

---

[13] Refer to appendix D
[14] Refer to appendix E
[15] Refer to appendix F
[16] Refer to appendix G
[17] Refer to section 4.1.2, 4.2.2 and 5.1.2

3.3.5 Paper-and-pencil test

Once the learners had completed the worksheets, they were asked to complete a short paper-and-pencil test individually. The emphasis of the grade twelve test was to determine the learners' ability to recall certain key concepts after they had engaged with the TRAC PAC. The emphasis of the grade eleven test was to determine whether learners could apply the skills and knowledge learned, after interacting with the TRAC PAC, to a new context. The results are discussed later[18].

3.4 RESEARCH SETTING

3.4.1 At the TRAC laboratory

In 2000, when the research started, the TRAC laboratory was still in its pilot stage. It consisted of a relatively large room that had two distinct sections. On the one side of the room, four TRAC PACs were set up as four workstations separated from one another by long workbenches. Not more than five learners were accommodated at each station. This meant that I could only work with a maximum number of twenty learners at any one time.

[18] Refer to section 4.1.3, 4.2.3 and 5.1.3

Picture 3: This picture was taken after the research had been conducted at the TRAC laboratory.

The other side of the room consisted of seating for twenty learners, which was where they completed the questionnaires and paper-and-pencil tests individually. Later this area was developed to accommodate twenty-four individual computer stations.

Picture 4: TRAC laboratory with computer stations after the research had been conducted.

Transport from and back to the schools for the learners was arranged by Stellenbosch University. I drove the mini-bus which the university made available.

On arrival at the laboratory, the learners were welcomed and thanked for their willingness to participate in the research project. They completed the register and were asked to wear nametags. Then they were informed why they were at the laboratory. They were told that this research project needed their (learner) input. Since the TRAC PAC had been introduced into the science classrooms in Western Cape schools, the question that needed to be answered was how we could best utilise this new technology in our schools. The learners were asked to be honest in their comments on their experiences. Their permission to use video and audio recording was also obtained. The learners were then asked to stand around one TRAC PAC, while I demonstrated its use.

The grade eleven learners were only required to complete one activity i.e. ‘Reference points and directions’, and I gave them a brief overview and demonstration of the activity. The learners were then asked to divide themselves into groups of no more than five learners per group. Each group worked at one of the four workstations, and the activity was set up so that all four groups of learners could complete the same activity at the same time. Learners were then required to follow the instructions on the worksheet and to answer the questions as they proceeded through the activity. During this time I was busy observing and conducting interviews. Once the learners had completed the activity, they were asked to complete a paper-and-pencil test as well as a questionnaire. On completion of these activities, the learners were taken back to their school.

The grade twelve learners were expected to complete three activities, namely activities two, three and five. Each workstation could only accommodate one of these three activities. As a result, the groups of learners had to rotate through the different workstations, once they had completed their activity, and had to proceed to the next workstation until all three activities had been completed. The grade twelve learners then followed a similar procedure to that completed by the grade eleven learners as mentioned above.

A TRAC facilitator, who was a member of the TRAC research team, was present in the TRAC laboratory while the learners were performing the different activities. The role of the facilitator was to help the learners with the different activities, as I was not always available to help the learners while collecting my own data.

3.4.2 At the high schools

At the time of this research I was a Physical Science teacher at a high school. I was not able to get study leave from the WCED to conduct this research. As a result, I had to conduct this section of my research part-time. I was fortunate enough to have a principal who allowed me time to leave the school on certain days in order to collect data. This definitely impacted on the type of data I was able to collect, as the time given to me to leave school was very limited. Therefore, in consultation with my supervisor, it was decided that I should focus on only two high schools.

One of the high schools where the classroom-based research was conducted was situated in Mitchell's Plain while the second school was situated in Paarl. In terms of their matriculation pass rates, both schools were considered to be top performing high schools at the time of this research project.

The Physical Science classrooms, where I was able to conduct my research, were situated on the first floor of each of the school buildings. The classrooms were designed to accommodate a maximum of thirty learners. Both classrooms had a storeroom where the TRAC PAC was kept. One of the teachers informed me that she was taking a risk in keeping the TRAC PAC in her class since the class did not have burglar bars and it was not protected by an alarm. It was too much effort to take the computer at the end of the day to the strong room that was situated in the principals' office. The other school was fortunate enough to have an alarm system installed in the classroom, which gave the TRAC PAC a reasonable measure of security. In both instances, the monitors, hard drives and keyboards were placed on top of a large, permanently fixed table, in front of the class.

Picture 5: TRAC PAC placed in front of class. The Physical Science teacher explains the procedure to be followed by the learners.

The classroom of one school was furnished with tables and chairs, with two learners seated at each table. The tables were arranged in two rows, facing the front of the classroom, with an aisle between the two rows. This aisle was used by the learners to move about freely while conducting the practical activity. In the classroom of the second school, individual groups of learners sat around two tables each, forming a total of six working groups.

3.4.2.1 The criteria for the selection of these two high schools.

- The schools had to be in possession of a TRAC PAC.

- The Physical Science teacher of the school where the data was to be collected had to have been using the TRAC PAC for at least three months prior to participating in this research.
- The schools had to be situated in previously disadvantaged communities.
- Permission from the principal of the school where the research was to be conducted had to be obtained.
- Permission from the Physical Science teacher to conduct this research in his/her classroom had to be obtained.
- Permission from my principal had to be obtained for me to leave school only at a time that did not interfere with my teaching schedule and administrative duties. At that time I was teaching 45 out of 49 periods a week. This left me with 4 "free" periods a week.

3.4.2.2 Obstacles experienced during this stage of the research.

- In order for me to visit a Physical Science classroom of another school during school hours, meant that I needed to synchronize my activities with those of the Physical Science teachers at the participating schools. The time when I was 'free' to leave school had to correspond with the same time when these teachers were teaching Physical Science. This became problematic. One school's timetable had changed twice within a period of six months due to teacher rationalisations. This in effect meant that the teacher had to make special arrangements with the learners in order to accommodate me.
- It was difficult to get a second school to agree to participate in this research. The school, which had initially agreed to participate, suddenly withdrew. It took a further six months to negotiate with a different school to participate in this research.

3.5 RESEARCH SAMPLE

TRAC SA had decided to focus its attention "... on schools in developing communities" (TRAC Annual Report, 1997:17). As a result, all the high schools that participated in the research met this criterion.

The research was conducted at the TRAC laboratory at Stellenbosch University as well as in the Physical Science classrooms of two high schools in the Western Cape.

When schools were identified to participate in the research at the TRAC laboratory, the following criteria were used:

- The schools had to be situated in previously disadvantaged communities in the Western Cape.

- The schools had to be situated as close as possible to the TRAC laboratory. There were four schools that satisfied this criterion. The remaining four schools were randomly identified. The schools were contacted telephonically, and the Physical Science teachers agreed to participate in this research. In total, eight high schools participated in the research at the TRAC laboratory.

The second part of this research was conducted in the Physical Science classrooms of two high schools. The following criteria were used when identifying the two schools:

- The schools had to be in possession of a TRAC PAC.

- The schools had to be situated in previously disadvantaged communities in the Western Cape.

- I had to receive permission from my principal to leave school, during normal school hours. I had to return to my school after the classroom visits were conducted to continue with my normal teaching duties. Even though I had received permission from my principal to conduct the research, permission was only granted on condition that it did not interfere with my teaching duties. This meant that I could only visit each school at a time when I was 'free' at school and when this coincided with the other teacher’s timetable. As a result, only two high schools could be accommodated. Another reason for conducting this research while teaching, was that it was difficult to obtain study leave for extended periods of time because there was no teacher(s) available to take over my classes.

3.5.1 Information about the learners that participated in the research

One hundred and four grade eleven learners and sixty-nine grade twelve learners from eight different high schools participated in the research at the TRAC laboratory. All these learners took Physical Science as a subject at school. In the other research sample where classroom visits were conducted at two different high schools, forty-four grade eleven learners participated in the research. The breakdown of the learner totals is as follows:

	TRAC Lab		**School**	**Total**
Learners	Gr 12	Gr 11	Gr 11	
Boys	28	42	27	97
Girls	41	62	17	120
Total	69	104	44	217

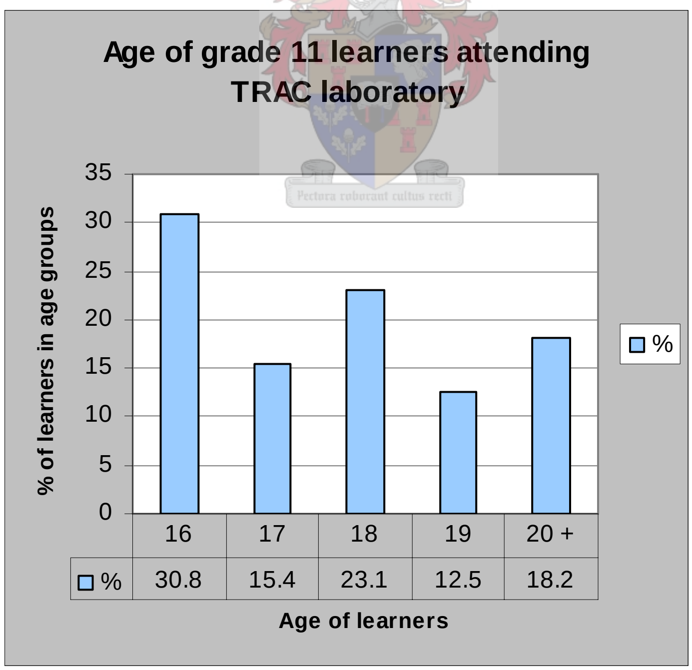
Table 8: Total number of learners who participated in the research at the TRAC laboratory and classroom visits.

It was not possible to determine on which grade (HG or SG) the learners had taken Physical Science. Even though I had asked the learners to indicate their grade on the questionnaire and the attendance register, they had all responded that they were either in grade eleven or grade twelve. When I approached the teachers informally about this issue after the research had been conducted, the teachers informed me that all the grade eleven learners were higher grade candidates, while the majority of learners in grade twelve were registered on the standard grade. Unfortunately, the exact totals were not available.

3.5.1.1 The age groups of the boys and girls at the TRAC laboratory

A Grade 11 learners

Forty-two boys and sixty-two girls participated in the grade eleven activity on reference points and directions[19] at the TRAC laboratory. The following graph represents the age groups of these learners.

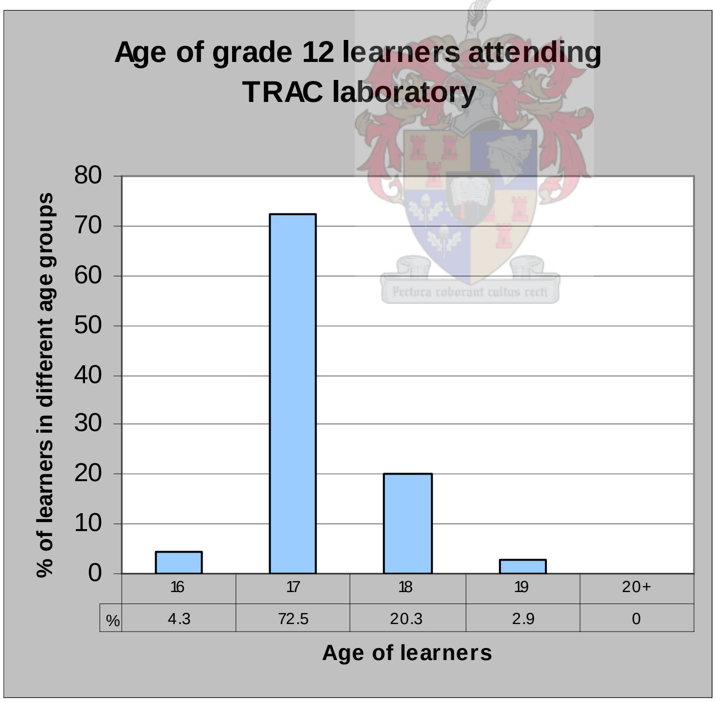


Graph 3: The age groups of the grade eleven learners that attended the TRAC laboratory.

From this graph it was clear that only 46,2 % of learners fell into the sixteen to seventeen year old age bracket whereas 53,8 % of learners was eighteen years old or older. This was interesting since it is normally accepted that a learner is sixteen to seventeen years old in grade eleven. It was surprising that the number of these older learners exceeded those of the learners who fitted the normal age group for grade eleven.

B Grade 12 learners

Twenty-eight boys and forty-one girls participated in the grade twelve activities[20]. The following graph represents the age group of these learners.



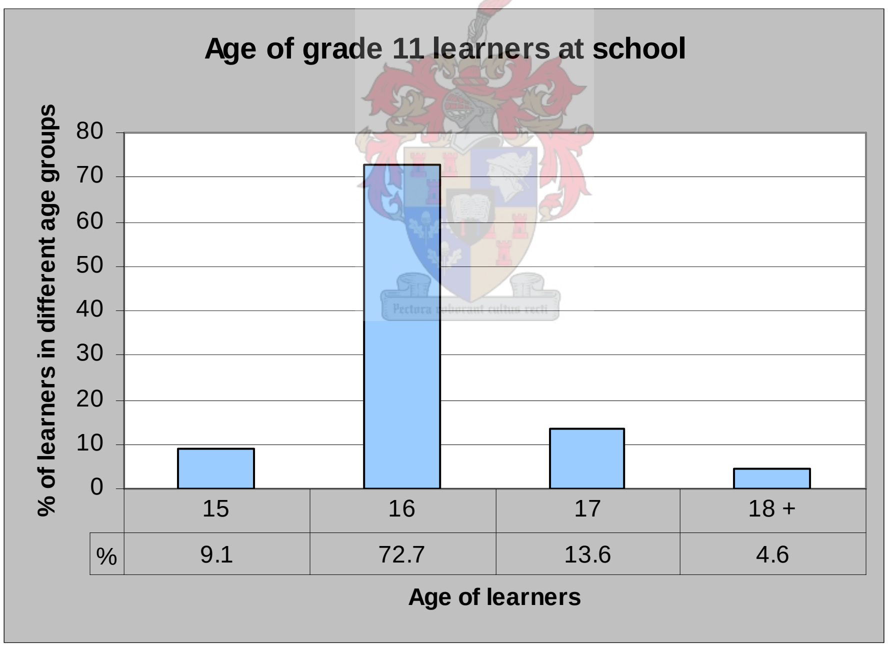
Graph 4: The age groups of grade twelve learners that attended the TRAC laboratory.

[19] Refer to appendix D
[20] Refer to appendices E, F and G for these activities

From this graph it was clearly evident that 72,5 % of the grade twelve learners that attended the TRAC laboratory was seventeen years old. This was to be expected since the normal school-going age for grade twelve learners is seventeen to eighteen years old.

3.5.1.2 The age groups of the boys and girls at the two high schools

As mentioned in section 3.5 above, I also visited two grade eleven Physical Science classrooms. Twenty-seven boys and seventeen girls participated in the grade eleven activity on reference points and directions[21]. The following graph represents the age groups of these learners.



Graph 5: The age groups of the grade eleven learners at the two high schools.

From this graph it was clear that 72,7 % of the grade eleven learners at both schools was sixteen years old. This is regarded as the acceptable school-going age for grade eleven learners.

[21] Refer to appendix D

CHAPTER 4

A CASE STUDY OF THE TRAC PAC AT THE TRAC LABORATORY

In this chapter, I describe the data that was collected at the TRAC laboratory where this section of the research was conducted.

4.1 DATA COLLECTED FROM THE GRADE 11 ACTIVITY

This chapter describes what actually happened when different groups of learners interacted with the TRAC PAC at the TRAC laboratory. The different techniques that were used to collect the data from the grade eleven activity are discussed.

The grade eleven learners participated in Activity One - reference points and directions[22]. This activity consisted of two parts. In Part One, the direction away from the motion sensor was chosen as positive and in Part Two of this activity, the direction towards the motion sensor was chosen as positive.

Learners had to try to imitate eight distinct displacement-time graphs by moving in front of the motion sensor. They were then expected to write down their observations in the space provided on the worksheet. Thereafter, they completed a paper-and-pencil test followed by a learner questionnaire. A few selected learners from particular groups were interviewed[23]. The following figure below (TRAC SA website, 2004), illustrates what the learners were expected to do.

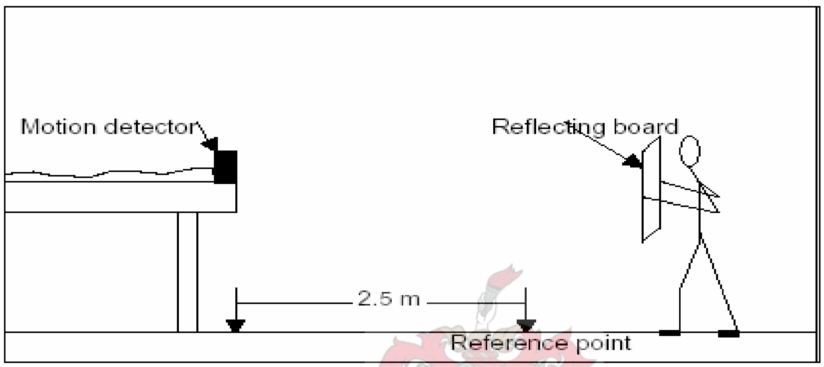


Figure 2: Set up of apparatus for Activity One.

4.1.1 Observations

4.1.1.1 First Observation

The first group to be observed consisted of two learners, a boy and a girl who were participating in Activity One (the learners will be named L1 and L2 respectively in the description below). The first part of the activity was referred to as: Part One – graph A. Here the learners had to learn that a horizontal line above the X-axis for a displacement

---

[22] Refer to appendix D
[23] Refer to section 3.3.2 for selection criteria

vs time graph implies that the motion of the learner is stationary in the direction chosen to be positive. The observation of this group is described below[24].

The learners positioned themselves close to the computer screen and started by reading the activity worksheet. L1 asked the facilitator what he should use to measure the 2,5 m. Even though the 1 m ruler was on the table, he needed the facilitator to help him. They measured the 2,5 m and made a line on the floor (reference point) using the piece of chalk that was supplied. I did not 'see' them trying to discuss the problem before trying to replicate the graph.

After drawing the chalk line on the floor, to indicate the reference point, L1 sat down in front of the computer while L2 took the piece of cardboard. L1 instructed L2 to stand on the chalk line. He clicked the "start" button using the mouse and told her to walk towards the sensor. The expected graph shape that appeared in the activity sheet did not appear on the computer screen. He then instructed her to go back to the chalk line and to walk in the opposite direction immediately once he clicked the "start" button. They did not get the expected graph shape to appear on the computer screen. A "distorted" graph shape appeared on the computer screen. L2 was instructed by L1 to try all sorts of variations such as lifting the board above her head, moving the board down slowly and then faster. This continued for four minutes.

I could see that they were confused and L2 told L1 to hold the board while she clicked the "start" button. L1 also first walked towards the sensor and then walked away from the sensor and lifted the board above his head. They still did not get the expected graph shape to appear on the computer screen. They did not attempt to ask for help. After another ten minutes, L1 called the facilitator. I then decided to join them and to take notes of what was being discussed.

The facilitator referred to graph A on the activity worksheet and asked L1 and L2:

[24] I have decided against placing the descriptions of this observation (and the observations that follow) in the appendix, as I want the reader to engage with my experiences of learners interacting with the TRAC

Facilitator: "*What does the horizontal line tell us about the displacement*"?

There was a lengthy pause, as they both seemed to be confused. The facilitator realised that they were not going to respond and proceeded to mark the X and Y-axis (inserting the numbers 1, 2, 3 and 4 at regular intervals). Then pointing with a finger along the horizontal line towards the Y-axis, he asked:

Facilitator: "What is the displacement now"?

L2: "*3 m*".

The facilitator continued to refer to the graph by tracing a finger along the X-axis and asked:

Facilitator: "What is the displacement at 2, 3 and 4 s"?

The both responded simultaneously "*3 m*".

The facilitator repeated the question: "What does the horizontal line tell us about the displacement"?

L2: "*The displacement remains the same*".

Facilitator: "What should your motion / movement be like to ensure that the displacement remains the same"?

L1: "*There should be no motion*".

The facilitator then left the group and they continued on their own. I continued to observe them. L1 then returned and sat down in front of the computer screen and told L2 to hold the board at chest height in front of her and to stand on the chalk line that was drawn on the floor. He then told her to walk away from the sensor and to stop. He then clicked the "start" button and the required graph shape appeared on the computer screen. They both smiled. L2 placed the board on the table and returned to her seat. L1 then wrote down his

---

PAC. I believe that this is an essential component of my research.

explanation of the movement completed by L2, in the space provided on the activity sheet. L2 also wrote down her observation after consulting with L1.

I then left the group, but continued to observe them, and became aware that they were struggling with graph C. Here the learners were required to obtain a straight-line graph starting from zero with a positive gradient of a displacement vs time graph and to understand that the graph implied movement at a constant velocity away from the reference point in a positive direction. I could see that the graph shape confused the learners. L1 was again sitting in front of the computer, while L2 was standing on the reference line with the board in her hands held at chest height. I observed that when L1 clicked the "start" button, L2 slowly lifted the board above her head, while she was standing still. They did not get the expected graph shape to appear on the computer screen. Again, she tried all sorts of variations of possible positions for the board, lifting the board above her head faster, moving the board down slowly and then faster. I then approached the learners and asked them to join me. I referred to graph C on the activity sheet. On the X-axis I filled in values 1, 2 and 3 at regular intervals. On the Y-axis I filled in the numbers 2, 4 and 6. Using my finger and placing it on 1s on the X-axis, I traced the point on the graph to which it corresponded on the Y-axis. I then proceeded to ask the learners the following questions:

Researcher: "What is the displacement at 1s"?

L2 responded: "*2 m, sir*".

Researcher: "What is the displacement at 2s"?

L2: "*4 m*".

Researcher: "What is the displacement at 3s"?

L2: "*6 m*".

Researcher: "What happens to the displacement as time increases"?

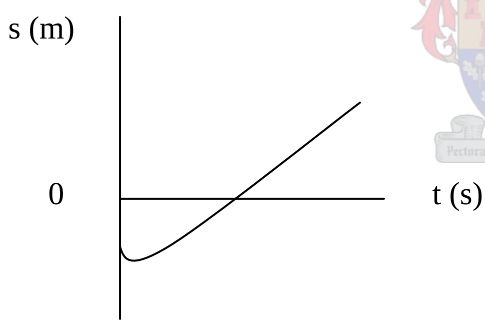
L1 responded: "*It increases*".

Researcher: "What motion needs to be followed then to imitate the same graph shape"?

L1: "*From the reference point move away from the sensor, in the positive direction*".

I then left them alone, but continued to observe them. L2 stood with the board held in both hands, about chest height, on the reference line drawn on the floor. She positioned her feet so that the toe of the shoe rested on the chalk line. L1 sat at the computer, and gave the instruction for L2 to walk away from the motion sensor. At the same time, he clicked the "start" button. The graph shape was not exactly the same as that which appeared on the activity sheet.

The following graph shape was obtained.



They then continued to struggle repeatedly in an attempt to try to get the required graph shape exactly like the one that appeared on the worksheet. I then approached the group again to ask them what the matter was and why they were repeating the activity so many times.

L1 said: "*The graph does not start from zero, but below the X-axis*".

Researcher: "What is wrong with that"?

L1: "*The graph should start from zero*".

Researcher: "What does the part of the graph below the X-axis represent"?

They remained silent. The researcher rephrased the question.

Researcher: "The chalk line drawn on the floor is represented by which point on the graph"?

L2: "*Zero*".

Researcher: "What does the Y-axis above point zero represent"?

L1: "*The displacement is positive i.e. away from the sensor*".

Researcher: "What does the Y-axis below the zero point represent"?

L2: "*The displacement is negative i.e. toward the sensor*".

Referring to the graph they obtained above, I asked:

"So what does the part of the graph below the zero point represent"?

L2: "*A negative displacement*".

Researcher: "Which means? Where should you be standing"?

L2: "*Towards the sensor*".

Researcher: "Are you standing towards the sensor"?

L2: "*No. I'm standing on the chalk/reference line*".

Researcher: "Why then does the graph start below the zero point i.e. the X-axis"?

Again, they could not answer, and there was a long pause. Here I explained to them that the motion sensor sends out pulses that strike the board that they hold in their hands, reflects off the board and goes back to the motion sensor. This information is then interpreted by the computer which then 'measures' the displacement of 2,5 m. I then explained to them that the piece of board should be held directly above the chalk line and that it was not their feet that would determine the displacement of 2, 5 m.

To determine whether they understood what I meant I asked them to explain why the graph started below the X-axis.

L1: "*The board actually protrudes over the chalk line that is in the negative direction. To get the graph to start from zero, we must hold the board directly above the chalk line and it does not matter where our feet are positioned*".

L1 then returned to the computer while L2 took the board in both hands. She walked to the chalk line and held the board at chest height and at about arms length away from her body but ensuring that the board was positioned directly over the chalk line. When they were both ready L1 clicked the "start" button and L2 walked away from the sensor. They both smiled as the expected graph shape appeared on the computer screen. L2 returned to her seat, after placing the board on the table. They both continued to write their explanation of the girl's movement in the space provided on the worksheet. While answering this part of the worksheet L2 did not refer to L1 at all.

The next part of the activity also resulted in some interesting observations. In graph D, the learners had to learn that a straight-line graph starting from a positive displacement with a negative gradient on a displacement vs time graph implied movement at a constant velocity towards the reference point.

L2 instructed L1 to hold the board while she sat in front of the computer. By now it seemed as if they understood what was expected of them. L1 immediately stood some distance away from the chalk line. L2 said, "Start" and simultaneously while he started walking towards the sensor, she clicked the "start" button on the screen using the mouse. The expected graph shape did not appear. Instead a "distorted" graph shape appeared on the computer screen. They both appeared confused and frustrated. After a while I informed L1 that he was standing too far away from the chalk line and that he should stand a bit closer. He did just that and they repeated the exercise. The required graph shape appeared on the screen. They consulted one another and then wrote down the movement that the boy completed. It took these two learners an hour to complete these four graphs.

My main observations can be summarized as follows:

- The boy required assistance with measuring 2,5 meters using a 1 meter ruler.
- No discussions took place prior to starting the activity. They merely 'jumped right into the activity' without first determining what was expected.
- When the learners could not get the expected graphs to appear on the computer screen, it took them a long time before they called for assistance.
- When "distorted" graph shapes appeared on the computer screen, the learners tried different variations. Perhaps the instructions should have included the distances where distortions tend to occur most frequently, thereby eliminating as many "distorted" graph shapes as possible.
- It became quite clear that the learners did not know what information could be derived from the graphs. It was only after intervention from the researcher or the facilitator that learners were able to 'read the graphs'.
- The learners expected the graph shape that appeared on the computer screen to be exactly the same as the graph shape that appeared on the worksheet. The learners repeated their attempts at obtaining the 'perfect' graph shape numerous times without trying to understand why the difference(s) occurred.
- The learners had difficulty understanding the role that the board, which they held in their hands, played in the activity.
- The learners displayed frustration when the expected graph shape was not obtained but were pleased when the expected graph shape was obtained.

- It took the learners an extremely long time to complete an activity which could have been completed in twenty minutes.

- A question which arises is whether the problems should be blamed on the TRAC PAC, or on the learners who are not thinking or not stimulated to think. This will be discussed further in Chapter Six.

4.1.1.2 Second Observation

This session involved learners from another school who completed the same activity on a different day. During this session I observed a group that consisted of five boys (the learners will be named L1, L2, L3, L4 and L5 respectively in the description below). The video recorder was used during this session. The time indicated below is the time that was displayed on the video recorder.

10:24:00 All five boys sat huddled together around the computer screen each reading the activity worksheet.

10:26:00 All the boys stood up and started with part 1 of the activity worksheet. L1 left the group to fetch the 1 metre ruler from another group. L2 moved to stand at the end of the table. L3 sat down in front of the computer while L4 and L5 stood around looking at the other groups. The learners did not consult one another to plan what they should do.

10:27:00 L1 returned and handed the metre stick to L2 who stood at the end of the table. He took the ruler and together with L4 and L5, who were looking around at other groups, bent down to measure 2,5 metres on the floor. L1 also joined the other boys while L3 remained seated in front of the computer and observed them.

10:28:00 The four boys were still bending, measuring the 2,5m. After one minute they all stood up.

10:28:20 L2, who initially stood at the end of the table, picked up the board from the table. He went to stand on the line marked on the floor, holding the board about knee high. The other three learners remained standing directly in the path between the sensor and the board. They (i.e. the boy with the board and the remaining three boys) then instructed L3, seated at the computer, to click the "start" button. The required graph shape that appeared in the activity sheet did not appear on the computer screen. A "distorted" graph shape appeared on the computer screen. I could see that they were confused. Holding the board, L2 then lifted the board slowly above his head as he instructed L3 to click the "start" button. When this did not work, one of the other boys (L4) took the board from L2. L4 then instructed L3 to click the "start" button as he started to walk towards the computer screen while slowly raising the board above his head. I then decided to intervene as L3 had not opened the correct file and the other boys were standing in the pathway between the sensor and the board.

10:30:00 Researcher: "Ok, now you three (referring to the boys standing in the pathway) have to move away as you will be obstructing the pulses sent out from the sensor".

I indicated, with my hands, that they had to stand behind L4, at the end of the table. L3 also got up to leave. I instructed him to remain seated at the computer.

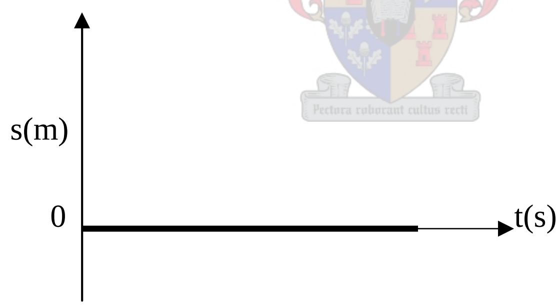
Again, I assisted the group, by pointing to the sensor and the board. I said: "There must be nothing between these two objects". I then instructed L3 to move in closer to the computer screen as he was sitting directly in the pathway between the sensor and the board.

10:30:45 Taking a copy of the activity worksheet from one of the learners, I went to L4. The other three boys all came to stand around us, while L3 remained seated at the computer.

Researcher: "Now what must you do"? Getting no response from the boys, I pointed to graph A on the activity worksheet. "Now you must get this graph, graph A, OK".

10:31:00 I then left the group of boys and returned to assist the learner sitting at the computer. I had to show him how to open the correct files so that they could proceed with the activity. At this stage I thought that the learners had not read the instructions, or that they did not understand what they had read. I then left the group.

10:31:40 L4, with the board, moved to stand on the chalk line drawn on the floor. L3 clicked the "start" button. The required graph shape did not appear. Instead the following graph shape appeared.



10:31:50 Researcher: Again I intervened. "Now what is not right there"? I asked.

Getting no response from the boys, I went to the computer screen. I then pointed at the line drawn on the computer screen (refer to the graph above) and asked, "Where is this horizontal line supposed to be"?

L3 said "*Positive*", referring to the activity worksheet.

Researcher: "Now, which side of the reference line is positive"? I asked as I pointed towards the chalk line drawn on the floor. Getting no response from the boys, I approached the group and stood on the chalk line with the boy holding the board. I informed them that the chalk line represented a zero displacement. Referring to the worksheet, I explained that the direction towards the sensor represented a negative displacement and that the direction away from the sensor represented a positive displacement. Again, I repeated the question "Now which side of the reference line is positive"?

10:32:18 The four boys simultaneously moved backwards.

Researcher: I said, "That’s right. Now you are standing on the positive side of the reference point".

10:32:20 I then left the group. L4, holding the board, remained standing while the other three boys moved out of the way and stood at the edge of the table. L3 clicked the "start" button and the same graph shape that appeared on the worksheet, appeared on the computer screen.

10:32:40 The group of boys did not know what they had to do. I intervened and informed them that they had to write down the movement performed by the boy with the board in his hands on the space provided in the activity worksheet. I left the group.

10:32:55 L3 got up from the computer, and joined the other four boys standing with the board. It appeared as if they were discussing a possible answer to explain graph A.

10:33:05 L3 returned to the computer, sat down and wrote down his answer in the activity worksheet, while getting clarity from his group members.

10:34:45 L3 stopped writing. The other four boys had remained standing at the same spot all this time. L4 still held on to the board while the other three boys hovered around him.

10:35:05 They then proceeded to answer graph B on the activity worksheet. L4, holding the board, took a few steps towards the sensor after receiving instructions from the other three boys. They followed by walking behind the boy.

10:35:17 L3 clicked the "start" button. The required graph shape appeared on the computer screen.

10:35:40 L3 then proceeded to write down the explanation of the movement for graph B.

10:35:44 L5 then proceeded to answer the explanations of the movement for the graphs by completing his worksheet.

10:36:05 All five learners were now actively busy answering the explanation of the movements for the graphs by completing their own worksheets. During that time the learners continually looked at one another's answers. They frequently returned to the worksheet completed by L3.

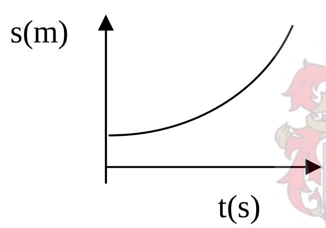
10:39:00 L5 took the board and tried to simulate the same graph shape that appeared on the worksheet. They were busy with graph C. L5 tried various possibilities, as he could not get the expected graph shape. He tried holding the board above his head, holding the board sideways and even holding the board on the floor.

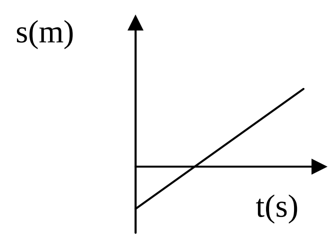
10:41:00 Their teacher intervened and offered some help. The teacher left and the boys all huddled around L3. It appeared as if they consulted amongst themselves as to what needed to be done next.

10:43:50 Their teacher intervened again to assist them.

10:44:40 The boys stopped their consultation. L5 picked up the board, stood on the positive side of the reference line and walked towards the reference line after L3 clicked the "start" button. The group of boys were not happy with the result and L5 repeated his movement. This still did not produce the expected results.

10:45:20 L5 stood on the reference line and walked away from the sensor in the positive direction. The boys were not satisfied with the graph shape drawn on the computer screen, as they could not get a straight line to appear on the computer screen. L5 repeated his movement many times. The different graph shapes that were obtained on the computer screen were the following:





L5 continued trying until he was satisfied with the graph shape. All the boys sat down and wrote down their explanation of the boy’s movement.

10:47:12 L5 got up from the table and walked towards the positive side of the reference line. Holding the board about chest height he instructed L3 to click the "start" button. He walked slowly towards the reference line. He overstepped the reference line and the required graph shape did not appear. He then repeated his movement a few times until he was satisfied with the results.

10:49:28 All the boys returned to the table and wrote down their explanations in their worksheet. However, they continued to consult the answers written by L3. It took them five minutes to write down their explanation for graph D.

At this point I stopped my observation and did not observe them as they completed Part Two of this activity.

The main findings from this observation can be summarized as follows:

- It appeared as if learners naturally assumed different roles as no learner took the lead. One learner sat in front of the computer, a second collected a ruler while the other learners waited.

- The learners started the activity without firstly opening the correct file on the computer.

- Learners were standing directly on the path between the motion sensor and the board.

- When "distorted" graph shapes appeared on the computer screen, learners would try different variations such as lifting the board above their heads.

- Researcher interventions were necessary because firstly, the learners were not following the instructions and were getting nowhere and secondly, the learners could not interpret the graph shapes that appeared on the worksheet.

- The learners continually looked at one another's answers when they had to write down the description of the movement on the worksheet.

- Learners repeated the movement numerous times if the expected graph shape that appeared on the worksheet did not appear on the computer screen.

- It was the first time that these learners had been exposed to using the TRAC PAC. Many learners spent a large amount of time repeating their movement, if the required graph shape did not appear on the computer screen. I noted that even a small deviation in the graph shape lead to the learners spending time repeating their movement without determining which factor of their movement they should change. As a result, on average, it took a class of twenty learners approximately one and a half hours to complete this activity.

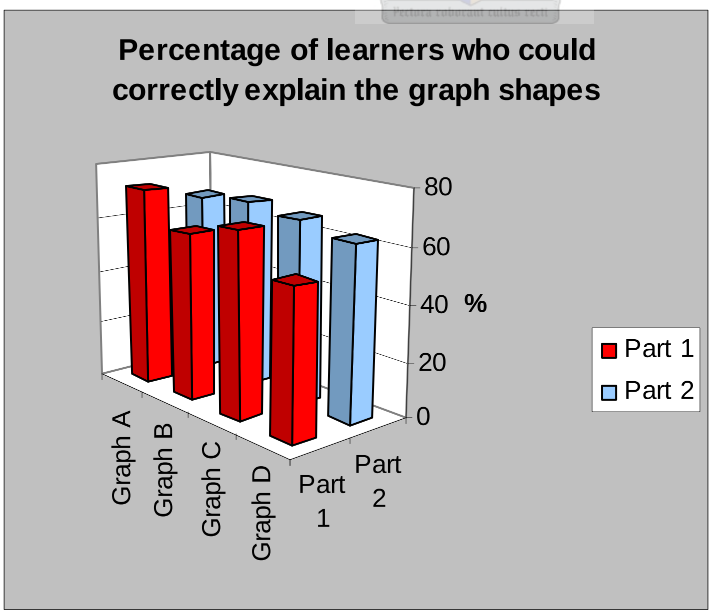
- Not one learner tried to understand why the computer generated a particular graph shape and as a result, tried to change his or her movement to see what would happen.

They could not predict what the graph shape would be and subsequently could not test their movement against their prediction.

- There was too much intervention by the facilitator, their teacher and myself. This was due to the limited time factor as the learners had to return to school by a specified time.

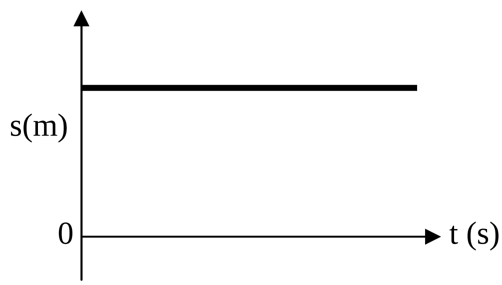
4.1.2 Worksheets

One hundred and four grade eleven learners completed the worksheet on Activity One. I marked these worksheets, using a memorandum that I prepared. Based on these findings, I was able to determine the percentage of learners who could correctly explain the movement that they had to imitate, against the eight graphs that appeared in the worksheet. These findings are illustrated in graph six, which appears below.



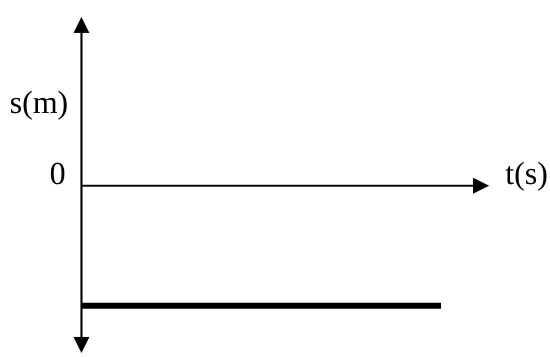
Graph 6: The percentage of learners who could correctly explain their movement to imitate eight displacement vs time graphs.

In graph A, which appeared in the worksheet, the following displacement vs time graph was given.



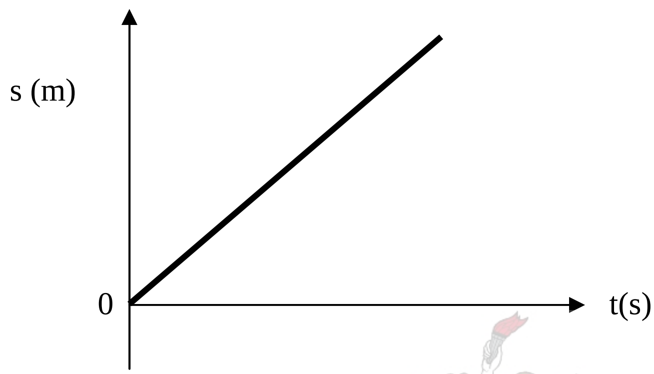
With the intervention of their teacher, the researcher and the facilitator, 72,1% of the learners could correctly explain that the learner remained stationary on the positive side of the reference line. In Part Two, where the reference direction was reversed, 66,3% of the learners could correctly explain that the learner remained stationary on the positive side of the reference line, which in this case is closer towards the motion sensor.

In graph B, the following displacement vs time graph was given.



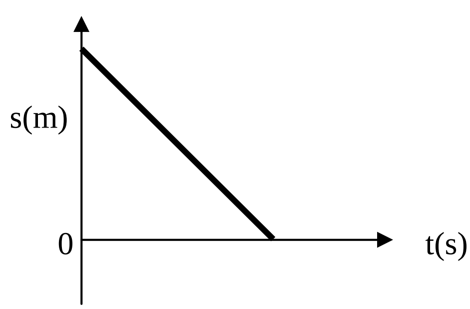
With this graph, 60,6% of learners could correctly explain that the learner remained stationary on the negative side of the reference line. In Part Two, 68,3% of learners could correctly explain that the learner remained stationary on the negative side of the reference line, which is further away from the motion sensor. There was an improvement of 7,7 % in the explanation offered by the learners.

In graph C, the following displacement vs time graph was given.



With this graph, 66,3 % of learners could correctly explain that the learner started on the reference line and walked away from the sensor. Very few learners could recognise that this straight line was only possible if the learner walked at a constant velocity. In Part Two, 66,0 % of learners could correctly explain that learner started on the reference line and walked towards the sensor.

In graph D, the following displacement vs time graph was given.



Here 52,9 % of learners could correctly explain that the learner started on the positive side of the reference line and walked towards the reference line and stopped on the line. When doing Part Two, 62,5 % of learners could correctly explain that the learner started on the positive side of the reference line, walked backwards towards the reference line and stopped on the line. There was an improvement of 9,6 % in the learners' explanations.

On average, when analysing the results on all eight graphs by the one hundred and four learners, 63 % of learners could correctly explain the movement of a learner in Part One of the activity. In Part Two, 65,8 % of learners could correctly explain the movement of a learner. This showed a very small improvement of 2,8 %. I believe that the average of 63% and 65,8 % of learners being able to correctly explain the movement for Parts One and Two respectively, would have been substantially lower without the intervention from the facilitator, their teacher and myself.

The learners struggled to explain the movement of a learner and to use science concepts in their explanations. Examples of what I did not accept as correct answers included the following:

Graph C Part One: "*Stand with a board in a reference point and move in a positive side facing in motion sensor and we find a graph*".

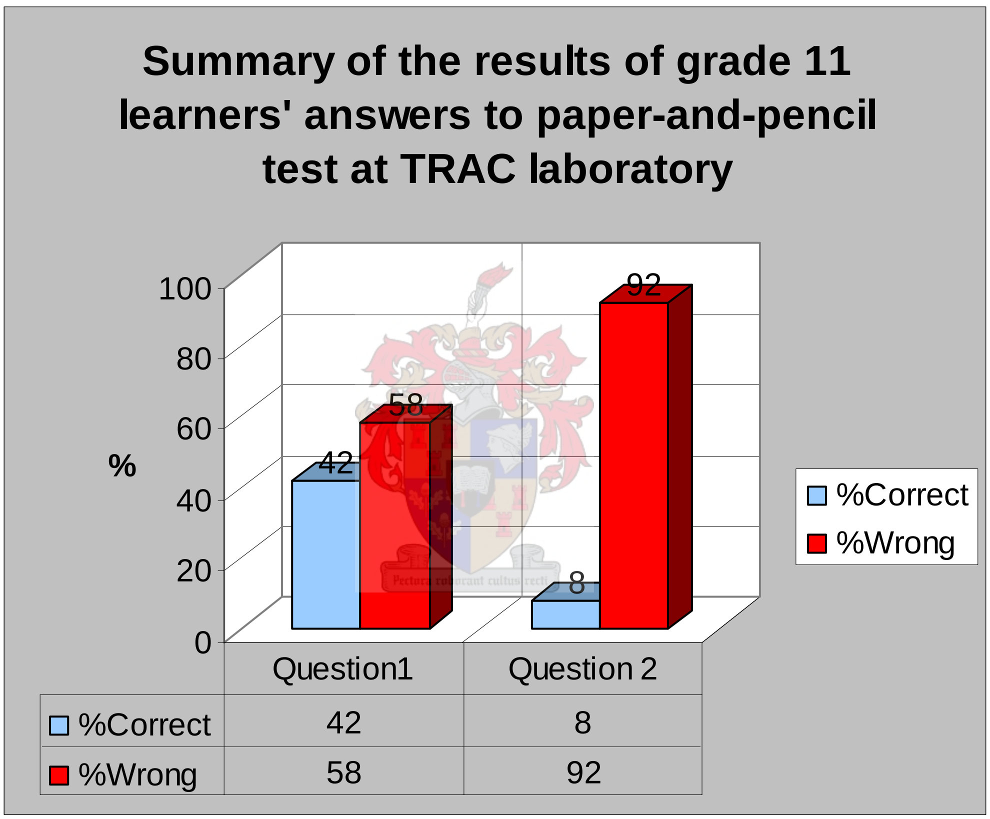
Graph C Part Two: "*We move from 2,5 m = 0 towards to get this line which directly proportional between displacement and time*".

I was, however, more lenient with others that attempted a more scientific explanation, e.g.

Graph B Part Two. Instead of writing that the learner remained stationary on the negative side of the reference point, some learners wrote: "s*tanding on a negative direction*".

4.1.3 Paper-and-pencil test

After completing the worksheet, the learners wrote a short paper-and-pencil test[25]. The learners answered a two-question test on the Physics concepts dealt with in the worksheet. The results are shown below.



Graph 7: Summary of results of grade eleven learners’ answers to paper-and-pencil test.

The format of the test was slightly different to that of the activity that the learners had completed. Instead of them being given a graph and asked to describe the movement, the movement was described to the learners and they had to draw the graph shape on the axis provided. The results in the table above show that only 42 % of the learners could supply the correct graph for question one. For question two, only 8 % of the learners could supply the correct answer.

4.1.4 Learner questionnaires

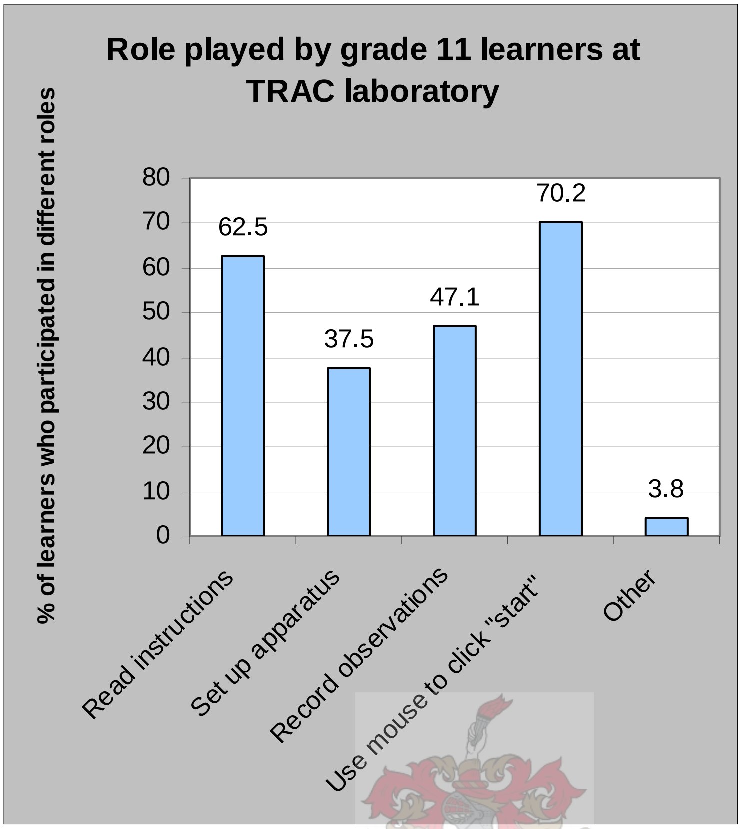
The learners then proceeded to the other side of the TRAC laboratory. Once seated, they proceeded to complete a questionnaire[26] I had drawn up. Each learner completed the questionnaire individually. The learners were reminded that they had to be completely honest when responding to the questions. The following information was obtained.

A The role played by each learner

This part of the questionnaire tried to determine the role that the learner played in the group when completing the activity. Five alternatives were given to the learners and the learners could identify more than one role. In fact the learner could even indicate that he or she participated in all five roles.

[25] Refer to appendix H.

[26] Refer to appendix B.



Graph 8: Different roles played by grade eleven learners at the TRAC laboratory.

When analysing the graph it was found that only 62,5 % of the learners indicated that they had read the instructions. I interpreted this to mean that the other learners could not have known much about the activity.

A total of 37,5% of the learners were involved in setting up the apparatus. This means that they held the board and walked up and down to imitate the movement required to get the same graph shape on the worksheet to appear on the computer screen.

When asked if they had recorded their observations, 47,1% of the learners responded that they had. I interpreted this to mean that the remaining learners simply copied the answers from those learners who had recorded their observations.

When asked if they had used the mouse to click the "start" button, 70,2 % of learners responded that they had. This seemed to indicate that learners were keen to use the computer.

Upon reflection, this data might be flawed. I realised that the learners might have agreed before the time that one learner should be responsible for reading the instructions, another for setting up the apparatus, another for recording the data and another for clicking the "start" button.

B Understanding of instructions

In the following part of the questionnaire, I wanted to know if learners understood the instructions when completing the activity. The responses from all one hundred and four learners indicated that they had all understood the instructions.

These responses contradict the findings in section A above as well as the observations recorded in sections 4.1.1.1 and 4.1.1.2. This point will be discussed further in section 6.5.2.

C Learners' experiences while at the TRAC laboratory

The following part of the questionnaire focussed on the learners' experiences while using the TRAC PAC to complete Activity One. The results were as follows:

- One hundred and three out of the one hundred and four learners responded that they had enjoyed the experience at the TRAC laboratory.

- A small number (13,5 %) of the learners indicated that even though they had enjoyed the experience, they were frustrated when, for example, "*I didn't get things right*" or "*I was not shown how to use the computer programme*".

- The learners were also asked to share other experiences that were not reflected on the questionnaire.

- 14,4 % of the learners enjoyed the opportunity to work with a computer.

- 13,5 % believed that the experience was educational.

- 13,5 % of the learners indicated that they were excited and eager to learn and that this experience made understanding the content easier.

The following responses appeared on some of the completed questionnaires:

> "*It was a great experience and for once in my life I actually enjoyed Physics. The computers played a beneficial factor in our task and I think it would be a good thing if it were used at school for this specific subject. And the food was good too*"!

> "*I'd come back anytime!! Thanks for the great opportunity to come here and have such a great learning experience*".

> "*It was a great learning experience for me and I'd love to do these practicals more often. Thank you for the wonderful opportunity*"!

> "*I had fun and I would like to come back sometime*"!

> "*It was so much easier to do physics on the computer. I really actually enjoyed and understood what I was doing! Thanks a lot*"!

D Dialogue

The final part of the questionnaire focussed on the type of dialogue that occurred between the group members. Five alternatives were given to the learners and the learners could identify more than one role.

Type of dialogue	**%**
Argued most of the time	40,4 %
Could not reach agreement	13,5 %
Agreed on everything	62,5 %
One learner knew all the answers, the rest of us just wrote down the answers	14,4 %
Other (please specify)	0 %

I interpreted this data to mean that the learners participated very well together as a group. They were prepared to differ with one another as indicated by the 40,4 % of the learners who responded to "argued most of the time". Once they had reached consensus on a particular issue, they then "agreed on everything" and completed the relevant section of the worksheet. This is evident from the 62,5 % of learners who responded to this part of the questionnaire. This interpretation is confirmed because only 14,4 % of the learners agreed with the statement "One learner knew all the answers, the rest of us just wrote down the answers".

4.1.5 Interviews

4.1.5.1 Learner Interviews

Four grade eleven learners participated in the interviews. They were interviewed individually. The main points of these interviews[27] are discussed below.

- Even though the learners indicated that it was their first time at the TRAC laboratory, they had all used a computer prior to the visit. They did not have computers at their homes but had taken courses offered at either Stellenbosch University or by organisations such as Scientific and Industrial Leadership Initiative (SAILI).

- All four learners indicated that they had enjoyed the session at the TRAC laboratory, for a variety of reasons:

  (i) One learner responded: "*I learned a lot … the things we do in class we did here on the computer. Using the computer made the work seem quite easy*".

  (ii) Two of the learners had enjoyed actually performing the practical activity because "*…the way we do practicals in class which (sic) is boring because all we do is talk about the practical…*"

  (iii) Three of the four learners indicated that they had enjoyed working with the other learners in their respective groups and said that this actually helped them to understand the concepts which they thought were difficult.

  (iv) All four learners indicated that the assistance which they had received from the researcher and the research facilitator was crucial to making their experience at the TRAC laboratory an enjoyable one.

[27] Refer to appendix J for the complete interviews.

- When the learners where offered a choice of either performing practical activities at their school or at the TRAC laboratory, all indicated that they would prefer the TRAC laboratory. The reasons given by the learners included the following:

  (i) A lack of space at school to perform practical experiments.

  (ii) Not enough apparatus for all the learners to perform the experiments.

  (iii) At the TRAC laboratory they could physically handle the apparatus which is something not normally done at school.

  (iv) At the TRAC laboratory they were given enough time to complete the practical activity. This appeared not to be the case at their school because they had to complete the practical activity within the time allocated for the periods in school.

- Not one of the learners could find one thing to say which they did not enjoy about their experience at the TRAC laboratory.

4.1.5.2 Teacher Interview

One teacher who had accompanied the grade eleven Physical Science learners to the TRAC laboratory was interviewed. The main points of this interview[28] are discussed below.

- The teacher felt that the visit to the TRAC laboratory was "…*an exciting experience for the learners*", because all the learners were given a chance to actually complete an activity on their own. The school's science laboratory did not have sufficient apparatus for all learners to actively participate in an activity.

- When the teacher was asked what she expected from an educational centre such as the TRAC laboratory her response was that it should benefit her learners by offering syllabus-related activities as well as the opportunity for her learners to experience 'hands on' activities.

- Financial constraints were by far the biggest limiting factor when this teacher decided to take learners to an educational centre such as the TRAC laboratory. "*The school and parents simply do not have the money to pay for transport to take learners away from school*".

- The teacher felt confident that a TRAC PAC could be used in the classroom. However, certain problems would first have to be overcome. Security problems were a huge concern at the school. Another problem that would have to be addressed was how to use one computer with fifty learners in the classroom.

4.2 DATA OBTAINED FROM THE GRADE 12 ACTIVITIES

The grade twelve learners that participated in the research conducted at the TRAC laboratory completed three activities. These activities[29] were also designed by the TRAC team and were meant to be syllabus-related. Activity Two investigated the relationship between mass and acceleration. Here learners were expected to find that the acceleration was inversely proportional to the mass of the system. Activity Three investigated the relationship between resultant force and acceleration. Here learners were expected to find that the acceleration was directly proportional to the resultant force. Activity Five investigated free fall as a special case of projectile motion. An inclined plane was designed so that a small ball could be rolled up this incline. A learner would be required to push this ball up the incline. The ball would reach a certain point on the incline plane and would roll back towards the learner. This inclined plane was designed so that a

[28] Refer to appendix I for the complete interview.

learner did not have to throw a ball up into the air. Throwing the ball up into the air would have made it difficult for the TRAC PAC's motion sensor to measure the motion of the ball. The learners were required to analyse three types of graphs for this motion i.e. displacement vs time, velocity vs time and acceleration vs time.

In total sixty-nine grade twelve learners from five different high schools were present in the TRAC laboratory on different days. Of these sixty-nine learners only forty-three learners completed Activity Two, fifty-six learners completed Activity Three and Thirty-seven learners completed Activity Five. The reason for this is that the learners could not complete all three activities on the same day as it took them on average more than four hours to complete just two activities. Owing to time constraints, these schools could not spend more than four hours at the TRAC laboratory. Since only one station for each activity was set up, it meant that the learners had to rotate the activities. Each station could only comfortably accommodate a maximum of five learners.

The schools were eager to participate because they were told that they could use the results of the activities for the continuous assessment mark of their learners. These marks are compulsory for all grade twelve learners as it contributes towards their final year mark. The teachers also informed me that they had already completed the sections that were to be covered at the TRAC laboratory viz. Newton's second law of motion and free fall, with their learners at school.

4.2.1 Observations of activities 2, 3 and 5

The day before the arrival of the first group of grade twelve learners, I set up the activities and completed the necessary preparations at the TRAC laboratory. The worksheets, tests and questionnaires were duplicated for the students. The following diagram illustrates the set-up of the apparatus required for Activity Two (TRAC SA website, 2004).

[29] Refer to appendices E, F and G.

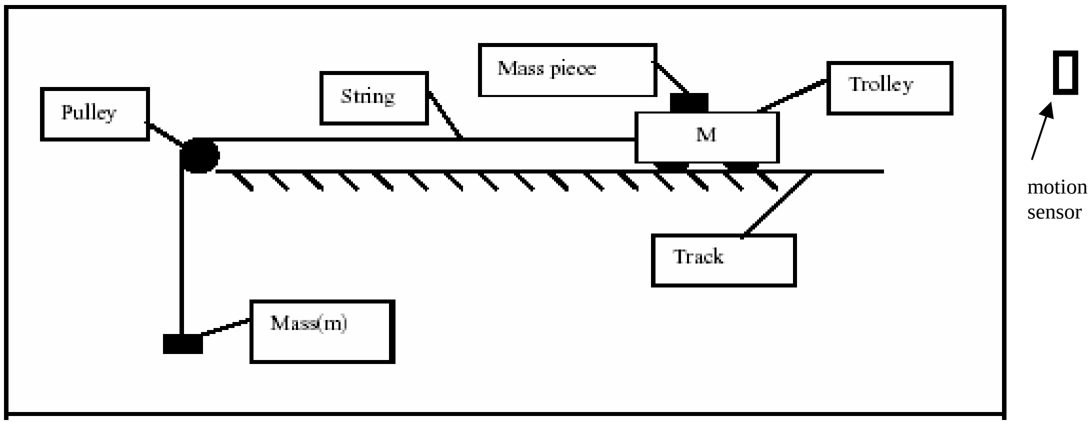
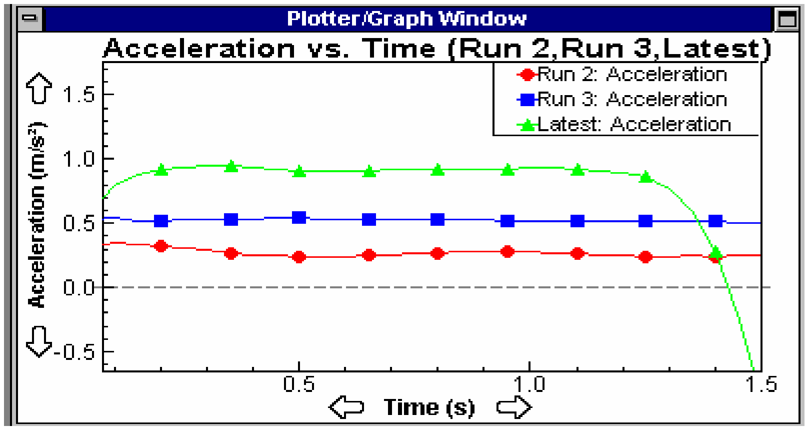


Figure 3: Set up of apparatus for Activity Two.

In this activity learners were expected to determine the mass of the trolley, using a triple beam balance, and subsequently had to determine the mass of the system. The motion sensor was situated behind the trolley. Once the situation indicated above was reached, the trolley was released and the "start" button was clicked. The motion sensor 'picked up' the motion of the trolley and relayed this information back to the computer. This information was 'converted' into a graph that reflected the acceleration that the trolley experienced vs time. The 'run' was completed. Once satisfactory results were obtained, the data was stored. Thereafter, a 1 kg mass piece was placed on top of the trolley and a second 'run' was performed. A third 'run' was performed when another 1 kg mass piece was added on top of the trolley. The following graph shapes were expected (TRAC SA website, 2004).



Graph 9: Expected graph shapes for Activity Two.

While preparing for the activities, I noticed that the results were not always consistent for this activity. This prompted me to take measurements of the exact location of each piece of apparatus in the activities, e.g. to obtain consistent results I found that raising the one end of the track 55 mm allowed the trolley to move at a constant velocity. For the motion sensor to 'pick up' the movement of the trolley, the best measurement that I obtained for the motion sensor was 10 cm away from the end of the track. I also found that if the trolley was situated 50 cm away from the motion sensor and 20 cm from each side of the runway, and was held in this position before the ‘run’ started, then the expected graph shapes were obtained. I thought that not obtaining consistent results would frustrate the learners as I certainly felt frustrated during this exercise.

4.2.1.1 Observation of Activity Two

The first group of learners arrived one and a half hours late because of transport problems. The school had made their own travelling arrangements. My first impression of the group of learners was that they were a multicultural group. They were dressed in casual clothes and not in school uniform. I wondered whether this would influence the behaviour of the learners and whether TRAC SA should insist that all learners who attended the sessions in the TRAC laboratory should wear their school uniform.

After the learners had settled down and were working on Activity Two at a workstation, I started my observation of a group of grade twelve learners. This group consisted of four boys. One learner went and sat at the computer to click the "start" button using the mouse. He was also responsible for clicking the "data" button that would allow the data to be stored onto the computer. A second learner walked around and watched the other groups. The third learner set up the apparatus as indicated on the diagram in Activity Two while the fourth learner merely observed passively and did not get involved. To ensure that they could proceed with the activity, the string had to be placed over the pulley. Once this was done, the learner who set up the apparatus moved the trolley to the furthest end of the track and told the learner seated at the computer to click the "start" button. At the same time, the learner released the trolley. When the graph shapes that appeared in the worksheet did not appear on the screen, the learners repeated the 'run'. The facilitator approached the group and realised that the boy seated at the computer had not opened the correct file for the activity. *This seemed to indicate that the learners had not read the instructions and had not planned nor discussed what was to be expected*. The facilitator then proceeded to show the learner how to open the correct file. Once again, the boys performed the same routine. One learner held on to the trolley and pulled it back to the furthest end of the track. At the same time when he released the trolley, the other boy seated at the computer clicked the "start" button and saved the data. Once again, the learners continued to repeat the 'run' and stored the data even though they could not obtain the same graph shape that appeared in the worksheet.

The facilitator then realised that they had performed the 'run' without having identified the mass of the system. The facilitator had to show the learners how to use the triple beam balance to measure the mass of the trolley. *When the worksheets of the learners were analysed, it was found that the learners could not interpret the mass pieces on the triple beam balance and as a result they recorded the readings from the triple beam balance incorrectly*. *It was also found that the learners could not convert the readings from grams to kilograms* e.g. *1370 grams was recorded as 0,137 kg*. They were shown by the facilitator that they had to add a one kg mass to the trolley after each 'run'. Thereafter, the learners had to repeat the activity again. This time they rushed through the activity and I got the impression they were neither thinking about nor understanding what they were doing.

They then proceeded to answer question one of the worksheet. The group had great difficulty in understanding this question. The question asked the learners to "make use of the graph on the screen of the computer and determine if the change in mass of the system influences the acceleration". Without giving the learners the answer, the facilitator tried to explain the question to the learners by repeatedly asking leading questions.

Facilitator: (Pointing to the graph on the screen) "What do the lines on the screen represent"?

Answer: (Given by one boy) "*Acceleration*".

Facilitator: "How many lines appear on the screen"?

Answer: "*Three*".

Facilitator: "How are the three lines arranged on the screen"?

Answer: "*Horizontally, one above the other*".

Facilitator: "What do these horizontal lines imply is happening"?

Answer: "*Acceleration is increasing.*"

(The facilitator realised that the answer was incorrect).

Facilitator: (Pointing to the graphs on the screen) "Which line represents the acceleration of your first run"?

Answer: (The boys discussed this amongst themselves and the boy seated at the computer pointed to the red line. Refer to the graph 9 above).

Facilitator: "OK. What did you change about the trolley when you performed the second run"?

Answer: "*We placed a 1 kg mass on top of the trolley*".

Facilitator: "Which line represents this acceleration"?

Answer: "*The blue line*"

Facilitator: "What did you do next"?

Answer: "*We added another 1 kg mass on top of the trolley*".

Facilitator: "Which line represents this acceleration"?

Answer: "*The green line*".

(The facilitator pointed at the computer screen and emphasized that the red line represented the first run, and then the blue line followed by the green line).

Facilitator: (Pointing along the Y-axis) "What happens to the value of the acceleration"?

Answer: "*It becomes smaller*".

Facilitator: "That is correct. So, if I increase the mass of the trolley, what happens to the acceleration"?

Answer: "*It becomes smaller*".

The facilitator was satisfied with the answer and left the group. The learners continued to answer the questions on the worksheet. Not long thereafter, they called the facilitator again. This time they wanted to know where they should find the value for the acceleration. This time the facilitator showed them how to read the acceleration from the graphs produced on the computer screen as well as what was meant by the term 'gradient'. While observing the group, it became apparent that only one learner answered the questions while the remaining three learners merely copied the answers from this learner. It took the learners an hour and fifteen minutes to complete this activity.

Summary of the main points from this observation are discussed.

- Two of the four learners were not actively involved in the activity. One learner seemed disinterested because he walked around while the other learner merely passively observed the proceedings and did not get involved.

- The remaining two learners who were involved were performing the activity even though the correct computer file had not been opened. The facilitator had to intervene and correct the situation.

- Another vital error that this group demonstrated was that they did not identify the mass of the system which required of them to add a 1 kg mass piece to the trolley after each 'run'.

- As a result, the learners were unable to use the triple beam balance to measure the mass of the trolley and again the facilitator had to intervene. For example, the learners incorrectly calculated that 1370 grams is equal to 0,137 kg.

- The learners had difficulty in understanding the questions that were asked in the worksheet. This was evident because the data that they were collecting was inaccurate. The intervention from the facilitator was needed.

- The facilitator also had to show them how to 'read' the acceleration from the graphs produced on the computer screen as well as what was meant by the term 'gradient'.

- Three of the learners merely copied the answers to the questions that appeared in the worksheet from the fourth learner who appeared to know the answers.

- It took the learners a long time to complete an activity that should have been completed within half an hour.

This observation gave me cause for concern. Were learners not receiving sufficient guidance? Were they not reading the worksheets correctly, or were the worksheets not set out logically?

4.2.1.2 Observation of Activity Three

This activity was similar to Activity Two. Here the mass of the system remained constant. Learners were expected to attach a mass piece to a hanger at the one end of the string while the other end of the string was attached to the trolley. This piece of string had to pass over a pulley as indicated in the diagram below. The remaining mass pieces were left on the trolley. The trolley was pulled up the runway track and held in this position until the learner seated at the computer was ready to click the "start" button. At this point, the trolley was released and the "start" button was clicked simultaneously. If the result appeared to be satisfactory, the data was then stored by clicking on the "data" button. After each successful ‘run’ a mass piece was removed from the trolley and added to the hanger and the procedure was repeated. The figure below illustrates the set-up of the apparatus for this activity (TRAC SA website, 2004).

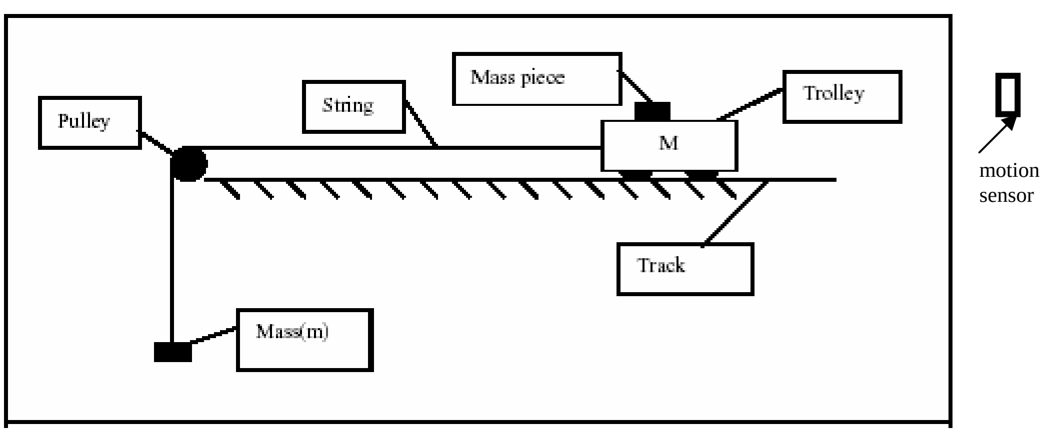
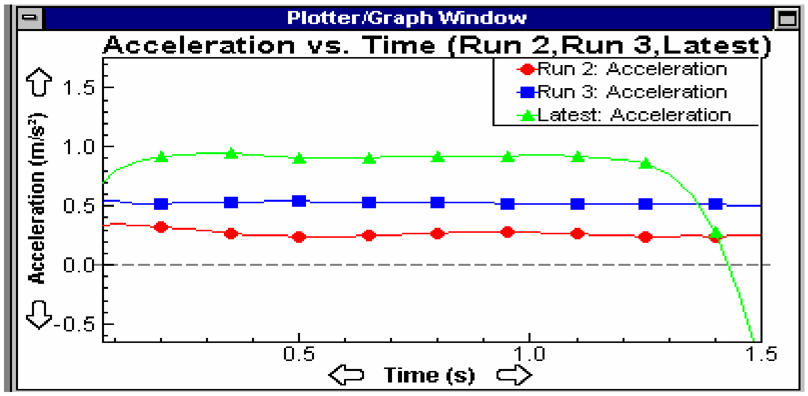


Figure 4: Set-up of apparatus for Activity Three.

The expected graph shape for this activity is indicated in the graph that appears below (TRAC SA website, 2004).



Graph 10: Expected graph shape for Activity Three.

This time I observed a different group of learners completing this activity. This group consisted of five girls. Only two learners were actively involved in the activity, one learner (referred to as L1) clicked the "start" button using the mouse while the other learner (referred to as L2) set up the apparatus for the 'run'. The other members of the group were just passive observers.

Almost immediately after they had read the instructions on the worksheet, I noticed that they could not follow the instructions and did not know what to do next. The facilitator had to show the learner seated at the computer how to open the correct file. The learners called the facilitator to explain the term 'variable'. This was the first question that formed part of the discussion that the learners had to complete before they started performing the activity. The facilitator tried to explain this concept to the learners. They then proceeded to perform the activity and to collect the required data.

L2 pulled the trolley to the furthest end of the runway and instructed L1 to click the "start" button. L2 immediately released the trolley and L1 clicked the "data" button to store the data onto the computer. At the end of this 'run', L2 took a mass piece off the trolley and added it to the hanger. The same procedure was repeated twice. The graph shape that appeared on the computer screen did not represent the graph shape that was shown in the worksheet. In fact the motion sensor had not registered the information and as a result a "distorted" graph shape appeared on the computer screen. The learners had to repeat the 'run'. After each attempt that failed to produce the expected graph shapes, the learners became frustrated. Instead of trying to understand why the same graph shapes did not appear on the computer screen and therefore changing what they were doing, the learners continued to repeat the same procedure over and over again. As the learners became frustrated, it appeared as if one learner could not understand the rationale for this activity because the learner asked me sarcastically: "*Why must we add the mass pieces to the hanger*"?

After the data from the three 'runs' were stored, the learners were required to display the graph shapes on the computer screen and to change the colours of each graph shape so that these graph shapes were clearly distinguishable. They also had to determine the average acceleration of each run from the computer screen. As they struggled with this, they became more frustrated. The facilitator was approached numerous times to assist them with these tasks.

When it came to answering the questions on the worksheet, the learner seated at the computer wrote down the answers and the other learners merely wrote down the answers given by this learner. Upon analysis of their worksheets, it became apparent that learners had difficulty understanding the science concepts that they were supposed to have learned. For example, when they were asked to "explain why the acceleration vs time graphs are straight-line graphs parallel to the x-axis", all the learners in this group answered, "*Because the acceleration is directly proportional to time*".

A summary of the observations is described below.

- The participation of the learners in this activity was cause for concern. Only two of the five girls in this group were actively involved in performing this activity while the remaining three learners were mere passive observers.

- The learners failed to implement the instructions that were given in the activity worksheet.

- The instructions clearly indicated that a computer file had to be opened before the learners could proceed with the activity. This was not done. As a result, incorrect graph shapes were obtained.

- The facilitator had to explain concepts such as 'variable' to the learners.

- The learners failed to recognise the difference between an expected graph shape as given in graph ten above and a "distorted" graph shape i.e. a graph that made absolutely no sense whatsoever.

- The learners made no attempt to try to understand why the graph shapes that they were obtaining were different to the expected graph shapes that appear in graph ten above.

- No attempt was made to change the way they performed the activity as they merely repeated the same procedure over and over again.

- Learners' frustration while performing the activity was evident.

- Intervention from the facilitator took place too frequently as they repeatedly called for assistance.

- It was obvious that the answers to the questions in the worksheet were copied by the learners of this group from only one learner as all answers were the same.

4.2.1.3 Observation of Activity Five

This activity[30] required the learners to "simulate free fall motion by rolling a ball up and down an incline to measure displacement, velocity and acceleration". The following figure below illustrates the set-up of the apparatus (TRAC SA website, 2004).

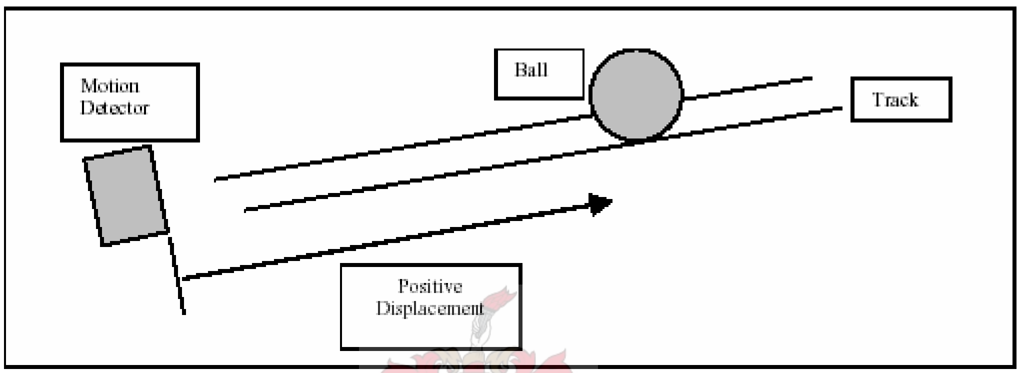
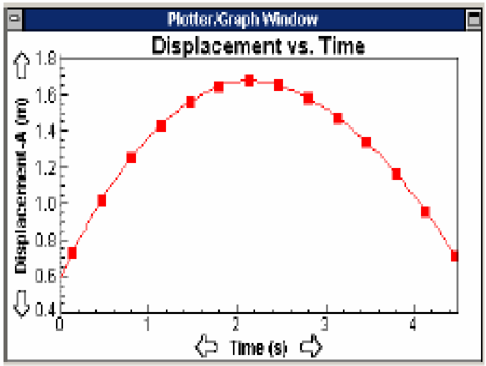
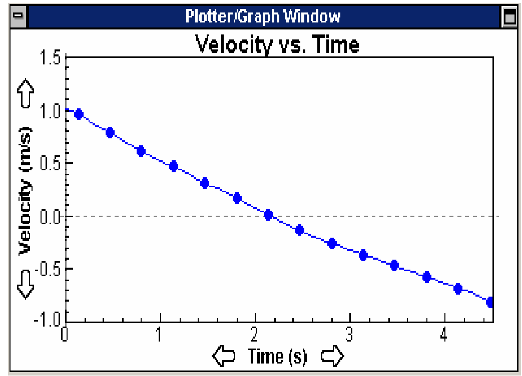


Figure 5: Set-up of apparatus for Activity Five.

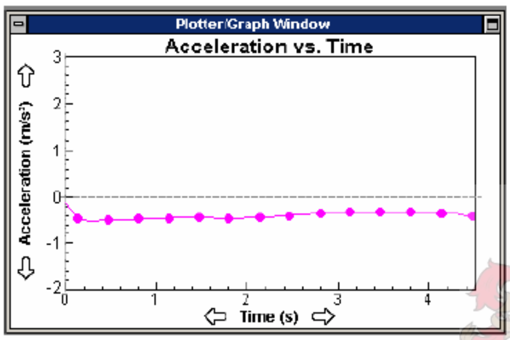
In this activity a learner was required to roll a ball up the incline while a second learner immediately clicked the "start" button. The motion sensor detected the movement of the ball and plotted three graphs on the screen. The learners were then required to analyse the graphs by answering the questions on the worksheet. The expected graph shapes are (TRAC SA website, 2004):



Graph 11: Displacement vs time graph.



Graph 12: Velocity vs time graph.



Graph 13: Acceleration vs time graph.

The group that I observed during this activity consisted of four boys and one girl. Almost immediately, it became clear that the boys had read the instructions while the girl did not. She just sat there looking around. Five minutes later, two of the boys stood up and got involved in setting up the apparatus. One of these boys (referred to as L1) rolled the ball up the incline plane while the other boy (referred to as L2) stood ready to catch the ball should it roll off the incline plane. The girl (referred to as L3), without being told by the boys, stood up and sat next to the computer ready to click the "start" button. Initially, they had a problem co-ordinating their timing between starting to roll the ball and clicking the "start" button at the same time. L2 instructed L1 and L2 to perform their actions on the count of three. Thereafter, other problems started to emerge. L1 could not give the ball a consistent speed as he tried to roll it up the incline. First, he rolled it too hard and it left the incline. Then he rolled it too softly, not giving the ball enough time on the incline to

[30] Refer to appendix G.

produce the graph shapes. Then he rolled the ball and it fell halfway off the incline. When he finally managed to roll the ball perfectly, L3 had forgotten to click the "start" button. After they had managed to overcome all the obstacles, the graph shapes that formed on the computer screen were "distorted" and the same procedure had to be repeated again. At this stage, the learners were becoming frustrated and it appeared as if they were not enjoying the activity anymore. When I asked what the problem was, L1 responded, "*We struggled to get the correctly shaped graph*". This part of the activity had taken them approximately twenty minutes to complete. Once the group had managed to obtain a suitable graph shape, they proceeded to answer the questions on the worksheet. L1 answered the questions while the others wrote down his answers.

The next part of the activity, which required learners to analyse the graph, also proved to be taxing to the learners. The first question required the learners to read the displacement and velocity values from the graph at a time (t_1) of 0,5 seconds. They could not identify which "function key" they had to use that would automatically display these values once they moved the cursor to 0,5 seconds on the graph. The facilitator was called in and this was demonstrated to the learners. When the group started to answer question three, they again called on the facilitator. In this question they were required to identify "a time later than t_1 at which the displacement is the same as at t_1" and had to record the time, displacement and velocity values from the graph. The facilitator had to assist them through asking leading questions.

Facilitator: "Where is the time 0,5 seconds represented on the graph"?

(L3 pointed to the screen using the cursor).

Facilitator: "What is the displacement reading at this time"?

L3: "*1,038m*".

Facilitator: "Where else on the graph will the displacement also read 1,038m".

(All the learners in the group then moved closer to the computer and they all gave instructions to the girl).

L2: "*Move the mouse"!*

L1: "*Up*".

"*To the left*" says another.

(As L3 moved the cursor around on the screen, all the learners huddled around the computer screen trying to read the displacement values that appeared on the screen).

L1: "*There it is*".

L2: "*Move back*".

(The group of learners now appeared to be confused as they were searching for a displacement reading of 1,038 m. This value did not appear at all, no matter how slowly they moved the cursor across the screen. They continued their search up and down the screen for an agonising five minutes until the facilitator decided to intervene and assist the learners once again. The facilitator asked them why they were struggling and one learner answered that they could not find 1,038 m.).

Facilitator: "*What have you found then*"?

L1 responds: "*1,041 meters*".

Facilitator: "*What is wrong with that answer*"?

L1: "*It is not 1,038 meters*".

Facilitator: "*What is the difference between 1,038 m and 1,041m*"? (No response). "*How many millimetres are there in 1,038 meters*"?

(Still getting no response from the learners, the facilitator informed them that 1000 millimetres equals 1 meter).

Facilitator: "*How many millimetres are there in 1,038 meters*"?

(L2 got up from the table, went to his school bag and returned with a calculator).

L2: "*1038 millimetres*".

Facilitator: "*And in 1,041 meters*"?

L2 responded: (After using his calculator) "*1041 millimetres*".

Facilitator: "*What is the difference between 1041 and 1038 millimetres*"?

L2 responded: "*3 millimetres*" after using his calculator once again.

Facilitator: "*How big is 3 millimetres*"? (No response).

Facilitator: "*Please fetch a ruler*".

(L2 left his seat, went to his schoolbag and returned with a ruler).

Facilitator: "*Please show me 3 millimetres*".

(L2 showed the facilitator).

Facilitator: "*Is that bigger or smaller than 1041 millimetres*"?

L2: "*Smaller*".

(The facilitator could then explain that the difference of 3 millimetres was so small that in fact 1,038 meters could be accepted to be equal to 1,041 meters in this case).

The learners experienced similar problems when asked to read the velocity values from the graph. Learners were confused about the readings of 0,219 m/s and –0,195 m/s. The facilitator once again had to explain that these values were very similar and that the negative value merely indicated the opposite direction of motion of the ball.

Immediately thereafter the learners were expected to read from the graph the value of the acceleration. Since the graph was never a perfectly straight line parallel to the time axis, the acceleration value was never constant. The learners once again had to be shown by the facilitator how to use the "regression" function key to determine the average acceleration value. By the time they reached the next question that asked them to determine the gradient of the velocity vs time graph, both the facilitator and the learners were quite visibly agitated. They asked the facilitator "*How do we do it*"? and "*Which values do we use*"? The facilitator responded by giving them the formula to calculate the gradient and promptly left the group.

It took the group approximately one hour and fifteen minutes to complete this activity with lots of help from the facilitator. I did not expect it to take so long for the learners to complete this activity.

A summary of this observation is described below.

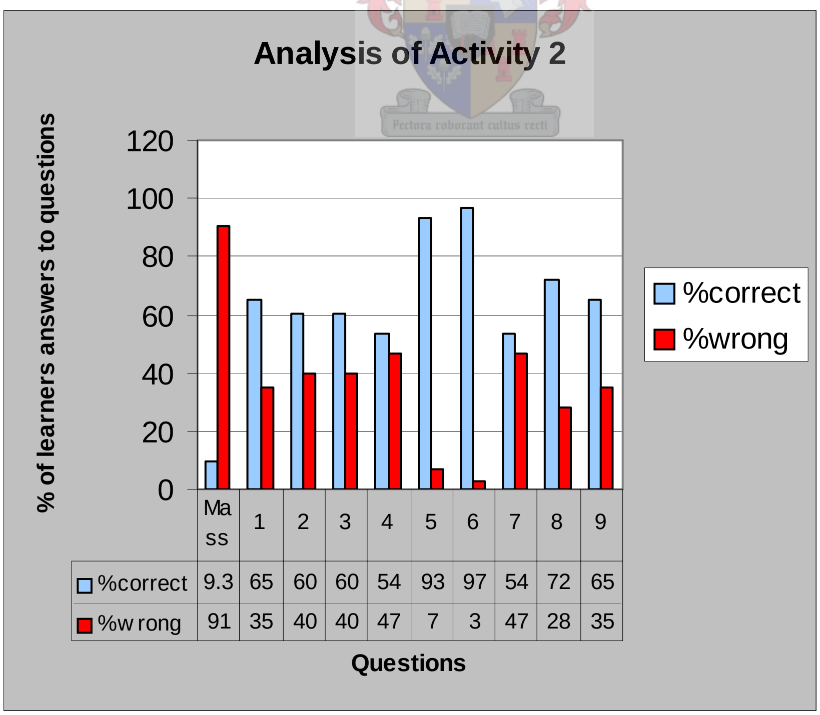
- Not all the learners read the instructions.
- Of the five learners, only three learners were actively engaged in the activity. The other two merely watched quietly from one side of the table.
- It took the group a long time before obtaining a suitable graph. Reasons for this delay included amongst others the co-ordination required to roll the ball consistently up the incline.
- Learners struggled to use different function keys such as the 'regression' function key which allowed them to read certain acceleration, displacement and velocity values from the graph.
- Too much assistance from the facilitator was evident.
- The lack of understanding of basic mathematical calculations is frightening. Learners could not distinguish the difference between 1,038 m and 1,041 m.
- Learners showed signs of frustration at having to repeat the activity and having to depend on guidance from the facilitator on numerous occasions. It could be that the worksheet did not contain enough instructions or that the instructions were too vague.

4.2.2 Worksheets

The research team, as mentioned earlier, set up the worksheets. Learners completed these worksheets at the TRAC laboratory while using the TRAC PAC. These worksheets contained instructions informing the learners of the procedures that they should follow as well as a series of questions on the activity that they were expected to answer. I marked these worksheets and the results are shown below.

4.2.2.1 Analysis of Activity Two

Forty-three grade twelve learners completed this activity[31]. The graphical illustration of their answers is given in graph 14 below.

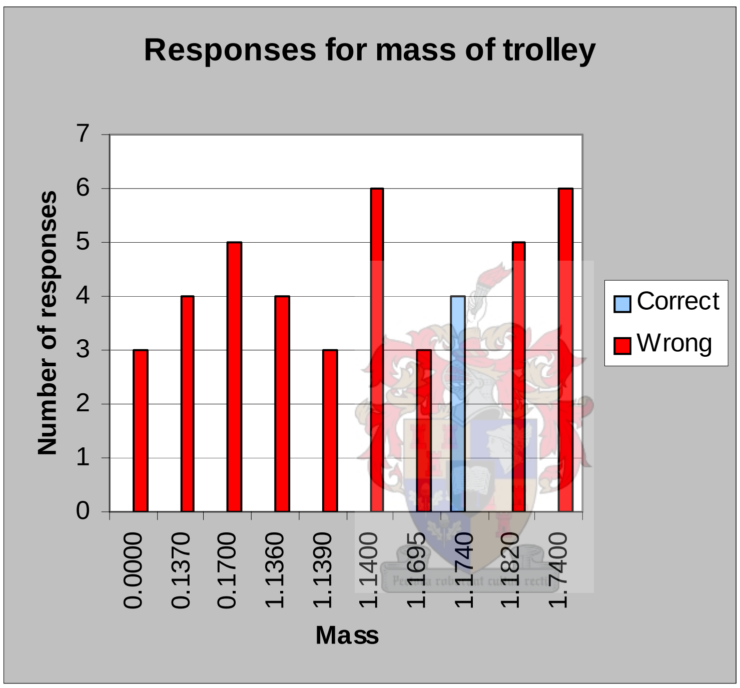


Graph 14: Grade twelve learners' responses to the Activity Two worksheet.

[31] Refer to appendix E

From this graph it is evident that, on average, 60 % of the learners could answer all the questions on the worksheet correctly.

It is important to note that only 9,3 % of the learners were able to correctly determine the mass of the trolley to be 1,174 kg using a triple beam balance. The graph below illustrates the responses for the mass of the trolley from these forty-three learners.

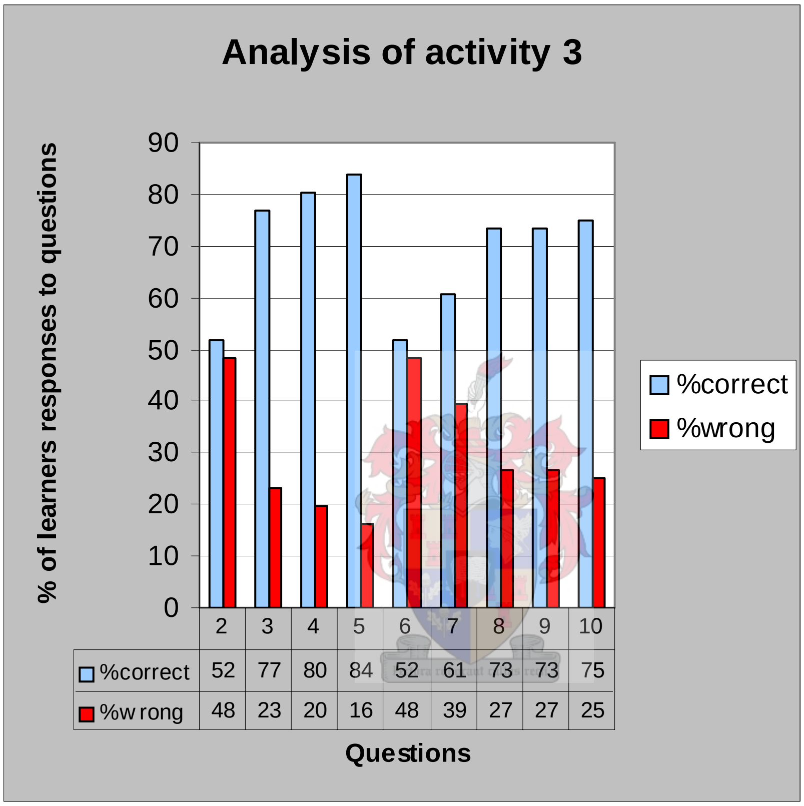


Graph 15: Responses from grade twelve learners on the mass of the trolley.

Different learners used the same trolley and triple beam balance for this activity. The many different mass readings that were recorded are reason for concern.

4.2.2.2 Analysis of Activity Three

Fifty-six learners completed this activity[32]. The graphical illustration of their answers to the questions is given in the graph below.



Graph 16: Grade twelve learners' responses to Activity Three.

It can be seen from the above graph that the learners struggled to answer questions two, six and seven correctly.

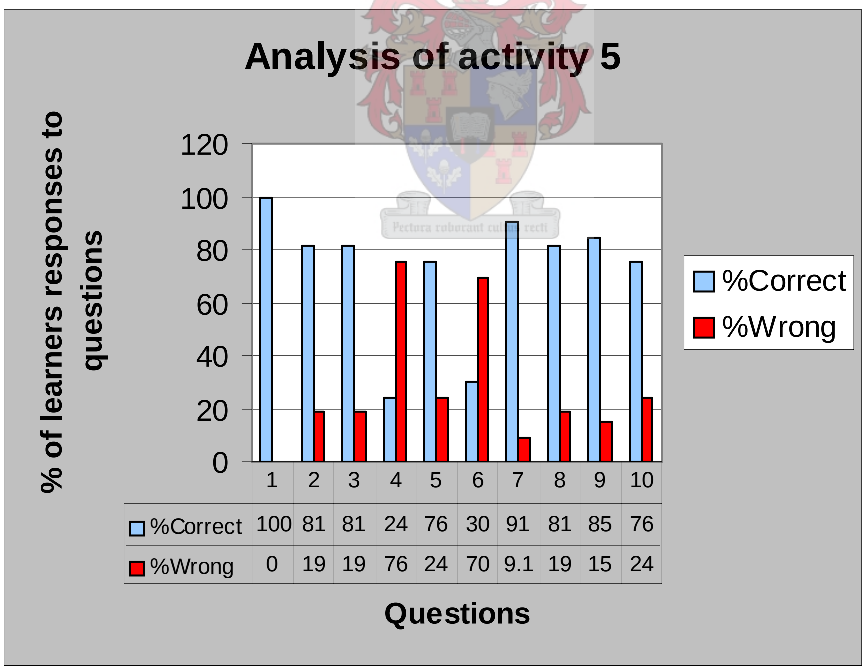
Question two required the learners to explain why the acceleration vs time graphs are straight-line graphs parallel to the time axis. Only 51,8 % of the learners could correctly explain that this indicated that the acceleration remains constant.

[32] Refer to appendix F

In question six the learners were asked to tabulate the force and the acceleration values. Only 51,8 % of the learners were able to indicate this correctly as many could not convert grams to Newton e.g. 50 g was indicated to be equal to 0,005 N. As a result of these incorrect values, question 7 also proved to be problematic for the learners, as they were required to plot a force vs acceleration graph.

4.2.2.3 Analysis of Activity Five

Thirty-three grade twelve learners completed this activity[33]. The graphical illustration of the learners' answers is indicated in the graph that appears below.



Graph 17: Grade twelve learners' responses to Activity Five.

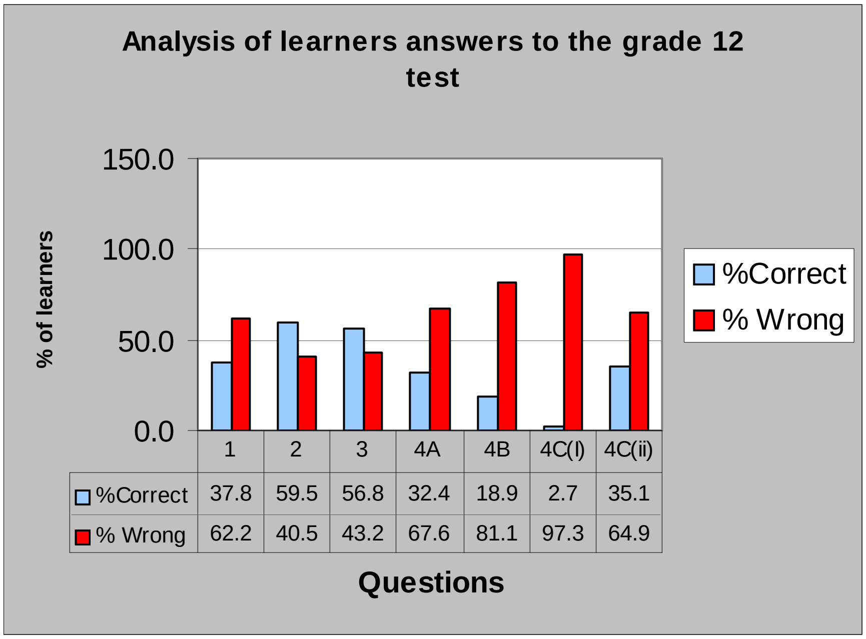
[33] Refer to appendix G.

From the graph, it is apparent that the learners had difficulty with questions four and six. Question four required the learners to indicate that the shape of the acceleration vs time graph is parallel to the time axis. This indicates that the acceleration remains constant. Only 24,2 % of the learners could answer this question correctly.

Question six required the learners to calculate the gradient of the velocity vs time graph. 30,3 % of the learners could answer this question correctly.

4.2.3 Paper-and-pencil test

After the learners had completed the worksheets, they were then asked to complete a short paper-and-pencil test. The aim behind the test was to determine whether learners were able to recall certain information from the three activities that they completed. In total only thirty-seven of the sixty-nine learners completed the test. The reason for this was that the learners had to return to their schools before the end of the school day as many learners were dependent on public transport to return to their homes. As a result, some of the schools left the TRAC laboratory before they could write the test. The results of those learners who were able to complete the test are indicated below.



Graph 18: Analysis of grade twelve learners' answers to paper-and-pencil test.

In question one, the learners were given the following question: "In activity 2, you investigated the relationship between the acceleration and the mass of the trolley". The learners were expected to know that the acceleration was inversely proportional to the mass of the system. Only 37,8 % of the learners were able to answer this question correctly.

Question two asked the learners to identify the variable that had to remain constant for question one to be correct. 59,5 % could correctly identify that the (resultant) force remained constant.

Question three focussed on activity three. In this question learners were asked to explain in their own words, "...what conclusion can be drawn from the relationship between the resultant force and acceleration". The learners were expected to answer that the acceleration was directly proportional to the resultant force. 56,8 % of the learners could answer this question correctly.

Question four focussed on Activity Five. Question 4 A asked the learners to complete the following sentence. "During free-fall the acceleration..." The learners were expected to answer that the acceleration remains constant. Only 32,4 % of the learners could answer this question correctly.

Referring to graph 18, question 4 B asked: "Why does the acceleration have a negative value"? Only 18,9 % of the learners could correctly explain that from the reference point, (i.e. the motion sensor) the direction away from the motion sensor (i.e. up) was calibrated as positive. However, acceleration always acts downward (in the case of free-fall). Therefore, acceleration has a negative value.

In question 4 C (i), the learners were asked: "At the turning point of the ball, what was the acceleration"? Learners were expected to answer that the acceleration remains constant (with a negative value) for the entire motion experienced by the ball, even at the turning point. Only 2,7 % of the learners could answer this question correctly.

In question 4 C (ii), the learners were asked: "At the turning point of the ball, what was the velocity"? Learners were expected to answer that the velocity was 0 $m.s^{-1}$. Only 35,1 % of the learners could answer this question correctly.

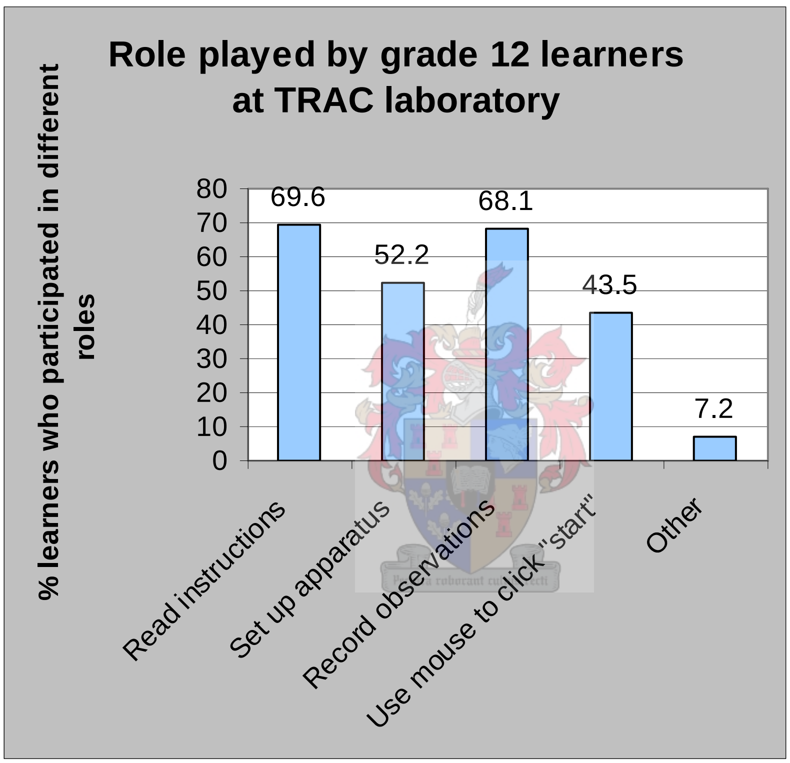
4.2.4 Questionnaires

4.2.4.1 Learner Questionnaires

All sixty-nine grade twelve learners answered the same questionnaire that was completed by the grade eleven learners after they had completed the practical activities and the worksheets. These are the responses from the sixty-nine learners.

A The role played by each learner

This part of the questionnaire tried to determine the role that the learner played in the group when completing the activities. Five alternatives were given to the learners and the learners could identify more than one role.



Graph 19: Different roles played by grade twelve learners while at the TRAC laboratory.

From this graph the following data emerged:

- 69,6 % of learners indicated that they had read the instructions, which implied that 30, 4 % of learners did not. I expected all the learners to have read the instructions so that they would know what to do during the activity and to know what the activity entailed.

- 52,2 % indicated that they set up the apparatus to perform the activity.

- Only 68,1 % of learners indicated that they recorded their observations during the activity. Since all the questions on the worksheets had been answered by all the learners, I interpreted this to mean that the other 31,9 % of learners merely copied the answers that appeared in their worksheets from the other learners in their group.

- Only 43,5 % clicked the "start" button. I was expecting many more learners to do this. I expected them to be eager to want to sit in front of the computer. Clearly this was not the case.

A possible flaw in this section of the questionnaire was described earlier in this chapter as part of the discussion on the grade eleven questionnaire.

B Understanding of instructions

In the following part of the questionnaire, I wanted to know if learners understood the instructions when completing the activity. A total of 84 % replied that they had understood the instructions. This result was not consistent with my observations. This issue will be discussed further in section 6.5.2.

C Learners' experiences while at the TRAC laboratory

The following part of the questionnaire focussed on the learners' experiences while using the TRAC PAC to complete the activity.

- 89,9 % responded that they had enjoyed their experience at the TRAC laboratory.

- 27,5 % indicated that they felt frustrated at times while they were carrying out the activities at the laboratory, especially when: "*I didn't get things right*", "*rolling the ball up the incline*" and "*repeating the activity a few times*".

The learners were also asked to share other experiences that were not reflected on the questionnaire. 24,6 % indicated that the experience was exciting and helped them to understand the work better.

D Dialogue

The final part of the questionnaire focussed on the type of dialogue that occurred between the group members. Five alternatives were given to the learners and the learners could identify more than one role.

Type of dialogue	%
Argued most of the time	68,1 %
Could not reach agreement	13 %
Agreed on everything	52,5 %
One learner knew all the answers, the rest of us just wrote down the answers	8,7 %
Other (please specify)	14,5 %

The responses of the grade twelve learners to this section of the questionnaire were similar to those of the grade eleven learners. It was evident that the learners discussed possible answers before reaching an agreement. This was clearly reflected in the responses of 68,1 % of the learners who responded that they "argued most of the time" and that they did not merely accept an answer from one learner. This was further underscored when only 8,7 % of learners agreed with the statement "One learner knew all the answers, the rest of us just wrote down the answers". The interpretation that learners discussed possible answers was confirmed because 14,5 % of the learners indicated, without any prompting, that they all worked together as a group to come up with an answer.

4.2.4.2 Teacher Questionnaires

Seven of the Physical Science teachers who taught the participating learners completed a questionnaire[34]. Of the seven questionnaires that were returned to me, only one was incompletely answered. The findings are discussed below.

A Personal background information about the teachers

- 40 % of the teachers that completed the questionnaire were male.
- The average age of the teachers at the time of the research was 36 years.
- The lowest professional qualification was a B.Sc. and the highest qualification was an M.Sc.
- The average number of years of teaching experience was 11,5 years.
- The average number of years of teaching Physical Science at high school was 9,8 years.

[34] Refer to appendix A.

B Classroom experience

(i) The number of learners taking Physical Science

The following table represents the number of learners taking Physical Science (grade 10 - 12) at the high schools of the seven teachers who completed the questionnaire.

Teacher	Grades		
	10	11	12
1	57	35	19
2	30	22	14
3	24	09	13
4	15	11	00
5	80	68	38
6	37	17	15
7	42	00	10

Table 9: The number of Physical Science learners at the high schools of the seven teachers who completed a questionnaire.

The data from this table shows that on average there are forty grade ten learners per teacher. This number drops dramatically to an average of fifteen grade twelve learners per teacher. I consider these averages to be rather low and reason for concern, given that universities are trying desperately to recruit learners who have passed the matriculation examination in Physical Science. There are just not enough learners at high schools taking the subject. This pattern of low learner numbers in Physical Science was reported earlier in section 2.1.

(ii) Practical work

The following part of the questionnaire listed all the practical work to be completed by grade twelve Physical Science learners as prescribed by the Western Cape Education Department in 1996. All these practicals were listed and teachers had to indicate whether the practical activities were completed in class. The practicals were categorised as [L]: which meant that learners had to perform the practical activities themselves or as [D]: which meant that the teacher had to perform the practical activities as a demonstration. The responses from the teachers indicated that:

- Of the practical activities that were categorised as [L], only 40 % were actually completed by the learners themselves.
- Of the practical activities that were categorised as [D], only 66,4 % were performed as teacher demonstrations.
- 75 % reported that they did not have a fully equipped laboratory.
- 60 % of the teachers indicated that they borrowed equipment that they did not have to perform an activity, either from other schools or from universities.
- 100 % of the teachers responded that they had to set up the apparatus, clean up and store the apparatus after completion of the activity, as they did not have a laboratory assistant to assist with the practicals. I interpreted this as a reason why teachers did not perform practical activities more regularly.
- 80 % of the science classrooms did not have security measures in place.

When asked to supply reasons for not performing practicals:

- 85,7 % responded that the lack of apparatus was a major obstacle.

- 28,6 % thought that the practical activities were not worthwhile to perform since learners did not learn anything from the practicals.

When asked to make recommendations to ensure that practical activities were completed:

- 42,8 % indicated that the syllabus content had to be scaled down, as it took too long for teachers to complete the syllabus and as a result little time was spent on practical work.

- 100 % responded that other institutions such as NGO's (non-governmental organisations) could be asked to assist teachers.

- 42,8 % believed that being able to borrow apparatus would benefit the teachers to complete the prescribed practical activities.

- Another response from one teacher indicated timetable problems experienced at schools. It was recommended that schools needed to allocate a period of at least three hours per week on their timetables that would allow for the completion of the practicals. To overcome this, one teacher responded that practical work was completed after school or over weekends.

C School outings

This section of the questionnaire focussed on the implications and type of destinations to which the teachers took their Physical Science learners.

- All respondents indicated that they did not take their learners out of school more than five times per year. In most cases, they only took their learners out of school once a year. The problem with this part of the questionnaire was that the option of 1-5 times was too large. I should have provided an alternative of 1-2 times as well.

- The types of venues and events preferred by teachers were competitions, exhibitions and practical activities rather than lecture and revision sessions.

- The teacher was normally responsible for making the travelling arrangements. Other teachers were expected to supervise that teacher's other classes in his/her absence during the outing. The disadvantage associated with learners going on outings was that the remaining teachers at the school complained that the learners were losing valuable instructional time in their other subjects such as languages.

- All the teachers responded that the school did not accept responsibility for paying the costs when learners left the school to visit an educational site. Ultimately, the learner was responsible for the payment of the costs unless the teacher was able to secure sponsorship.

- Teachers were asked to respond to a hypothetical situation. They had to indicate whether they would prefer to complete the prescribed practical activities at a fully functional laboratory, which is close to school, or whether they would prefer their own fully functional laboratory. 83 % indicated that they would prefer to attend the facility close to their school.

D Computer literacy of teachers

This last part of the questionnaire focussed on the computer literacy of the teachers.

All respondents indicated that they owned a personal computer, and 71 % indicated that they were confident to extremely confident in using a computer. When asked whether they would use a computer in their classroom if they had access to one, all indicated that they would. Reasons given by teachers included: "*It complements what is taught by the teacher*" and "*pupils will understand the concepts better and will be more interested in the subject*".

4.2.5 Interviews

4.2.5.1 Teacher interviews

Two teachers who had accompanied their grade twelve Physical Science learners to the TRAC laboratory were interviewed. The main points of these interviews[35] are discussed below.

- I wanted to determine what criteria an educational centre must satisfy before a Physical Science teacher would take his or her learners to it. One teacher responded that the centre had to offer syllabus-related practical activities that could be used for the continuous assessment mark of the learners as prescribed by the WCED. The other teacher responded quite firmly that the "…experience must benefit the learners and they must feel that they have learned".

- Once a teacher had taken his or her learners to an educational centre, I wanted to determine which factor(s) would influence their decision not to bring learners to the centre again. One teacher responded that the biggest factor would be the financial costs associated with transporting the learners to a centre. The reason for this was that the schools simply did not have the financial resources to pay the transport costs. The parents could not afford the expense either. The second teacher responded that centres that did not offer the learners 'hands on' experiences that required them "…to think about what they are doing" and those centres that merely offered "…a walk-through exhibition …" would not motivate this teacher to take her learners to the centre again.

- Identifying the difficulties that Physical Science teachers experienced in their classrooms would provide valuable insights into possible solutions that an educational centre could offer the teacher. Both teachers responded that they had too little time to complete the syllabus within the year and to satisfy the departmental continuous assessment requirements. Another problem related to time was that the time allocated on the school's daily timetable was not sufficient to complete a practical activity. As a result "…a practical activity usually takes a few days to complete" which confused the learners.

One of the teachers was in possession of a TRAC PAC at his school. Therefore, the questions that follow were not asked when I interviewed the other teacher.

- When I asked the teacher where the TRAC PAC was situated at school, the teacher replied that it was kept in the school's computer laboratory, always ready to be used. The reason for it being kept there and not in the science laboratory was that safety precautions were already in place there.

- The biggest benefit, identified by the teacher, in having a TRAC PAC at the school was that "…I can use it to reinforce certain concepts that the learners are experiencing problems with, while I am teaching…My experience is that the use of the TRAC PAC definitely helps the learners to grasp certain concepts quickly". I was not certain about the validity of this comment from the teacher, based on my observations described earlier in this chapter. This comment is discussed further in chapter 6.

- The main problem associated with taking learners to the TRAC laboratory was that too much time would have passed between the identification of problems with certain science concepts in class and an eventual visit to the laboratory. Therefore, the teacher argued that it would be "…more beneficial if the learner gets to use the TRAC PAC when he or she comes into contact with the concepts and not to wait for time to pass before using the TRAC PAC to reinforce those concepts".

- When I asked the teacher to recommend whether TRAC PACs should be placed in schools or in an educational centre such as the TRAC laboratory, the teacher's response was: "It is a difficult choice to make". The reasons offered by the teacher are given below:

---

[35] Refer to appendix K for the complete interviews.

(i) It could not be guaranteed that even if all schools were given TRAC PACs that they would in fact use it because its use was dependant on how confident the teacher felt about using the program.

(ii) On the other hand the TRAC laboratory catered for those teachers who did "…not feel confident in using the TRAC PAC".

The teacher's final response to the above-mentioned recommendation was that in an ideal environment it would be advantageous to have both a TRAC PAC at each school as well as a TRAC laboratory.

4.2.5.2 Learner interviews

Five grade twelve learners were interviewed during the course of the research at the TRAC laboratory. They were interviewed individually and on different days. The teachers of the learners identified the respondents in these interviews[36]. The main points of these interviews are discussed below.

- Three of the five learners indicated that they had enjoyed the experience at the TRAC laboratory. Reasons given by these learners included amongst others: "I have learned lots of things here today that I would not have learned at school"; learning from other learners or helping those who did not understand; the assistance that they received from the researcher and facilitator when they experienced difficulties and the ability to learn from their mistakes.

- The other two learners did not find the experience at the TRAC laboratory particularly useful. One learner commented that she did not find the real-time appearance of the graphs on the computer screen "…helpful" because "I need to

[36] Refer to appendix L for the complete interviews.

understand why a particular graph shape is obtained". The other learner responded that "There is something missing. I cannot put my finger on it".

- The following advice was offered by the learners. This advice was aimed specifically at improving the experiences of the learners at the TRAC laboratory.

  (i) Integrate the use of the TRAC PACs with other applications such as computer simulations and the Internet.

  (ii) Provide a 'Help section' which learners can click on when they experience difficulty with certain concepts such as 'gradient'.

  (iii) Limit the time spent by the learners at the TRAC laboratory when completing practical activities. Do not attempt to complete all practical activities on one day. Rather make the necessary arrangements for schools to return to the venue on another day.

  (iv) The learners must also play their part. They must be prepared i.e. they must know their work, before they visit the laboratory.

- When three of the learners were asked to state whether they would prefer to perform their practicals in their classrooms or at a venue such as the TRAC laboratory, all replied "…the lab". The reasons given were similar to those that appear in the first bullet above.

- Three of the five learners were asked to identify the main differences between performing practical activities in their classrooms to those that they performed at the TRAC laboratory. All these learners replied that there was a lack of apparatus at school. This implied that only some learners were actively engaged with the apparatus "…while the other learners are merely spectators". This was not the case at the TRAC laboratory because all learners were engaged with the practical activities.

4.3 SUMMARY OF DATA COLLECTED

The data collected at the TRAC laboratory is summarised below:

- One hundred and four grade eleven learners completed an activity worksheet on reference points and direction, a questionnaire and a paper-and-pencil test.

- Sixty-nine grade twelve learners completed activity worksheets two and three on Newton's second law of motion as well as activity worksheet five on free fall motion.

- Sixty-nine grade twelve learners also completed a questionnaire.

- Thirty-seven of the sixty-nine grade twelve learners completed a paper-and-pencil test.

- Five grade twelve learners and four grade eleven learners were interviewed in a separate smaller room adjoining the TRAC laboratory. All learners were asked the same questions, but in some cases, depending on the responses of the learners, additional questions were asked. Their responses were captured on a Dictaphone after the learners had given their permission.

- Seven teachers completed a questionnaire, one of which was incomplete.

- Three teachers (one grade eleven teacher and two grade twelve teachers) agreed to participate in an interview. The responses of the teacher were also captured on a Dictaphone after their consent had been obtained.

- Observations of the interactions of five groups of learners (three grade twelve and two grade eleven groups) were done while they completed their practical activities. A video recorder was strategically placed in the TRAC laboratory, after permission from the teachers and learners had been obtained.

A discussion of these results and their implications is presented in Chapter Six.

CHAPTER 5

THE USE OF THE TRAC PAC IN TWO SCHOOLS IN THE WESTERN CAPE: A CASE STUDY

In this chapter I describe the data that was collected at the two high schools where this section of the research was conducted.

5.1 DATA COLLECTED AT THE TWO HIGH SCHOOLS

5.1.1 Observation

5.1.1.1 First Observation

This grade eleven Physical Science class consisted of twenty-two learners who were required to complete an activity on reference points and directions[37]. The teacher informed me that the learners had used the TRAC PAC when they were in grade 10 and that the theory required for the activity had already been taught. During this classroom visit, the learners and the teacher granted me permission to use a video camera. I used

[37] Refer to appendix D

this to assist me with my observations. The times indicated below are the times that appeared on the video camera. Fictitious names were given to the learners.

The following observations were made:

The computer was placed on the right-hand side of the large, permanently fixed table in front of the class. All the learners sat facing the computer at tables (two learners per table) arranged in rows on the right hand side of the classroom. An aisle was kept open between the rows of tables in order for the learners to move freely while conducting the activity.

13:49 The learners were all seated quietly at their tables, reading the instructions to the activity. The teacher explained that they had to imitate the graphs that appeared on their worksheet through their movement in front of the motion sensor of the TRAC PAC, and that this movement needed to be carefully observed and recorded. The graphs were labelled A to H and the teacher assigned learners to come to the front of the class to imitate the graphs that appeared on the worksheet.

13:51 The teacher called on Sean to complete the first instruction. He was asked to measure 2,5 m away from the sensor using a 1 metre ruler. At first, he took the ruler and measured 2,5 m in the air. His classmates shouted at him "…put it on the floor".

13:52 The teacher nominated Noel, to sit at the computer and click the "start" button using the mouse.

13:54 The teacher called upon the first learner Faizel, to imitate graph A. The teacher spoke to the entire class:

"*What does he need to do? We need to watch what he is doing. We need to encourage him and tell him what he is doing wrong. He needs to move so* *that we can see the first graph A that appears on the computer. Once he is done and we are satisfied that the graph imitates that on the paper, then you have five minutes to write up and describe the movement. Can we start*"?

13:55 At first Faizel stood, with a piece of cardboard held in front of him, not knowing what to do. His classmates shouted instructions at him.

"*Go closer to the screen*", someone shouted as Noel clicked the "start" button.

"*There we are*", someone else said.

The class laughed and clapped hands.

They were happy with the result. Faizel was able to imitate the shape of graph A by standing still at a position on the positive side of the reference point. They all wrote down what they had observed in the space allocated on the worksheet next to graph A. The teacher reminded them: "*Just write down what you saw, no consulting*".

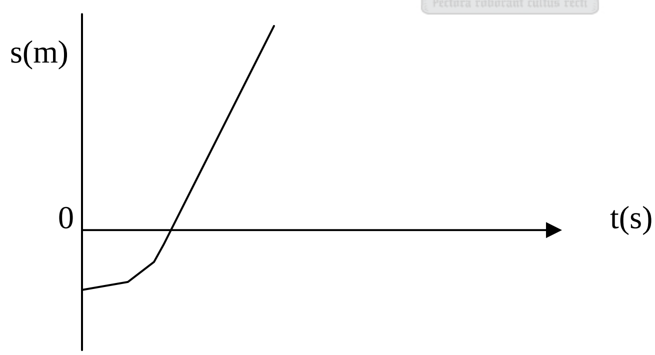
13:59 Martin was the next learner who took up the piece of cardboard. He was responsible for imitating graph B. At first he walked away from the sensor. One of his classmates pushed him forward. The learners laughed. He repeated his attempt again by standing still, closer to the motion sensor. The expected graph shape appeared on the computer screen. He was able to imitate the shape of graph B by standing still on the negative side of the reference point. The learners become quiet again as they wrote down their observation of Martin’s movement.

14:02 It was then Sean’s turn to come forward. He was responsible for imitating the shape of graph C. He held the piece of cardboard at chest height. He positioned himself at the point where Martin had stopped. As a result, when Noel clicked the "start" button, the expected graph shape did not appear on the computer screen. His classmates encouraged him to move.

"*You have to walk*", shouted one learner.
"*Move backwards*", shouted another.
"*Move to the side*", said another learner.

They all gave advice to Sean at the same time. He did not know which way to go.
He walked back, twisted his body, lifted the board above his head and even tried to hold the board sideways. All of this was done in an attempt to get a positive gradient graph, which was given on the worksheet, to appear on the computer screen. He repeatedly walked up and down the aisle and tried different variations with the board after Noel had clicked the "start" button. His classmates were very vocal in encouraging his movements. There was lots of laughter as well.

At this stage it became clear to me that they spent too much time trying to imitate the same graph shape that appeared on the worksheet exactly. Sean repeated his movement in front of the motion sensor numerous times, because the learners were not satisfied with the graph shape that was generated on the computer screen. The graph that was produced did not start exactly at zero as indicated on the worksheet.



The above graph shape appeared regularly on the computer screen and the learners were not satisfied with the result. The learners seemed to have forgotten that the purpose of the whole exercise was merely to determine the movement of the learner that resulted in a specific graph shape. His movement was already correct after the second attempt, but the learners made Sean repeat his movement for a further eight minutes. I deduced from this that the learners tended to focus too much of their attention on what appeared on the computer screen, rather than trying to understand the movement of the boy.

14:10 An exact replica of the graph appeared on the computer screen. The learners were now satisfied with the result and they completed their description of Sean's movement.

14:13 Kamila was the next learner identified by the teacher to imitate graph D. She held the board at chest height, as was done by the other learners. She stood on the reference line and walked up and down the aisle on the instructions of her classmates, after Noel had clicked the "start" button. After her second attempt, she started from the furthest point away from the motion sensor and walked towards the reference line. She was able to imitate the same graph shape that appeared on the worksheet. Her classmates were satisfied with the results, and she returned to her seat.

14:15 The learners wrote down their observation.

14:17 I then assisted Noel to open the second file that was saved on the computer. This file had been calibrated so that the direction towards the sensor was taken as positive. This section of the worksheet was referred to as Part Two.

14:19 Karen was then called upon by her teacher to be the next learner to imitate graph A of Part Two. Her classmates coaxed her in the correct direction. Karen stood still at a position on the positive side of the reference point while Noel clicked the "start" button. The expected graph shape was obtained very quickly. The learners were satisfied with the results and wrote down their observation of Karen's movement.

14:21 Carol was called upon to complete graph B. She stood still on the negative side of the reference point while Noel clicked the "start" button. This was done without any help from her classmates. The learners recorded their observations.

14:22 Farouk attempted to imitate the shape of graph C, that had a positive gradient. He repeated his movement numerous times, while his classmates gave him instructions as to how he should move. Again the learners focused too much on getting the graph to start from point zero and did not focus on the movement of the learner (refer to Sean's movement as described above at 14:02).

14:25 The entire class wrote down their observations.

14:26 Patrick held the board at chest height as he stood in front of the motion sensor trying to imitate graph D. He stood close to the motion sensor and moved away from the sensor very quickly as Noel clicked the "start" button. The shape of the graph became "distorted". He tried again. This time he walked back slowly and the graph extended over the time-axis as he passed the reference line. The graph shape that appeared on the computer screen was either "distorted" or not perfect, and he repeated his movement numerous times before the teacher intervened and said that the graph was fine.

14:29 The learners wrote down their observations.

14:30 I handed out a paper-and-pencil test to the learners after I had asked some of the learners to move to different seats. I did this because I did not want the learners to sit next to one another. I tried to eliminate the possibility of them copying the answers from one another. This was the same test that was completed by the grade eleven learners at the TRAC laboratory[38].

14:35 After collecting their answer scripts, I then handed out the learner questionnaire[39]. Each learner was asked to complete the questionnaire honestly and without eliciting answers from their friends as there were no right or wrong answers. The teacher and I collected the questionnaire from the learners and I thanked the learners for their participation. The teacher dismissed the learners at 14:40.

A summary of the observations is given below.

- The teacher gave the learners enough time to first read through the instructions on the worksheet.
- A learner had difficulty in measuring 2, 5 m using a 1 m ruler.
- The teacher gave clear instructions to the learners about what was expected from them.
- The classmates gave instructions to those learners who had difficulty in demonstrating the movement required for a specific graph.
- The classmates laughed when the movement of a learner resulted in "distorted" graph shapes.
- Learners were required to write down their observations without eliciting answers from other learners seated next to them.
- When a learner tried to imitate graph C, the learner tried various movements in an attempt to get the graph on the computer screen to display a positive gradient.

[38] Refer to appendix H.
[39] Refer to appendix B.

- Learners were too focussed on obtaining exactly the same graph shape that appeared on the worksheet. Any deviation from this perfect form was not satisfactory and as a result, the movement was repeated over and over again.
- As a result, I believed that the learners did not understand that the description of the movement of a learner was important.

5.1.1.2 Second Observation

Another classroom observation of the above activity[40] took place at a different school on a different day. During this observation a video recorder was also used. The teacher informed me that he had already taught the section of work that was being used in this research. The TRAC PAC, together with the motion sensor, was mounted on a table in front of the classroom[41]. The learners were seated in groups of between three to five learners per group.

I was introduced to the learners by the Physical Science teacher. I thanked the learners for allowing me to conduct my research in their classroom and informed them that their honest opinions and views had to be expressed at all times.

The teacher introduced the lesson by summarising what he had taught previously about reference points and directions. During the introduction, the teacher reminded the learners that they had used the TRAC PAC previously when they had completed a grade 10 pendulum activity. The teacher emphasised that the focus of the activity to be completed was for them to be able to describe the movement of a learner holding a piece of cardboard at chest height and walking in front of the motion sensor. The movement of the learner had to correspond with a displacement vs time graph in the worksheet to be handed out to the learners.

[40] Refer to appendix D.

Once copies of the worksheet had been handed out to everyone, the teacher explained that a reference point 2,5 m away from the motion sensor had to be measured and marked on the floor. The teacher called for a volunteer. A boy came to the front of the classroom, took a 1m ruler and initially measured the distance in the air.

Picture 6: Boy measuring 2,5 m in the air using a 1 m ruler.

His classmates laughed as they informed him that he should measure the distance by placing the ruler on the floor. The learner then placed it on the floor to measure the 2,5 m and drew a chalk-line to indicate the mark. This mark is referred to as the reference point.

The teacher then identified certain groups of learners to focus on a specific graph. The teacher explained that the groups should discuss the movement that had to be performed in order to imitate the graph shape that had been allocated to them. The learners were given five minutes to discuss the movement of their specific graph. The discussions that took place were very hushed and learners whispered to each other. This was very unusual and I believed that it was because of my presence in the classroom.

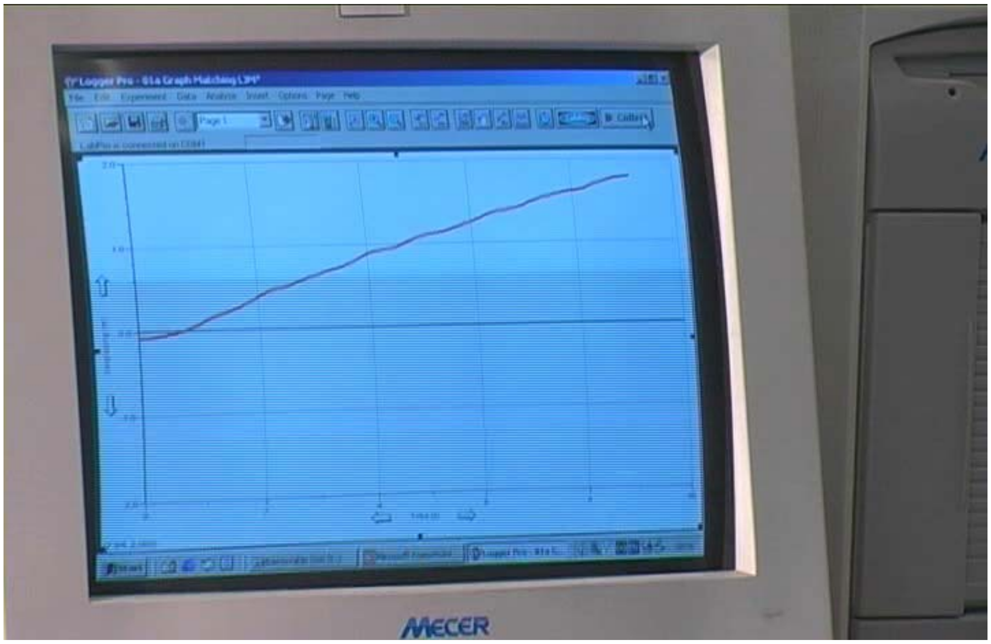
[41] Refer to picture 5.

After the five minutes had elapsed, the teacher called upon the first group to imitate graph[42] A. This group consisted of three girls. Two of these girls (referred to as L1 and L2 respectively) stood up from their tables and approached the front of the classroom where the TRAC PAC was situated. L1 took hold of the board and held it at chest height while L2 approached the TRAC PAC to click the "start" button. L1 then walked to the chalk line and stood still on the positive side of the chalk-line. L2 clicked the "start" button and a similarly shaped graph to the one in the worksheet appeared on the computer screen. The teacher asked if the learners were satisfied with the graph. The learners responded positively and all the learners were given an opportunity to write down their observations of the movement in the space allocated on the worksheet.

A second group, which consisted of four boys and a girl, were asked to imitate graph B. Two boys (referred to as L3 and L4 respectively) stood up and approached the TRAC PAC. Initially, L3, who held the board, stood on the chalk line while L4 clicked the "start" button. The expected graph shape did not appear on the computer screen. The learners were not satisfied with the result. The learner was encouraged by his classmates to stand in front of the motion sensor, on the negative side of the reference point. After a third attempt the expected graph shape appeared on the computer screen. The two boys returned to their seats and all the learners were told to write down their observations.

The third group consisted of three girls and one boy. They were tasked with imitating graph C. One girl and one boy (referred to as L5 and L6 respectively) left their table and took up their positions in front of the class. L6 went to the computer to click the "start" button, while L5 held the board and stood on the chalk line. Once they had taken up their positions, L6 clicked the "start" button and L5 walked slowly away from the motion sensor. L5 was not satisfied with the graph shape that appeared on the computer screen because the graph did not start from zero as illustrated below.

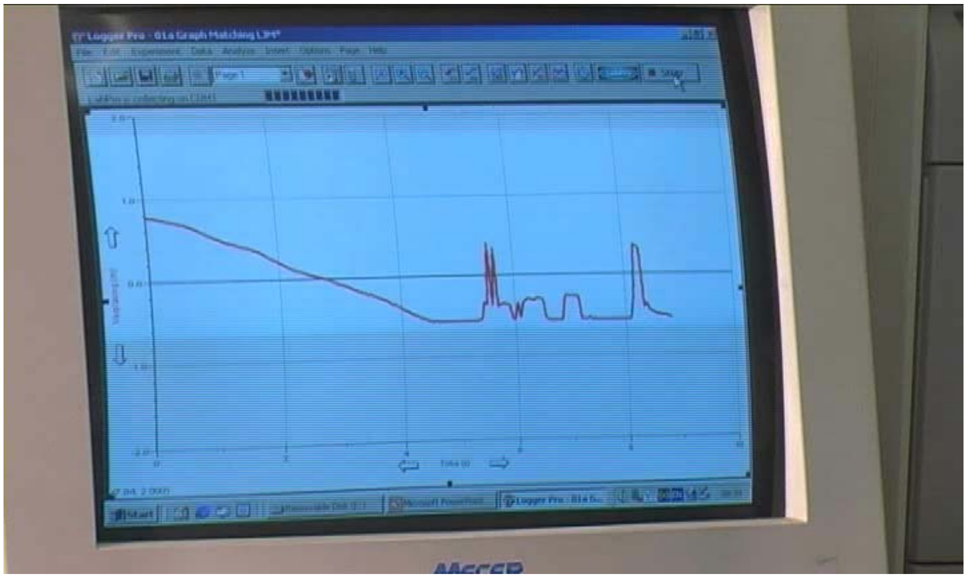
[42] Refer to appendix D



Picture 7: Shape of graph C.

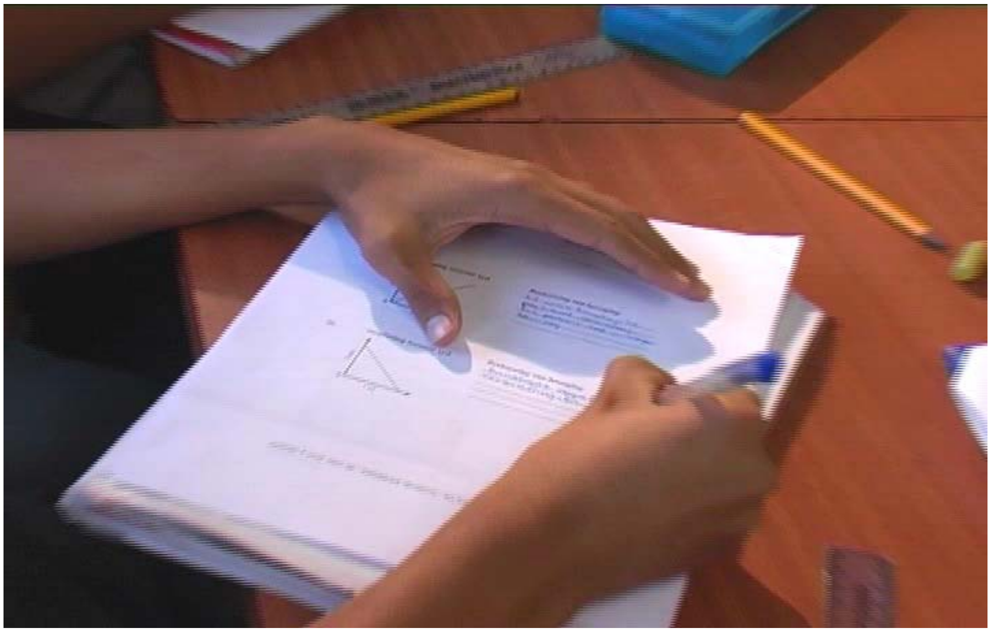
After numerous attempts, the expected graph shape was obtained and all learners were given an opportunity to write down their observations.

The fourth group was instructed to imitate graph D. This group consisted of two girls and one boy. Two girls (referred to as L7 and L8 respectively) stood up from their tables and approached the TRAC PAC. Before they started, they had their own private consultation, with L7 whispering instructions into the ear of L8, much to the amusement of their classmates. After their consultation, L7 approached the computer to click the "start" button, while L8 picked up the board and stood some distance away from the reference point. When the "start" button was clicked, L8 moved towards the motion sensor. She did not stop on the chalk-line, but continued and walked past the reference point. As a result, the expected graph shape did not appear on the computer screen. The following graph was obtained.



Picture 8: Incorrect shape of graph D.

The learner appeared confused and embarrassed when the expected graph shape did not appear. After the fourth attempt L8 walked until she reached the reference line and stopped. The expected graph shape was obtained and all the learners were given an opportunity to write down their observations. During these sessions, learners were encouraged not to copy answers from one another and were asked to write down their own answers. As a result, no discussions between learners took place as they wrote down their observations.



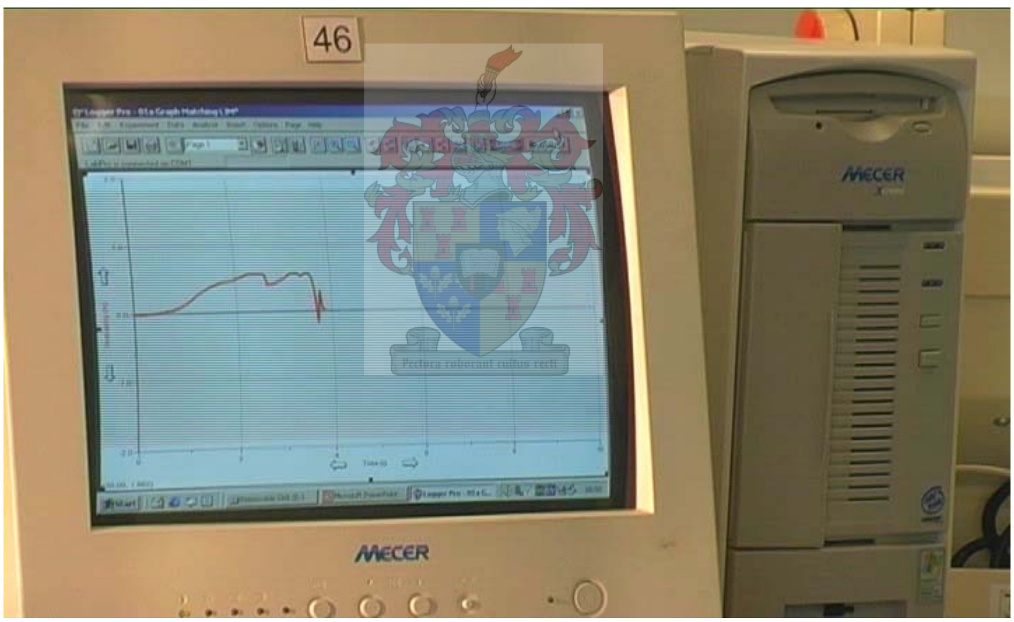
Picture 9: A learner writing down his observation of the movement required for graph D.

The Part Two of this activity, the direction towards the sensor was taken as positive. The learners were still expected to imitate the shape of the same four displacement vs time graphs that appeared in Part One.

The group that was tasked with imitating graph A consisted of two girls. The girl holding the board managed to imitate the graph shape after the third attempt. Initially, the girl stood still on the reference line, then moved back and stood on the negative side of the reference line. Finally, she moved forward and stood still on the positive side of the reference line. All the learners were satisfied with the result and were given an opportunity to write down their observations on the worksheet.

The following group that was responsible for demonstrating the movement required for graph B consisted of three boys. Two boys (referred to as L9 and L10 respectively) participated in this demonstration. L9 stood next to the TRAC PAC to click the "start" button, while L10 picked up the board and stood on the chalk-line. When this did not produce the required graph shape, L10 moved backwards and stood still while L9 clicked the "start" button. The required graph shape appeared on the computer screen and the boys returned to their seats. All learners then completed their observation.

Two of the three boys from the following group tried to imitate the shape of graph C eleven times before the teacher informed the boys that the graph shape was satisfactory. Although the graph shape had been obtained earlier, the boys nevertheless continued because the graph that appeared on the computer screen did not have the same graph shape as in the worksheet. On more than one occasion all the learners laughed when differences to the expected graph shape appeared on the computer screen, as illustrated below.



Picture 10: Shape of graph C after numerous attempts.

During this attempt, I noted that the time of ten seconds allocated on the computer screen for the graph shape to be formed was too much. The graph shape was obtained after about three seconds. Therefore, all that the teacher had to do was to change the setting of the time-axis before repeating the movement again. I also observed that the shape of the graph was influenced by the data received by the motion sensor. As a result, the graph shape illustrated above, dropped to the time-axis after approximately four seconds. This type of distortion in the graph shape resulted in learners laughing out loud and I believed that it impacted negatively on the learners' understanding of the concept that was being taught. Another observation was that the graph initially first ran parallel to the time-axis before showing a positive gradient. This point would need to be made clear to the learners in future, because the issue of positive constant acceleration and positive constant velocity was not clearly distinguished during this activity. When a learner held the board and started to move from the reference point, s/he first accelerated before moving with at a constant speed.

By now all the groups had been given an opportunity to imitate the shapes of different graphs. However, graph D remained. The teacher then called on volunteers. A boy and a girl from different groups then approached the TRAC PAC. They experienced similar problems to those identified for graph C above. The boy who held the board was able to imitate the graph shape after the first attempt, but was not satisfied with the graph shape. As a result, the movement was repeated for more than thirteen times. During this time, the distortion that was mentioned in graph C above was also evident again. All the learners laughed when this distortion was displayed on the computer screen. After a while, the boy who was holding the board became so despondent after the many failed attempts that two other learners were asked to demonstrate the movement required to imitate the graph shape. Only through sheer perseverance was one learner able to imitate the graph shape.

A summary of the observations is given below.

- The teacher had taught the content prior to the research being conducted.
- The TRAC PAC was placed on a large table in front of the classroom.
- The tables in the classroom were grouped thereby easily facilitating group work amongst learners.

- The inability of a learner to make accurate measurements seemed to indicate the lack of basic scientific skills.

- Learners were given sufficient time to read the instructions and interact with one another within their respective groups.

- Through trial and error and advice from other classmates, the learners were able to imitate the shapes of graphs A and B after a maximum of three attempts.

- However, graphs C and D proved to be more challenging for the learners. The learners repeated their movement numerous times because they were not satisfied with the graph shapes. If the graph was not exactly the same as the graph that appeared on the worksheet, they repeated their movement. In most cases, this was not necessary, as they had initially completed the correct movement.

- The classmates found it hilarious if the movement of a learner did not correspond with the expected graph shape.

- The time allocation of ten seconds on the X-axis was too much. The expected graph shape usually appeared within the first four seconds. The teacher was not able to intervene and make the necessary adjustments.

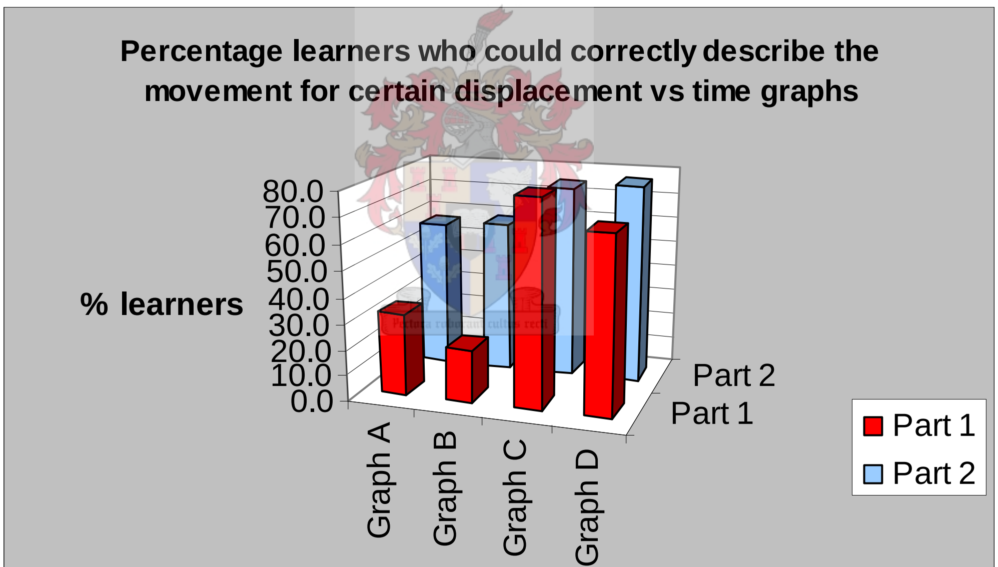
- The interference that was 'picked up' by the motion sensor created graphs that did not resemble the expected graphs shapes and as a result, the learners had to repeat their movements.

- The learners were not able to distinguish between positive acceleration and positive constant velocity for displacement vs time graphs

- Learners became despondent when their numerous attempts did not produce the expected graph shape. This may have had a negative effect on the learners' understanding of the displacement vs time graphs.

5.1.2 Worksheet

Forty-four grade eleven learners from the two high schools completed the worksheet called reference points and directions[43]. Using a memorandum I had drawn up, I marked these worksheets to determine whether the learners could make observations and describe them. This enabled me to determine their level of understanding of what they had observed. Based on these findings, I was able to determine the percentage of learners who could correctly explain the movement that other learners had to imitate against the eight graphs that appeared in the worksheet. These findings are illustrated in graph 20, which appears below.



	Graph A	Graph B	Graph C	Graph D
Part 1	31.8	20.5	79.6	68.2
Part 2	56.8	59.1	75	77.3

Graph 20: Percentage of learners who could correctly describe the movement for certain displacement vs time graphs.

[43] Refer to appendix D.

In Part One of this worksheet, the direction away from the motion sensor was calibrated to be in a positive direction. In Part Two the direction towards the motion sensor was calibrated to be in a negative direction.

In graph A, Part One, the learners were expected to have observed that the movement of a fellow learner should have remained stationary on the positive side of the reference line. 31.8 % of the learners could provide the correct explanation. For Part Two, where the learners were also expected to have observed the same movement as in Part One, 56,8 % of the learners could provide the correct explanation. This showed an improvement of 25 %.

In graph B, Part One, the learners were expected to have observed that the movement of a fellow learner should have remained stationary on the negative side of the reference line. 20,5 % of the learners could provide the correct explanation. For Part Two, 59,1 % of the learners could provide the correct explanation. This showed an improvement of 38,6 %.

In graph C, Part One, the learners were expected to have observed the movement of a fellow learner and to have written that the movement would have taken place (at a constant velocity) in a positive direction away from the reference line. Graph 20 shows that 79,6 % of the learners were able to provide the correct explanation for Part One, while 75 % gave the correct explanation for Part Two. This indicated a decrease of 4,6 %.

For graph D, Part One, the learners were expected to have observed that a fellow learner had started on the positive side of the reference line, walked towards the reference line, and stopped on the reference line. It can be seen that 68,2 % of the learners were able to provide the correct explanation for Part One, while 77,3 % of the learners gave the correct explanation for Part Two. This showed an improvement of 9,1 %.

While marking the learners' descriptions of the movements, I found that I had to mark leniently and not strictly according to the memorandum. I found that the learners could not communicate what they had observed clearly. Here is one example that I marked as incorrect: "*When he moves forward it is negative when he moves backward it is positive when he moves beyond 2,5*". This response had absolutely no bearing on graph A. I was more lenient with one learner's response for graph C: "*He moved backwards at a constant pace and velocity increases uniformly*". I credited the learner for "*He moved backward at a constant pace…*" and ignored the last part "*…and velocity increases uniformly*". I was expecting the learners to indicate that the movement had started from the reference line.

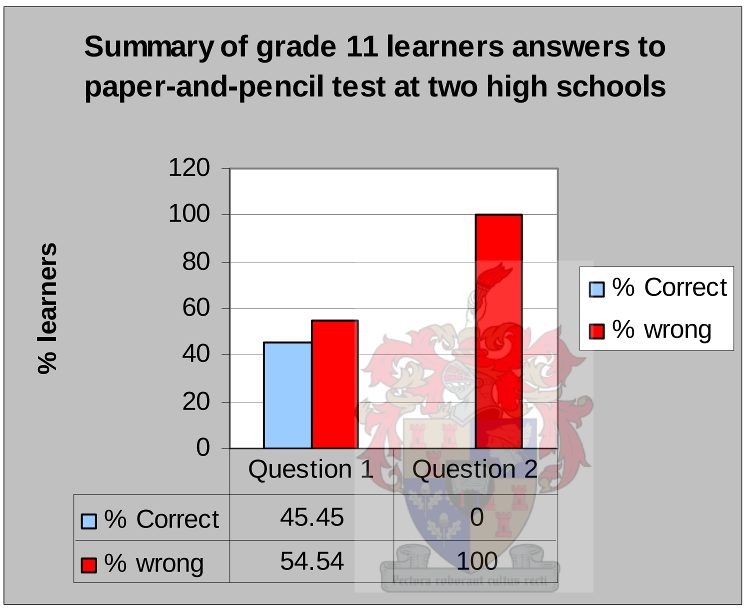
The learners also used the scientific terminology out of context. It was evident that the teacher had taught the learners certain concepts but that some could not identify the context within which the correct terminology should be used. Here is a typical example in response to graph C: "*Moving to the back with uniform velocity and uniform acceleration in motion with the detector in a positive direction starting from the point start*". The learner used the terms 'uniform velocity' and 'uniform acceleration' as though they were the same, and probably did not understand the difference between these two concepts.

These results raised the concern that these learners were not able to communicate effectively. This issue is discussed further in Chapter Six.

Overall, I concluded that as the learners progressed through the activity, their level of understanding improved. This is evident from graph 20 above, which shows that for three of the four graphs, there had been an increase in the percentage of learners who were able to describe the movement of a fellow learner correctly.

5.1.3 Paper-and-pencil test

In total, forty-four learners completed the paper-and-pencil test[44] immediately after they had completed the activity worksheet. The following graph illustrates the results of the test.



Graph 21: Grade eleven learners' answers to the paper-and-pencil test at two high schools.

From the results displayed in the graph above, it can be seen that 45,54 % of learners were able to answer question one correctly. None of the forty-four learners were able to answer question two correctly. This is in sharp contrast to question one, but corresponds with the results of the learners who participated in the same activity at the TRAC laboratory[45]. I present possible reasons for the difficulties learners experienced with question two in Chapter Six.

5.1.4 Questionnaires

Two teachers completed the teacher questionnaire[46], while forty-four learners completed the learner questionnaire[47].

5.1.4.1 Learner questionnaires

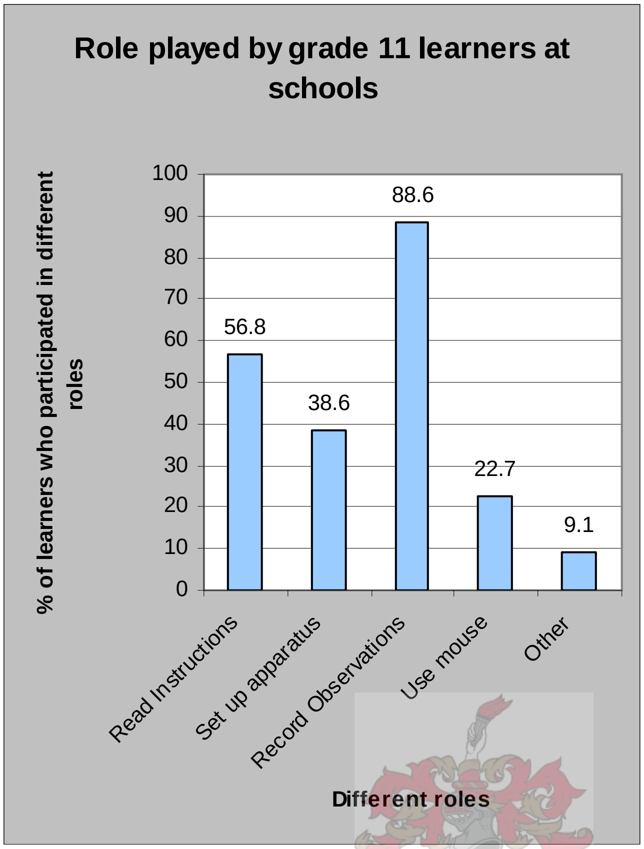
Each learner completed the questionnaire individually, immediately after completing the paper-and-pencil test. The questionnaire focused on different aspects of using the TRAC PAC, and the data is described below.

A The role played by each learner

In this section of the questionnaire I wanted learners to choose the role that they had played within their groups from a possible list of five alternatives. A summary of these roles are illustrated in the graph below.

---

[44] Refer to appendix H.
[45] Refer to graph 7.
[46] Refer to appendix A
[47] Refer to appendix B



Graph 22: Different roles played by grade eleven learners at school.

After analysing the graph, I found that 56,8 % of the learners indicated that they had read the instructions that appeared on the activity worksheet. Did this mean that the remaining 43,2 % of learners who did not read the instructions had actually understood what the activity was all about? Another possibility exists. Since the learners were seated in groups, it might have been possible for the groups to have identified a particular learner to be responsible for reading the instructions, who then explained the activity to the rest of the group.

The second role that was identified on the questionnaire was that of setting up the apparatus. This role required a learner to hold the board and walk up and down in front of the motion sensor in order to imitate the movement required to obtain a particular graph shape. Graph 22 indicates that 38,6 % of learners were involved in this role.

The next role asked if the learners had recorded their observations while completing the activity. According to their responses, 88,6 % had done so. I interpreted this to mean that learners had recorded their observations because the teacher and I had reminded them constantly to be honest in their responses.

The low percentage of 22,2 % which responded that they had used the mouse to click the "start" button, was expected, as only one learner from each group clicked the "start" button.

Other roles that 9,1 % of the learners identified included taking part in discussions and answering certain questions.

B Understanding of instructions

I included this in the questionnaire because I wanted to know if learners had understood the instructions while completing the activity. All forty-four learners indicated that they had understood the instructions. The possible reason for this could be a result of the teacher taking control of the pace at which the activity was completed and allowing the learners an opportunity to read the instructions. However, I acknowledge that the learners' perception that they had understood the instructions might not necessarily have been true.

C Learners' experiences while using the TRAC PAC in the classroom

I wanted the learners to share their experiences of using the TRAC PAC to complete the activity in their classrooms. These are summarised below.

- Only one learner indicated that s/he did not enjoy the experience.

- 6,8 % of the learners indicated that they had experienced frustration while completing the activity. The reasons for their frustration included: "*when graphs did not look like those on the worksheet*" and "*we had to repeat the activity on numerous occasions*".
- The learners were also given an opportunity to share other experiences that were not reflected on the questionnaire. These are indicated below:
    1. 27,2 % of the learners indicated that they had found the experience interesting.
    2. 18,2 % of the learners indicated that they had felt nervous.
    3. 9 % indicated that it was different to the way they were normally taught when they did not use the TRAC PAC.

D Dialogue

In this final part of the questionnaire I wanted to determine what dialogue had taken place between the learners within their groups as I was not able to listen to their discussions during my observations. Five alternatives were given and the learners could identify more than one role.

Type of dialogue	**%**
Argued most of the time	40,9
Could not reach agreement	4,5
Agreed on everything	95,5
One learner knew all the answers, the rest of us just wrote down the answers	0
Other (please specify)	18,2

This data clearly showed that no learner dominated the group discussions. Instead, it appeared that lively, even heated discussions took place between all the learners within the group, because 40,9 % of the learners indicated that they "Argued most of the time". After the discussions had taken place, consensus was reached on what approach to follow, as can be seen from the 95,5 % who "Agreed on everything".

5.1.4.2 Teacher questionnaires

Both Physical Science teachers completed the questionnaire[48]. The results of the questionnaire are described below.

A Background information about the teachers

- One teacher is female and the other male.
- Both teachers are in their early forties.
- The lowest professional qualification is a grade twelve certificate and the highest is a B.Sc degree.
- The teachers had ten and fifteen years experience of teaching of Physical Science respectively.
- Both teachers had a total of fifteen years' teaching experience.

[48] Refer to appendix A

B **Classroom experience**

(i) Number of learners taking Physical Science

The following table represents the number of learners taking Physical Science (grade 10 - 12) at the two high schools were the research was conducted.

Teacher	Grades		
	10	11	12
1	72	51	36
2	34	22	60

Table 10: The number of Physical Science learners at the two high schools.

Not much can be deduced from these average numbers, as they only represented two high schools.

(ii) Practical work

This part of the questionnaire is similar to the one described in Chapter Four, section 4.2.4.2. The responses from both teachers indicated that:

- Their learners performed 90,9 % of the practicals required by the syllabus
- The teachers demonstrated 62,5 % of the practicals required by the syllabus
- Their school was in possession of all the apparatus and chemicals needed to complete all the prescribed practical activities.

- They did not have a laboratory assistant or a separate classroom in which to conduct the practical activities. Teachers had to set up the apparatus before the learners entered the classroom, rearrange the seating and clean up after the completion of the practical activity. I believed that this hampered the teachers' ability to perform the required number of practical activities.

- Both schools had the minimum security measures in place.

- When asked why certain practical activities were not completed, one teacher responded that these practical activities did not work and the results were not convincing.

- Both teachers believed that other institutions such as NGO's had a role to play in helping the teacher to complete those practical activities that were not completed at school.

- One teacher was of the opinion that teachers needed to receive continuous training on how to manage classrooms while performing practical activities and on how to use apparatus to perform the practical activities.

C School outings

This section of the questionnaire focussed on the type of destinations to which Physical Science learners were taken by their school and the implications of such visits.

- One teacher indicated that her learners were not taken on any educational excursions during their grade twelve year as all the time was needed to complete the teaching of the syllabus. The other teacher indicated that his learners were taken on educational excursions between one to five times per year.

- The teacher who took learners on educational excursions preferred lectures and practical demonstrations as common destinations. The teacher was responsible for making the necessary travelling arrangements and the learners were solely responsible for the travelling expenses. This teacher felt that being absent from school for most of the day was a great disadvantage for the learners, as they missed their normal classes in other subjects.

- Both teachers indicated that they would prefer to have their own fully equipped science laboratory as opposed to taking their learners to a centre where they could complete their practical activities. The reason for this preference was that they would have control over the teaching and learning that took place.

D Computer literacy

As the TRAC PAC is a computer application, I wanted to determine how computer literate the Physical Science teachers were.

- Both teachers indicated that they owned personal computers and used the basic computer applications such as the Internet, word processor and CD ROMs.

- On a scale of 1 to 10, with 1 being not confident and 10 being extremely confident, one teacher gave a rating of 5 and the other a rating of 8 for their computer literacy.

- Both teachers indicated that they would use a computer in their classrooms because it "*enhances the teaching and learning that takes place in the classroom*".

5.1.5 Interview

5.1.5.1 Teacher interviews

Interviews were conducted with both Physical Science teachers whose classes participated in my school-based research. These interviews were audio-recorded. I wanted to gain insight into their perspectives on the use of the TRAC PAC at high schools in the Western Cape. A summary of the main points of the interviews[49] are given below .

- The use of the TRAC PAC in Physical Science classrooms had the following advantages:
    1. It was regarded as an additional resource that could facilitate teaching and learning in the Physical Science classroom.
    2. The learners were able to use the TRAC PAC on their own and as a result would be stimulated to learn more.
    3. It would expose learners to using different methods to collect data.
    4. It would prepare learners to participate in an information technology environment.
    5. The activities completed with the use of the TRAC PAC met the departmental requirements for continuous assessment (CASS), thereby contributing to the reduction in the workload of teachers.
    6. The learners would benefit by being able to understand graphs better than through the traditional way (i.e. manually) of generating graphs in the classroom.

- The following disadvantages associated with using the TRAC PAC in Physical Science classrooms were mentioned:

1. Using the computer could be intimidating if a teacher was not confident in using the TRAC PAC effectively.
2. Using the TRAC PAC effectively required quite a lot of preparation from the teachers, for which they often did not have the time.
3. The possibility that such expensive equipment might be stolen was very real. As a result, extreme security measures had to be taken. The TRAC PAC had to be dismantled and reassembled as it was moved between the classroom and a place of safety. This limited its usage in the classroom.
4. The small computer screen limited the ability of learners in a classroom to see the images that appeared on the screen. This was particularly evident in classrooms with large numbers of learners.
5. No assessment instruments such as rubrics for practical activities, which are required by the department, were available. Teachers did not have the time to develop their own instruments for the TRAC practical activities.

- The teachers, however, believed that the advantages of using the TRAC PAC far outweighed the disadvantages.

- The teachers only used the TRAC PAC when covering certain chapters in grades ten, eleven and twelve.

- Both teachers considered the following factors to be important when deciding to take learners to the TRAC laboratory at Stellenbosch University:
    1. The support and assistance that was offered to the teachers and learners at the laboratory was better than at school.
    2. The laboratory had more computers available for all learners to actively participate in the practical activity at the same time.
    3. Learners grasped difficult concepts better when taught in a different setting.

- However, they regarded the following to be disadvantages of the TRAC laboratory.

[49] Refer to appendix M for complete interviews.

1. The activities were completed by the learners at the TRAC laboratory after the concepts had been taught by the teacher. These activities were not integrated with the normal teaching and learning programme.
2. When learners were required to complete more than one activity during a visit to the TRAC laboratory, it was assessed to contribute towards the learner's continuous mark (CASS). However, the assessment process did not meet the continuous assessment criteria, which implied regular assessment throughout an academic year.
3. Transportation costs to the laboratory were expensive.

- When asked to provide advice to teachers using the TRAC PAC at their schools and TRAC SA on what they believed was necessary for the optimal use of the TRAC PAC, they responded:
    1. TRAC SA must provide assessment instruments, as required by the education department, to accompany the practical activities that are completed by learners using the TRAC PAC.
    2. TRAC SA must retrain teachers constantly and ensure that the worksheets and computer programme are user-friendly.
    3. TRAC SA must offer support to teachers who use the TRAC PAC in their classrooms either through a help-desk or an assistant who can visit the classroom while the TRAC PAC is being used.
    4. Teachers who have the TRAC PAC at their schools must integrate the TRAC PAC into their normal classroom procedure and should not use the TRAC PAC as an 'add on'.
    5. Teachers have to enjoy using the TRAC PAC and have to be thoroughly prepared before using the TRAC PAC.
    6. Teachers must encourage their learners to use the TRAC PAC on their own.
    7. Teachers must be encouraged to use the TRAC PAC as often as possible.

- Both indicated that they would definitely choose having a TRAC PAC in their classroom instead of taking their learners to the TRAC laboratory, because it saved on travelling costs and learners would be able to work at their own pace at school.

5.1.5.2 Learner interviews

Three learners from two different schools participated in the interviews. An audio recorder was used in all cases after receiving permission from the learners and their teachers. The teachers identified the learners who participated in the interviews[50] based on their ability to respond honestly to questions. A summary of the responses from the learners is given below.

- All three learners indicated that they had enjoyed the session with the TRAC PAC.
- When asked to provide reasons why they enjoyed the session, the responses included:
  1. "It was very, very interesting and different"
  2. "…using this computer regularly can make the understanding of the work so much quicker and easier".
  3. "…I think I learned a lot this morning".
  4. "It was interesting to hear the opinion of other learners".
- All of them mentioned that they were able to 'see for themselves' how the graphs appeared on the computer screen. Brasell[51] refers to real-time observations being very important for learning and even a 20-30 second delay hampers the learning of science concepts.
- Two of the three learners were asked what type of discussions took place in their own groups before they had to demonstrate the movement required for a particular graph. Both learners said that initially each member of the group had his or her own

[50] Refer to appendix N for the complete interviews.

interpretation of what to do, but after sharing ideas with one another they all reached consensus about what to do.

- One learner felt that even though he felt more confident about the work after using the TRAC PAC, he believed that some learners in his class still might not understand and would therefore require some additional assistance from the teacher.

5.2 SUMMARY OF DATA COLLECTED

A summary of the data that was collected at the two high schools is given below.

- Two classroom observations were done while the learners used the TRAC PAC to complete the practical activity. In both cases, a video-recorder was used after permission was obtained from teachers and learners.
- Forty-four grade eleven learners completed a paper-and-pencil test, an activity worksheet on reference points and direction as well as a questionnaire.
- Three learners from two different high schools agreed to be interviewed.
- Two teachers completed a questionnaire and agreed to be interviewed.

These results and their implications are explored in Chapter Six.

[51] Refer to section 2.6.4.

CHAPTER 6

ANALYSIS, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

I conducted this research, in an attempt to address the question: "How can the TRAC PAC be utilised optimally?" Duguet (1990:172) and Lapp *et al*. (2000:509) have also recommended that further research is needed on the pedagogical advantages of MBLs. The primary purpose of the TRAC PAC is to assist Physical Science learners to develop their cognitive as well as their science processing skills which they are expected to have mastered by the time that they leave high school. A secondary purpose of the TRAC PAC is for the teacher to use it to motivate learners to succeed with Physical Science as a subject at high school. An understanding of the interaction between the learner and the TRAC PAC as well as the teacher and the TRAC PAC is therefore necessary to determine whether the TRAC PAC is effective or not.

The teacher is ultimately responsible for ensuring that learners develop these necessary skills. How the teacher uses the TRAC PAC to develop these skills is an important factor that must be considered. Therefore, this research focused on the practical realities experienced by teachers and learners while using the TRAC PAC in the science classroom or at the TRAC laboratory as well as the learners' experiences and performance while and after using the TRAC PAC. An analysis of the practical realities, learners' experiences and performance as advantages or disadvantages of the TRAC PAC is described in this chapter. The shortcomings of this research are given and the chapter concludes with recommendations for the optimal use of the TRAC PAC.

6.2 ANALYSIS OF DATA

Ratcliffe (in Merriam, 1988:167) informs one that data on its own is meaningless and that it needs to be interpreted. When interpreting the data, I was aware that my biases could influence the interpretation of the data.

The qualitative researcher, according to Merriam (1988:124) "...does not know what will be discovered, what or whom to concentrate on, or what the final analysis will be like". Therefore, I decided to analyse the data that I collected through the identification of categories, as I was searching for "…recurring regularities in the data" (Merriam, 1988:133). Goetz and LeCompte (in Merriam, 1984:133) state, "Devising categories is largely an intuitive process, but it is also systematic and informed by the study's purpose, the investigator's orientation and knowledge, and the 'constructs made explicit by the participants of the study'".

"Devising categories involves both convergent and divergent thinking (Cuba and Lincoln in Merriam, 1988:134). *Convergence* is determining what things fit together – which pieces of data converge on a single category or theme. *Divergence* is the task of fleshing out the categories once they have been developed". For example, I realised as I analysed the data that on more than one occasion different learners were unable to use a 1 meter ruler to measure 2,5 meters accurately. In another instance, different learners were unable to measure the mass of a trolley using a triple beam balance. These two pieces of information informed me that a category had been identified through convergence, namely, that learners lacked a basic skill called measurement. The identification of the different skills lead to a process of divergence, where I was able to recommend that learners had to be able to perform certain basic skills before using the TRAC PAC. This is one of the factors I believe will contribute towards the optimal use of the TRAC PAC.

Cuba and Lincoln (in Merriam, 1988:135) provide guidelines to the researcher when developing categories. I have focused on two of these guidelines.

- "The number of people who mention something or the frequency with which something arises in the data indicates an important dimension". As an example, the overwhelming majority of learners indicated through interviews and questionnaires that they enjoyed working with the TRAC PAC. Therefore, the category 'engaging learner interest' was identified.

- "One's audience may determine what is important". In this research, the teacher and learners are the audience, as this research will influence the use of the TRAC PAC in either the classroom or a laboratory.

The categories that were identified are discussed below.

6.3 ADVANTAGES OF THE TRAC PAC

The following advantages of the TRAC PAC were identified.

6.3.1 Engaging learner interest

In the learner questionnaire[52], learners were asked to indicate whether they had enjoyed the experience of using the TRAC PAC. Analysis of this data showed that 99 % of the

[52] Refer to appendix B

grade eleven learners[53] and 89 % of the grade twelve learners[54] who had visited the TRAC laboratory had enjoyed the experience of using the TRAC PAC. A similar result was also obtained from the questionnaire completed by the grade eleven learners who participated in this research at their school. The analysis of their data showed that 97 % of the learners[55] indicated that they too enjoyed the experience of using the TRAC PAC. Without any prompting or space allocated for additional comments on the questionnaire, some learners added their own feedback, e.g. "*It was so much easier to do Physics on the computer*. *I really actually enjoyed and understood what I was doing! Thanks a lot*!"[56]

The analysis of teacher and learner interviews confirmed that learners enjoyed the experience of using the TRAC PAC in the laboratory and in their classrooms. The advantage of conducting interviews with the teacher and learners was that they were able to provide reasons for this enjoyment. One reason given by a learner was that the work dealt with was syllabus-related: "… *the things we do in class we did here on the computer*". Another reason, provided by the teacher and learners, was that learners were given the opportunity to perform the practical activity themselves "…*the way we do practicals in class which (sic) is boring because all we do is talk about the practical*…" It is not my intention to list all the reasons here why learners have enjoyed the experience[57].

The responses to the learner questionnaire, mentioned above, indicate that a small percentage of learners did not enjoy the experience of using the TRAC PAC. Reasons for this were obtained during the interviews with learners. I documented[58] that one learner did not find the real-time appearance of the graphs on the computer screen "…*helpful*…" because "…*I need to understand why a particular shape graph is obtained*".

Despite the fact that some learners indicated that they did not enjoy the experience of using the TRAC PAC, I was convinced that the overwhelming majority of learners

[53] Refer to section 4.1.4
[54] Refer to section 4.2.4.1
[55] Refer to section 5.1.4.1
[56] Refer to section 4.1.4 for additional comments
[57] Rather, one can refer to sections 4.1.5.1, 4.1.5.2, 4.2.5.2 and 5.1.5.2 for additional reasons.
[58] Refer to section 4.2.5.2

enjoyed the experience of using the TRAC PAC at both the school and the TRAC laboratory. This was evident in the responses of learners in the learner questionnaire, their responses when interviewed as well as the responses of one teacher who was interviewed.

The learners who participated in this research at the TRAC laboratory were using the TRAC PAC for the first time. A teacher who had the TRAC PAC at school[59] observed: "*I try to use it at least once per term*" when asked in an interview how often the TRAC PAC was used. The use of the TRAC PAC for the first time and the very limited use of the TRAC PAC at school prompted me to ask the following two questions: Could it be that the learners' enjoyment of using the TRAC PAC was because of the 'novelty' experience of using it? Would they still enjoy using the TRAC PAC if they were to use it frequently? I was unable to provide answers to these questions.

I mentioned above that learners enjoyed using the TRAC PAC. However, this enjoyment did not necessarily imply that learners actually learned something. I do not believe that there is a direct relationship between learner enjoyment and learner learning. This is discussed further in section 6.4.4 where the learners' paper-and-pencil test results are analysed.

Learner enjoyment, I believe, is coupled directly to the ability of the TRAC PAC to encourage the learners to actually be enthusiastic and interested, for a short while at least, about the subject matter. If the learners find the experience attractive, then this is an important factor that contributes towards the optimal use of the TRAC PAC.

[59] Refer to appendix M

6.3.2 Improvement in understanding of content

The worksheet[60] completed by the grade eleven learners at the two high schools as well as at the TRAC laboratory required that they describe the movement required to replicate eight displacement vs time graphs. Part One of this worksheet contained four graphs where the direction away from the motion sensor was calibrated to be positive, while for Part Two, the remaining four graphs, the direction towards the motion sensor was calibrated to be positive. The analysis of these worksheets indicated that although there were instances where there was a decrease in the ability of learners to describe the movement between parts one and two, the majority of responses indicated that there was an increase in the ability of learners to describe the movement between parts one and two. Graph 6 represents[61] the analysis of the one hundred and four grade eleven learners who attended the TRAC laboratory. Graph 20 represents[62] the analysis of forty-four learners at their respective schools.

In graph 6, the instances which indicate a decrease in description of the movement between parts one and two are indicated for graphs A and C. Graph 20 also shows this information for Graph C. In all other instances there was an increase in the ability of learners to describe the movement of a graph between parts one and two.

I can deduce from these results that while the learners used the TRAC PAC they were able to demonstrate an overall improvement in the description of their observations. However, some doubts remain. I am not certain whether learning actually took place and whether this improvement was significant. The reason for this uncertainty is the poor results of the paper-and-pencil test completed by these learners which reflected a different picture to the one mentioned above. The results of the paper-and-pencil test are discussed in section 6.4.4. Another possible reason to doubt the significance of this improvement was that the learners completed the answers on the worksheets immediately

[60] Refer to appendix D
[61] Refer to page 104
[62] Refer to page 167

after they had completed a particular section of the worksheet. The results could possibly have been different had they completed the answers the following day.

6.3.3. The ability to implement the TRAC PAC in either the classroom or the TRAC laboratory

When four of the five teachers interviewed, were asked to choose between having a TRAC PAC in their classroom or taking their learners to the TRAC laboratory, their typical response was: "*I would definitely choose to have the TRAC PAC in my classroom*"[63 and 64]. These teachers provided the following reasons to motivate why they believed that the TRAC PAC should definitely be placed in their classrooms:

- The learners will be able "...to grasp certain concepts quickly" and it can be used to assist learners who experience difficulty understanding certain science concepts[65].
- They gave six advantages of using the TRAC PAC in their classrooms[66]. These advantages are summarised below:
  1. It is a resource that can facilitate teaching and learning.
  2. It motivates learners to learn.
  3. It provides learners with an alternative method of collecting data.
  4. It prepares learners for the world of work.
  5. It reduces the workload of teachers, as it is compatible with the departmental CASS requirements.
  6. It helps learners to understand graphs better.

These advantages listed above, provided by the teachers during their respective interviews, made me wonder whether these advantages only applied to the classroom and not to the TRAC laboratory. I think that whether the TRAC PAC is used in the

[63] Refer to appendix M.
[64] Refer to sections 4.1.5.2, 4.2.5.1 and 5.1.5.1.
[65] Refer to section 4.2.5.1.
[66] Refer to section 5.1.5.1.

classroom or the TRAC laboratory, it would still 'facilitate teaching and learning, motivate learners to learn, etc.' I also question the other reasons provided i.e. the ability of learners to 'grasp certain concepts easier' and 'it helps learners to understand graphs easier'. The results of the paper-and-pencil test conducted casts doubt on these reasons provided by teachers as to why they would prefer the TRAC PAC in their classrooms. These results are discussed further in section 6.4.4.

The response of a fifth teacher, I believe, provided a more realistic answer to the question about whether the TRAC PAC should be placed in classrooms or in the TRAC laboratory. This teacher, who was also interviewed[67], was in possession of a TRAC PAC at school and had brought his learners to the TRAC laboratory. Therefore, this teacher had experienced both scenarios. I tend to agree with the following responses from this teacher: "*It is a difficult choice to make*", because both had its own advantages and disadvantages, and "*the ideal situation would obviously be to have both set-ups…*"

6.4 DISADVANTAGES OF THE TRAC PAC

The following disadvantages of using the TRAC PAC were identified.

6.4.1 Distorted graph shapes

Whether learners used the TRAC PAC at school or in the TRAC laboratory, the graph shape that was expected to appear on the computer screen often did not appear. This must be considered as one of the major disadvantages of the TRAC PAC. On all the worksheets that were provided to both grade eleven and twelve learners, an almost perfectly drawn graph was given. When the learners tried to replicate the graph, the graph that appeared on the computer screen was either not 'perfect' or in other cases did not resemble the expected graph shape at all. These graphs I refer to as "distorted" graph shapes. Examples of these "distorted" graph shapes can be found in Chapter Five[68]. Evidence of these "distorted" graph shapes can be found in the observations of grade eleven learners at the TRAC laboratory and in their classrooms while they performed the activity on reference points and directions[69]. Similar examples can also be found in the observations of the grade twelve learners when they completed the activity on the relationship between the resultant force and acceleration[70].

Learners not familiar with the technique of selecting the usable or relevant sections of the graphs often became frustrated or repeated the whole procedure. These difficulties are discussed fully here.

(A) Learner frustration

I noted during my observations that grade eleven learners showed signs of frustration while they were carrying out their activity, when the expected graph shape, which appeared in the worksheet, did not appear on the computer screen. They were frustrated because no matter what they did, they could not replicate the graph. Some learners tried different variations such as raising the board above their head or walking slower or faster, all to no avail[71]. The most obvious display for learner frustration was evident when a grade twelve learner asked me sarcastically: "*Why must we add the mass pieces to the hanger*?" after the expected graph shape did not appear after numerous attempts

---

[67] Refer to appendix K and section 4.2.5.1
[68] Refer to pictures 7 and 10
[69] Refer to section 4.1.1.1, 4.2.1.2 and 5.1.1.2, respectively.
[70] Refer to section 4.2.2.2
[71] Refer to sections 4.1.1.1; 5.1.1.1 and 5.1.1.3 for more detailed descriptions.

while completing Activity Three[72]. This frustration was also evident while a different group of learners struggled to replicate the expected graph shape while rolling a ball up an incline in Activity Five[73].

This learner frustration was confirmed in the responses that learners provided in the completed learner questionnaire. In response to the question: "*Were you frustrated while completing the practicals?*", 13,5% of the grade eleven learners and 27,5 % of the grade twelve learners at the TRAC laboratory, as well as 6,8 % of the grade eleven learners at their respective schools, responded positively. Reasons offered by learners as to why they were frustrated included amongst others, "*When I didn't get things right*" and "*repeating the activity a few times*"[74].

(B) Repetition of the activity

Whenever a "distorted" graph shape appeared on the computer screen, learners repeated the activity over and over again in an attempt to replicate exactly the same graph shape that appeared in the worksheet. In some cases, learners changed their actions such as raising the board above their heads while others simply repeated the same actions I am tempted to say that their actions bordered on desperation to replicate the graph. During my observation[75] of a group of grade eleven learners, I saw that they repeated their movements, trying different variations for ten minutes in an attempt to replicate graph A, before calling for assistance. This pattern was also observed while other groups of learners tried to replicate the expected graph shapes[76].

A point that needs to be clarified is that the learners were not repeating the activity in order to gain a better understanding of how to do the task, but rather to obtain the

[72] Refer to section 4.2.2.2
[73] Refer to section 4.2.1.2
[74] Refer to sections 4.2.4.1, 4.1.4 and 5.1.4.1, respectively for further elaboration on this point.
[75] Refer to section 4.1.1.1.
[76] Refer to sections 4.1.1.1 and 5.1.1.2 for additional validation of this observation.

expected graph shape that appeared on the worksheet. I got the impression that learners seemed to have forgotten that the purpose of the whole exercise was to determine the movement of the learner that resulted in a specifically shaped graph. This was particularly evident when learners had to replicate graphs C and D. In one instance[77], I observed that the movement of a learner was already correct after the second attempt, but he repeated his movement for a further eight minutes in an attempt to replicate the same graph shape that appeared on the worksheet. This was also evident during other observations of learner interaction with the TRAC PAC as they completed the accompanying worksheet[78]. I therefore deduced that the learners tended to focus much of their attention on what appeared on the computer screen, rather than trying to understand the movement that a learner should perform in order to obtain a specific graph shape.

Critical outcome number four expects that learners must be able to "collect, analyse, organise and critically evaluate information"[79]. The frustration that learners experienced and the *ad nauseam* repetition of an activity made me wonder whether learners were able to evaluate information that they were confronted with critically. Surely the learners should have asked why the expected graph shape did not appear. They should also have realised that the graphs supplied by textbooks and presented by their teachers were not always 'perfect'. They should have known that science is a discipline that requires the collection of lots of data, which give rise to many questions that need answers. This did not happen. Therefore I believe that this is an area of learner development for which the TRAC PAC has great potential.

The question that needed to be answered was "Why did these 'distorted' graphs appear?" As I set up the apparatus in preparation for the grade twelve activities[80], I found that I had to set the exact parameters before reliable results could be obtained. For instance, I found that if the trolley was set at a distance of 50 cm away from the motion sensor, then

[77] Refer to section 5.1.1.2
[78] Refer to section 4.2.2.2, 5.1.1.1 and 5.1.1.3.
[79] Mentioned in section 2.3.1.2.
[80] Refer to section 4.2.1.

the chances of obtaining the expected graph shape was increased dramatically. Based on the analysis of the data collected during this research, I concluded that these "distorted" graph shapes appeared due to:

- The inability of learners to perform an action correctly. For example, rolling the ball up an incline.
- Learners were not familiar with possible remedial actions. For example, when learners stood too far away from the motion sensor and the motion sensor did not pick up their movement, they should merely have moved closer to the motion sensor.
- Incorrect computer settings. For example, it was observed that learners had opened the incorrect computer file.
- Learners were unable to differentiate between data that was collected before and after an action had taken place. For example, the ball was rolled up and then down an incline. After the ball had stopped, the motion sensor was still collecting data, yet learners did not ignore this data.
- Not enough effort was made in setting up the apparatus. There were certain exact parameters that had to be set to ensure that constant, reliable graph shapes were obtained at all times.

I believe that addressing these points would greatly reduce the possibility of "distorted" graph shapes appearing on the computer screen.

6.4.2 Time consuming

Learners spent too much time completing an activity that I thought would be done quickly. I observed that it took two grade eleven learners an hour to complete the first four graphs of Activity One, four grade twelve learners an hour and fifteen minutes to complete Activity Two and twenty minutes to roll a ball satisfactorily up an incline plane in Activity Five[81].

[81] Refer to sections 4.1.1.1, 4.2.1.1 and 4.2.1.2.

I believe that the reason for the learners spending such a large amount of time to replicate a few graphs was due to the learners' unfamiliarity with the TRAC PAC, which they were using for the first time. Thus they could not have been expected to use the TRAC PAC efficiently.

6.4.3 The need for considerable intervention from the researcher, facilitator or teacher

I need to clarify why I think that the constant support offered to the learners by the researcher, facilitator or the learners' teacher can be considered to be a disadvantage. It was initially envisaged that learners would interact with the TRAC PAC on their own. However, this was not the case. Considerable support was necessary because learners either could not continue with the activity or were failing hopelessly in their attempts. Considering the time constraints in any classroom environment, the researcher, facilitator or teacher would not be able to assist all groups experiencing problems. This could result in some learners not receiving the support they require to continue with their activity.

Evidence of the amount of support given to learners can be found in the observations of grade eleven and twelve learners as they completed their respective activities[82]. The type of support that was offered to learners was divided into two groups, namely TRAC support and General Science support. The TRAC group identified the types of support that were given to learners that were specifically related to the TRAC computer program. The General Science group identified the types of support that was given to learners that were considered to be of a general science nature.

In the TRAC group, the types of support given to learners included:

[82] Refer to sections 4.1.1.1, 4.1.1.2, 4.2.1.1, 4.2.2.2 and 4.2.1.2

- explaining to the learners why "distorted" graphs appeared on the computer screen.
- assisting learners to obtain the expected graph shape on the computer screen.
- opening the correct computer file.
- explaining the function of the motion sensor.
- assisting learners to use the different function keys such as the 'regression' function key to enable them to 'read' the acceleration values from the graph.

In the General Science group, the types of support given to learners included:

- assisting learners to determine the mass of a trolley using a triple beam balance.
- assisting learners to 'read' the graphs that appeared on the computer screen.
- explaining science concepts such as 'variable'.
- assisting learners with their understanding of the questions that appeared on the worksheet.

Without this support, learners would have taken even longer to complete their respective activities, and would have presented even weaker results. However, the types of support mentioned above indicated that the learners who participated in this research grappled with basic science concepts and skills as well as basic computer skills. I expected the learners to have mastered these skills and since they had not, we were kept busy with remedial action before proceeding to the science concepts. Addressing these issues before the learners actually completed an activity using the TRAC PAC would have enhanced the optimal use of the TRAC PAC. As the TRAC PAC should help to develop learner independence, I conclude that too much support from the researcher, facilitator or teacher is a disadvantage when using the TRAC PAC.

6.4.4 Limited contribution to 'transfer of learning'

In a report of a workshop held at the National Science Foundation, Mestre (2002:3) broadly defines transfer of learning as "... the ability to apply knowledge or procedures learned in one context to new contexts". I had hoped that learners would be able to demonstrate that transfer of learning had taken place by successfully answering questions in a paper-and-pencil test after they had completed an activity using the TRAC PAC. However, the poor paper-and-pencil test results indicated the inability of learners to 'transfer' what they had learned while using the TRAC PAC, to an unfamiliar context. These results do not come as a surprise, as it is acknowledged in Mestre (2002:4) as well as in Perkins and Salomon (1992:3) that ample evidence exists that support the claim that transfer of learning does not take place readily.

The purpose of the grade eleven paper-and-pencil test was to determine whether learners were able to apply what they had learned while using the TRAC PAC. The purpose of the grade twelve paper-and-pencil test was to determine whether learners were able to recall what they had learned.

The grade eleven test results are illustrated[83] in graphs 7 and 21 and the grade twelve test results are illustrated[84] in graph 18. In total, 148 grade eleven learners wrote the two-question test. Sixty-four learners, or 43% of the total number of learners, were able to answer question one correctly. Only eight learners, or 5,4% of the total number of learners, were able to answer the second question correctly.

Thirty-seven grade twelve learners answered the test at the TRAC laboratory. More than 50 % of the learners were able to supply the correct answers for questions two and three. However, learners performed poorly on questions one and four. In question one, only 37,8 % of the learners were able to supply the correct answer. The percentage of learners who were able to answer the sub-questions in question four are given below:

- Question 4 A, 32,4 % of learners.
- Question 4 B, 18,9 % of learners.

---

[83] Refer to pages 108 and 170 respectively
[84] Refer to page 136

- Question 4 C(i), 2,7 % of learners.
- Question 4 C (ii), 35,1 % of learners.

I reported in section 6.3.2 that there seemed to be an improvement in the learners' ability to answer questions correctly in the worksheets after using the TRAC PAC. However, when they were confronted with a new situation such as the paper-and-pencil test, where they were required to transfer their knowledge from the activity they had completed with the TRAC PAC to the new situation, they were unable to do so. This seemed to indicate that either the transfer of knowledge did not occur or it could have meant that no real understanding of the work had taken place.

I reported[85] in Chapter Two that many researchers have documented that learners are able to demonstrate an improvement in their understanding of science concepts after using MBLs. The results that I am presenting here seem to contradict what researchers such as Thornton and Sokoloff and many others have documented. Thornton and Sokoloff (1996:16) argue that using MBLs dramatically improved learners' understanding of Newton's Laws. They state that this improvement was evident after learners had completed a "…carefully designed sequence of guided laboratory activities in mechanics … and weekly conceptual homework…" This I believe is where the difference lies between my results and the evidence provided by these researchers. Firstly, these improved results were determined after learners had spent a large amount of time using the MBL. In most cases, this was a semester. In my research, the learners were only in contact with the MBL (TRAC PAC) for a few hours on one day. Secondly, learners completed homework on a weekly basis. As a result, the learners were given time to reflect upon what they had learned. This was not the case in my research. Thirdly, pre- and- post testing of learners took place at the beginning and end of a semester. This was not the case in my research. The test that learners wrote took place immediately after they had completed an activity worksheet.

From the results, it appears as though a 'once-off' interaction between learners and the TRAC PAC does not contribute significantly to their understanding of the concepts.

[85] Refer to section 2.6.4.

6.5 FACTORS THAT HAMPER THE OPTIMAL USE OF THE TRAC PAC

Through no fault of the TRAC PAC, I believe that the following aspects need to be given attention before the learners use the TRAC PAC. We cannot assume that all learners are at a particular level of expertise when they enter the TRAC laboratory. Therefore, certain concepts and skills need to be reinforced before learners use the TRAC PAC. These will be discussed briefly.

6.5.1 Learners lack certain basic skills

When I started with this research, I assumed that learners were capable of demonstrating certain basic skills. Upon analysis of the data, I am of the opinion that this is one area which definitely influences the optimal use of the TRAC PAC. The types of skills that I have found to be lacking and that are necessary when using the TRAC PAC are:

- **Measurement skills**. Here it was apparent that learners lacked the skills to take accurate measurements, which is a vital element for any scientific study. Examples found during this research included: using a 1 meter ruler to measure 2,5 meters and using a triple beam balance to determine the mass of a trolley. I base these claims on my observations[86] of the grade eleven learners' inability to use a 1 meter ruler to measure 2,5 meters accurately.

  This inability to take accurate measurements was also evident with the grade twelve learners who were required to determine the mass of the same trolley using the same

[86] Refer to sections 4.1.1.1, 5.1.1.2 and 5.1.1.3.

triple beam balance while completing[87] Activity Two. Upon analysis of the learners' worksheets, I found that only 9,3 % of the learners were able to correctly determine the mass of the trolley[88]. These results were obtained by different groups of grade twelve learners, who visited the TRAC laboratory on different days, and who were required to determine the mass of the same trolley, using the same triple beam balance.

I interpreted this data to imply that learners did not understand the importance of taking accurate measurements. In section 2.1, I discussed the issue that schools either lacked the facilities or, if they did have the facilities, did not perform many practical activities. Therefore, I believed that these skills were not taught in the Physical Science classrooms and had to be addressed before learners used the TRAC PAC to ensure its optimal use.

- **Communication skills**. The inability of learners to accurately describe their observations of learners' movements in an attempt to replicate eight displacement vs time graphs is evident in the analysis of learners' responses to the worksheets that they completed. Examples[89] of learners' inability to accurately describe the movement for graph C in Part One are given. Learners were expected to have answered "We walked at a constant velocity away from the reference point in a positive direction". Instead, learners' answers were reasons for concern, e.g.

- "*Stand with a board in a reference point and move in a positive side facing in motion sensor and we find a graph*" and
- "*Moving to the back with uniform velocity and uniform acceleration in motion with the sensor in a positive direction starting from the point start*".

In graph C Part Two, where the direction towards the sensor was calibrated to be positive, learners' responses such as "*we move from 2,5 m = 0 towards to get this line which directly proportional between displacement and time*", highlighted the inability of learners to communicate effectively.

[87] Refer to appendix E. This is documented in section 4.2.1.1.
[88] Refer to graph 15.

I am of the opinion that these responses demonstrated that learners had not grasped the concepts that they were expected to have learned while using the TRAC PAC. This clearly indicated that learners were not able to master critical outcome[90] number five, which requires learners to be able to communicate effectively. I also believe that learners entered the TRAC laboratory or their classrooms with their own interpretations or understanding of certain science concepts. Their incorrect understanding of these concepts was highlighted while they used the TRAC PAC. One factor, which will contribute towards the optimal use of the TRAC PAC, will be if it can encourage learners to satisfy this critical outcome.

- **Basic mathematical calculation skills**. It was assumed that grade twelve learners were able to perform certain basic mathematical calculations and to understand the implications of these calculations. However, this was not found to be the case during this research. The inability of learners to perform basic mathematical calculations negatively influenced their participation in the different activities. When a group of learners[91] measured the mass of the trolley in Activity Two, they recorded that 1370 grams was equal to 0,137 kg. Another group of learners[92] had to convert grams to Newtons. They recorded that 50 grams was equal to 0,005 N. When a different group of learners[93] were required to read displacement values from a displacement vs time graph at 0,5 seconds, they could not interpret 1,038 m to approximate 1,041 m. The learners had great difficulty in understanding that these two values had a difference of 3 mm, which in this case was negligible.

Once again, the lack of basic skills hampered the optimal use of the TRAC PAC. What can TRAC SA do to address these issues?

---

[89] Refer to sections 4.1.2 and 5.1.2.
[90] Refer to section 2.3.1.2
[91] Refer to section 4.2.1.1
[92] Refer to section 4.2.1.2
[93] Refer to section 4.2.1.2.

- **Basic content knowledge**. Learners asked the facilitator or researcher to explain terms[94] such as "variable" and "gradient". I found this unsettling as I had expected learners to know what these terms meant. This indicated to me that learners lacked an understanding of basic science concepts. In another example, a learner wrote[95] "*Moving to the back with uniform velocity and uniform acceleration in motion with the sensor in a positive direction starting from the point start*". This suggested that the learner has confused the concepts ‘uniform velocity’ and ‘uniform acceleration’ although in fact an object of uniform velocity has a uniform acceleration of zero. This lack of basic content knowledge is reason for concern and illustrates that these can hamper the optimal use of the TRAC PAC.

In this section I have highlighted the learners' lack of certain basic science skills and concepts prior to them using the TRAC PAC. The optimal use of the TRAC PAC is dependent on learners possessing certain basic skills.

6.5.2 Learners do not follow instructions

Each worksheet completed by learners contained instructions which they were required to follow. This requirement assumed that learners could read the instructions. The first instruction asked for a certain computer file to be opened (each activity had its own file name). On more than one occasion[96] at the TRAC laboratory, it was observed that learners started using the TRAC PAC without opening the correct computer file. Only one learner, in each group, was seated at the computer and tasked with opening the appropriate computer file. Therefore, when this learner made a mistake, the group was unable to participate effectively in the activity and as a result, the graphs that they obtained became meaningless. It was only through the intervention of the researcher or facilitator that this problem was identified and rectified.

[94] Refer to sections 4.2.2.2 and 4.2.1.2
[95] Refer to section 5.1.2
[96] Refer to sections 4.1.1.2, 4.2.1.1 and 4.2.2.2

A second example[97] which illustrated that learners did not follow the instructions at the TRAC laboratory, was observed when a group of grade twelve learners were required to add mass pieces to the trolley after each run. The instructions were not followed and as a result, the graphs that were obtained were irrelevant. However, when the TRAC PAC was used in the classroom, the teacher took the lead and either read the instructions[98] for the learners or gave the learners the opportunity to read the instructions[99]. This ensured that the instructions were followed.

When learners were asked in a questionnaire, "*What role did you play in the group*?" one of the choices given was whether they had "read instructions" or not. The analysis of their responses showed that 56,8 % of the grade eleven learners[100] surveyed at their schools responded affirmatively to this question. A further 62,5 % of the grade eleven learners[101] and 69,6 % of the grade twelve learners[102] surveyed at the TRAC laboratory, indicated that they had read the instructions. The question that arises is: did the remaining learners not read the instructions and thereby not understand the instructions? The next question in the questionnaire asked "*Did you understand the instructions*?" To this question, all the grade eleven learners and 84 % of the grade twelve learners responded affirmatively. Interpretation of this data means that even though a learner did not indicate that s/he had read the instructions, s/he had nevertheless understood the instructions. This interpretation was highly unlikely. Another possibility exists. Since the learners were seated in groups, it might have been possible for the groups to have identified different roles for different learners. One such role could have been that a particular learner was responsible for reading the instructions. If this was the case, then this learner should have clearly taken the lead and should have indicated if certain instructions were not followed. The fact that learners started their activity without opening the correct computer file and not adding mass pieces to the trolley until the researcher or facilitator intervened seemed to indicate that this was not the case. Another possibility could have been that because

[97] Refer to section 4.2.1.1
[98] Refer to section 5.1.1.1
[99] Refer to section 5.1.1.3
[100] Refer to section 5.1.4.1
[101] Refer to section 4.1.4
[102] Refer to section 4.2.4.1

learners were allocated certain roles, the learner could only have read and understood the instructions that were applicable to that particular part of the activity. If this was the case, then the learners could master only a particular section of the activity and not understand the activity as a whole. This might explain why the learners obtained such poor test results. In addition, some teachers had read the instructions to their learners at school, and this could have resulted in the low percentage of learners indicating that they had read the instructions.

The fact that all the learners did not indicate that they had read the instructions could be as a result of different interpretations of the question by different learners. Nonetheless, whatever the interpretation, I conclude that even though learners might have read the instructions initially, whether partially or completely, there seemed to be enough evidence to suggest that learners were unable to follow the instructions given on the worksheets. This could be another factor which influences the optimal use of the TRAC PAC and could be researched further.

6.5.3 Teacher confidence

I believe that teacher confidence plays a huge role in the successful utilisation of the TRAC PAC in the classroom. If the teacher was not confident while using the TRAC PAC, the teacher would be unable to intervene and solve problems that might arise while using the TRAC PAC. During the observation[103] of a group of grade eleven learners trying to replicate graph C, it was evident that learners were struggling to obtain the required graph on the computer screen. The inability of the teacher to identify the problem and provide possible solutions lead to too much time being spent on trying to replicate the graph. I believe that this could have had a negative impact on the learners' ability to assimilate the information. This could have confused the learners and influenced their learning. The dependence by teachers on the instructions that appeared

[103] Refer to section 5.1.1.3.

in the worksheets was also evident. Teachers and learners followed these instructions diligently. No deviation from these instructions took place. I interpreted this to mean that the teachers were not confident as they relied heavily on the procedure described in the worksheet. Interviews conducted with teachers as well as the literature review support the view that teacher confidence is vital in ensuring the optimal use of the TRAC PAC[104].

6.5.4 Small computer screen

The use of only one TRAC PAC in a Physical Science classroom is further complicated by the fact that it has a small computer screen. During my classroom observations[105], the TRAC PAC was always placed in front of the classroom[106]. The problem with this was that learners had difficulty seeing the graphs as they appeared on the computer screen. During one of the classroom observations[107], it was evident that the screen was too small for all the learners to see because those learners who were seated at the back of the classroom stood up from their seats to get a better view of the graph on the computer screen.

Besides the classroom observation, teacher interviews[108] also confirmed that a small computer screen is ineffective while using a single TRAC PAC with a large number of learners.

[104] Refer to section 5.1.5.1 and 2.4.2.
[105] As documented in sections 5.1.1.1, 5.1.1.2 and 5.1.1.3
[106] Refer to picture 5
[107] Refer to section 5.1.1.1
[108] Refer to section 5.1.5.1

6.5.5 The financial costs of visiting the TRAC laboratory

The optimal use of the TRAC PAC at the TRAC laboratory is dependent on the number of learners that visit the TRAC laboratory. These numbers are dependent on the motivation of teachers to take learners, the number of times per year that the learners can visit as well as the costs involved in transporting the learners to the TRAC laboratory. In interviews[109], teachers reported that apart from syllabus-related activities and learner excitement, additional support and financial assistance to undertake such visits would motivate them to take their learners to the TRAC laboratory. The lack of such support would not encourage the teachers to return.

Even though the TRAC laboratory at the University of Stellenbosch offered some support, the reality remained that school visits to the TRAC laboratory[110] did not happen frequently. A major obstacle in getting the learners to the TRAC laboratory was the financial implication. Whenever learners left school on educational outings, it was the responsibility of the learners to cover the transport costs. Given the socio-economic environment of the learners that attended high school in previously disadvantaged communities, neither the school nor the learners had the financial resources to pay for the expensive travelling costs to the TRAC laboratory. Evidence for this factor can be found in teacher responses to a questionnaire[111] and in interviews with teachers[112].

Unless the financial burden can be overcome through obtaining a sponsor to transport learners to the TRAC laboratory, the optimal use of the TRAC laboratory will not be fully realised.

[109] Refer to sections 4.1.5.2, 4.2.5.1 and 5.1.5.1
[110] Refer to the response of the teacher questionnaire in sections 4.2.4 and 5.1.4.2.
[111] Refer to sections 4.2.4 and 5.1.4.2
[112] Refer to sections 4.1.5.2, 4.2.5.1 and 5.1.5.1

6.5.6 Security of the TRAC PAC in classrooms

I believe that the TRAC PAC was not being utilised optimally in the Physical Science classrooms because it was not an integral part of the teaching environment. This judgement is based on my classroom observations[113] and teacher interviews[114]. Owing to high risk of the TRAC PAC being stolen, extreme security measures needed to be in place. As a result, the TRAC PAC was normally stored in a safe place such as a storeroom[115]. This prohibited the TRAC PAC from finding a permanent place in the Physical Science classroom. The TRAC PAC was therefore only used once or twice per term[116] per grade to complete the required practical activities.

Because of the stringent security measures that were in place in schools that had the TRAC PAC, its use in the Physical Science classroom was seen as an 'add-on'. The challenge for TRAC SA was to develop strategies that could be shared with teachers that would ensure that the TRAC PAC became an integral part of the classroom as highlighted in the literature review[117].

6.6 GROUPWORK: AN ADVANTAGE OR DISADVANTAGE?

At the TRAC laboratory, learners were allowed to form their own groups. This decision was taken because I did not know the learners and, as they were entering a new environment, I did not want them to feel uncomfortable. At the two high schools the grouping of learners was different. In both schools, learners sat in groups or at tables

[113] Refer to section 5.1.1.1
[114] Refer to section 5.1.5.1 and appendix M
[115] This was mentioned in section 1.2
[116] Refer to appendix M
[117] Refer to section 2.4.2.

where they felt comfortable. The number of learners per group or table ranged from two to five learners.

During my observations of different groups[118] at the TRAC laboratory, the following was evident. Once the learners were grouped around a TRAC PAC there was no clear indication as to who would lead the group. There was also no clear indication of the different roles to be played by each group member. The learners only identified two roles. These two roles required one learner to sit at the computer to click the "start" button while a second learner held the board or set up the apparatus (as required in the grade twelve activities). As a result, if the group contained more than two learners then the remaining learners were merely passive observers who did not participate in any discussion or decision-making opportunities within the group.

The format of the group work that took place at schools might have differed in format from that at the TRAC laboratory, but the results were similar. At the schools, the teacher was in control of the pace and sequencing of the activities. This resulted in not all learners actively participating in the activity. For instance, at one school the teacher[119] would identify which learners would perform certain roles such as clicking the "start" button and imitating a particular shaped graph. At the other school, the teacher[120] might take a different approach by identifying a group to imitate a certain graph and allowing the group to decide who would actually perform the movement and click the "start" button. It was therefore impossible for the teacher to identify a role for all learners to play in the completion of the activity. One learner summarised this point quite well during an interview with the following response: "*At school, the teacher will be at the computer with two or three learners assisting him with the set-up of the apparatus while the other learners are mere spectators*".

When it came to answering questions on the worksheets in the TRAC laboratory, those learners who actively participated in the activity wrote down their answers while it

[118] Refer to section 4.1.1.1, 4.1.1.2, 4.2.1.1, 4.2.2.2 and 4.2.1.2
[119] Refer to section 5.1.1.1 and 5.1.1.2

appeared as if the others merely copied the answers. This interpretation was also revealed during an interview[121] with a grade twelve learner who responded that "*One person knows all the answers*". This interpretation appeared to be confirmed when the learners' worksheets were analysed. The learners were asked to write the names of their group members on their own worksheet. It was therefore easy to compare the answers of different learners in the same group. This was evident when the same wording for an answer was repeated by all the learners from the same group. The answers to the questions were exact copies of one learner's answers. An example to illustrate this point was taken from the worksheets of a group consisting of four grade eleven learners who completed Activity One on 'Reference points and directions'. All four learners' description of graph A in Part One read: "*Stood still in position of rest 1 m away from reference point in a positive direction*". To ensure that this was not merely coincidental, I found that the descriptions of the other graphs were also identical.

However, a totally different interpretation was evident when the learner questionnaire was analysed. A section of the questionnaire asked the grade eleven and twelve learners[122] to indicate what dialogue had occurred between group members. These results seemed to indicate that learners worked together quite well as a group, even if they were prepared to differ in opinion from one another. This was clear from the 68,1 % of grade twelve learners and 40,4 % of grade eleven learners' response to "*argued most of the time*". Nonetheless, the ability to reach consensus on issues was evident from 62,5 % of the grade eleven learners and 52,5 % of the grade twelve learners' response to "*agreed to everything*". These two findings seemed to suggest that learners did not copy the answers from one learner, but rather that they first discussed different possibilities to which they all agreed. This was confirmed when only14,4 % of the grade eleven learners and 8,7 % of the grade twelve learners responded positively to the statement "*One learner knew all the answers, the rest of us just wrote down the answers*". Interviews[123] conducted with learners suggested that this interpretation was correct. The response "*To work in a group*

[120] Refer to section 5.1.1.3
[121] Refer to appendix L. An interview conducted with the second learner.
[122] Refer to sections 4.1.4 and 4.2.4.1
[123] Refer to appendix L

was great, we could help one another if someone did not understand" confirmed that learners assisted one another. This may provide a reason why learners' answers were identical, and makes it difficult for me to make a judgement on whether they merely copied from one learner or not.

The main difference between group work at the TRAC laboratory and the high schools was that at the schools the teachers took control and directed the pace at which groups of learners interacted with the TRAC PAC, while at the TRAC laboratory the groups were allowed to interact with the TRAC PAC on their own. A possible consequence of allowing group work while using the TRAC PAC was that one was not certain whether learners were in fact learning or merely copying answers from one another. I am not denying the important role that group work has to play in the development of learner understanding of science content and concepts. In fact, I agree with critical outcome[124] number two which expects learners to be able to "work effectively with others as members of a team, group, organisation and community". However, I believe that group work needs to be structured in such a way that all learners are actively involved at all times and that their roles are clearly defined. On the other hand, I would caution that not all activities must be completed through group work.

6.7 FACILITATION SKILLS

As mentioned in section 6.6 above, only a limited number of learners actively participated in their group activities. Only one learner would be seated at the computer to click the "start" button while a second learner would set up the apparatus. The remaining group members were either passive observers or walked around in the TRAC laboratory. This indicated that group interactions were not what they were supposed to be. It was expected that when an activity was developed, it had to be completed by a group of

[124] Refer to section 2.3.1.2.

learners, with all members of the group performing a specific task. Besides allocating a specific task to each learner, all learners were expected to provide their input on the successful completion of the activity. This communication between the different group members was vital to ensure that all learners learned something during the activity. From the discussion in section 6.6, I felt that all learners were not actively participants in their group. To remedy this, teachers and TRAC SA facilitators must utilise different facilitation techniques to ensure that all learners actively participate within their group.

6.8 RECOMMENDATIONS

Based upon the findings of this study, from both the empirical and literature study, I would like to make the following recommendations for the optimal use of TRAC PACs in science education in South African schools:

6.8.1 Recommendations from the empirical study

- In section 6.5.1, I identified that that the learners surveyed in this study lacked basic science and mathematical skills and concepts. I believe that this contributes towards the TRAC PAC not being used optimally. For example, not converting a mass piece of 50 g to 0,5 N would influence a learner's ability to complete an activity successfully. This implies that the facilitator must intervene. The facilitator must then spend unnecessary time on developing skills that the learner should already have mastered. The current set of activities that learners complete while interacting with the TRAC PAC was designed on the assumption that the learners all possess the necessary skills. TRAC SA must be creative in its development and design of the activities that it presents to learners. A possible solution to this problem would be for TRAC SA to identify the basic skills required for each activity and to set up a series of tests to determine whether the learners have mastered certain skills prior to using the TRAC PAC. These tests could be sent to the schools, or alternatively, they could be made available on the TRAC SA website. Teachers must be instructed to give the tests to their learners before the TRAC PAC is used at their school or at the TRAC laboratory, and to identify and remedy any shortcomings that their learners experience. The results of these tests should be analysed by TRAC SA and a detailed, thoroughly planned and sequenced series of activities, which is able to assess learner progress, should be developed specifically to address the needs of the learners. Where learners struggle with understanding certain basic science concepts, a possible solution would be to incorporate a *'Help'* section into the computer program.

- It was evident from this research that learners did not follow the instructions, such as opening the correct computer file, that were given on the worksheets. As a result, intervention from the facilitator or teacher was required. The possibility exists that the facilitator or teacher might not identify that learners have not followed the instructions. This will negatively influence the learner's participation in the activity and might also result in the learner drawing wrong conclusions from the results obtained. A possible strategy that could be implemented to address this issue is to first encourage learners to read the instructions and then to allow them an opportunity to demonstrate their understanding of the instructions before they can continue with the activity. Alternatively, the computer program, which is used by the TRAC PAC, must be altered in such a way that the learner cannot proceed unless the correct instructions are followed. The learner is then forced to call the facilitator or teacher who can then intervene and provide the learner with a solution.

- Two main observations of teacher interactions with the TRAC PAC were made during this research.

Firstly, when the TRAC PAC was used in the classrooms, teachers followed the same strategy. They set up the TRAC PAC in front of the classroom, they controlled the pace and type of interaction that took place and their learners responded to their instructions. It should be possible for TRAC SA to identify different teaching strategies and to encourage teachers to use them. Instead of using one TRAC PAC with a small screen with the entire class, it might also be possible to use the TRAC PAC with only a limited number of learners. Learners could be divided into different groups and each group could be provided with a different activity where one of these activities involves using the TRAC PAC. The learners could then possibly rotate through the different activities. Another possible strategy would be to display the graph, which appears on the small computer screen, on a bigger screen using a data projector. It might also be feasible to use the computer laboratories that are present in many high schools in the Western Cape. Through the effective use of the computer network in these laboratories, all graphs could be made to appear on the different computer screens simultaneously.

Secondly, teachers agreed that the TRAC PAC could be used in their classrooms to benefit their learners. Yet teachers only used the TRAC PAC for very short periods of time. A reason given by teachers was that they had too little time to complete practical activities as well as the syllabus in order to satisfy departmental requirements. This seemed to indicate that teachers were unable to manage their time or classrooms effectively. It could also indicate that the teachers were not able to integrate ICT effectively into their lessons. I believe that TRAC SA should offer compulsory teacher training sessions which focuses on providing teachers with classroom management skills as well as illustrating the many different teaching strategies that will enable them to integrate the TRAC PAC in their lessons more frequently.

- In order to increase learner participation, different learning strategies such as predict-observe-explain (POE) can be developed through the use of the TRAC PAC. This strategy (POE) expects the learners first to make a prediction about an event, then observe the event and finally explain whether the prediction made initially is correct or not.

When learners used the TRAC PAC at the TRAC laboratory or at their schools, the activities were completed through groupwork. The main concern identified was that all learners were not actively participating in the activities. Those learners who were not active participants were mere spectators. This is not what is expected when using the TRAC PAC. TRAC SA should clearly identify which activities lend itself to groupwork. Once those activities have been identified, the different roles to be played by learners must be identified and clearly communicated to the learners. Teachers and facilitators must also be aware of these different roles. TRAC SA should offer workshops to teachers and facilitators to demonstrate how to facilitate group work effectively. TRAC SA must acknowledge that not all activities must be completed through groupwork. Activities can also be designed that allows for individual participation.

- In section 1.3, I noted that the aims and objectives of TRAC SA are "... to increase the number of qualified pupils, particularly among historically disadvantaged communities, applying to study in SET fields..." The question that arises is: "How is this going to be accomplished"? As mentioned in section 2.4.2, simply placing a computer in a classroom is no guarantee that it will be used effectively. This research has found that, in most cases, the TRAC PAC was only used once per term in the classroom and that learners only interacted with the TRAC PAC at the TRAC laboratory during one visit. The TRAC PAC cannot be used as a 'once-off' event with the expectation that it will have a huge impact on Physical Science learners.

  My recommendation would be that TRAC SA should develop and maintain a clearly focussed strategy that would ensure greater learner participation in the SET fields. It might be necessary to first work with a small group of learners or schools to ensure that the strategy is feasible. Thereafter, the focus could shift to increasing the number of learners or schools participating in the TRAC program. I would like to put forward a possible strategy that could be implemented. Teachers who are in possession of TRAC PACs at their schools must provide TRAC SA with a detailed plan of when and how they will use the TRAC PAC during their teaching. This plan must be analysed, and suggestions for improvement to the plan must be returned to the teacher. Schools that prefer to use the TRAC laboratory must ensure that their learners participate regularly in a series of activities aimed at preparing them for further study in the SET fields. TRAC SA can either provide an itinerary to the school or the school must provide TRAC SA with one. However, merely providing an itinerary or a plan is no guarantee that the TRAC PAC will be used successfully. Therefore, learner participation must be monitored regularly and additional support must be given where required.

- The teachers who participated in this research indicated that they felt confident when using a computer. However, when using the TRAC PAC, they were unable to intervene when a problem arose. I believe that the reason for this was that they did not engage with the TRAC PAC on a regular basis. To remedy this, TRAC SA must demand that teachers interact with the TRAC PAC regularly. TRAC SA has the necessary infrastructure in place to ensure that teachers communicate, at least once a term, via the TRAC SA website or through regular meetings. Although a discussion forum exists on their website, the question arises whether it is actually used since it requires an Internet link and time from the teachers to interact. This communication amongst teachers is vital because it creates the space that allows them the opportunity to continually reflect and critique the optimal utilisation of the TRAC PAC. Teachers can then apply what they have learned by either providing suggestions for the improvement of the existing activities, or they could design new activities and then test them in their classrooms. This I believe will contribute significantly towards the teachers feeling confident when using the TRAC PAC.

- The probability of obtaining "distorted" graphs must be greatly reduced or ideally it must be eliminated. This implies that learners and facilitators need to be informed about when "distorted" graph shapes are most likely to be formed. This can be done by including these precautions in the instructions that are given on the worksheets. These instructions must be clear enough so as to eliminate the possibility of obtaining "distorted" graphs, which are caused, for example, by inappropriate distances of objects and/or people placed in the path of the motion sensor. Steps should be taken to ensure that "distorted" graph shapes do not appear and if they do appear, then learners need to know when to discard the information.

- Financial constraints of learners and schools limit learners' visits to the TRAC laboratory. Additional sponsors must be found to subsidise the transport costs. An approach needs to be adopted where not all schools will receive the subsidy. Only those schools who really cannot afford the costs should be considered on condition that they participate for at least one year. These schools would then be 'adopted' by TRAC SA and the needs of these learners could be identified and addressed.

6.8.2 Recommendations from the literature study

- The changes brought about by the DOE require that Physical Science learners should master clearly defined outcomes. Although the activities used in this research have the potential to encourage learners to master the outcomes, these activities were not designed specifically with these outcomes in mind. In section 2.3.2.1.2 (A), the principles of OBE were discussed. These principles must be implemented whenever TRAC SA develops materials to be used together with the TRAC PAC. This will ensure that the materials satisfy the requirements of the DOE.

- Besides the introduction of outcomes, the DOE has also introduced new content into the Physical Science and Natural Science curricula. Anecdotal evidence indicates that many teachers have not received any formal training on this new content and therefore do not have the necessary knowledge to teach the new content successfully. I believe that TRAC SA has the potential to develop a teacher-training course, with SAQA accreditation, that will assist teachers to understand the new subject content.

- This research found that learners were enthusiastic when using the TRAC PAC. This enthusiasm must be exploited by providing the learners with a variety of options from which to choose. The integration of different computer applications with the TRAC PAC allows for this variety. The TRAC PAC is not only an MBL, but also a computer that can utilise different computer applications such as spreadsheets, databases, the Internet, etc. I discussed these different applications in section 2.6. Here, I present one possible recommendation to illustrate the integration process: Learners are taken through the typical method of collecting data while using the TRAC PAC. This data is then copied into a spreadsheet application and a graph is drawn. This graph could then be compared to the one that was obtained when using the TRAC PAC. This strategy allows the learners an opportunity to compare the two graphs that were obtained i.e. one from TRAC PAC and the other from the spreadsheet. It is possible that this will strengthen the learners' understanding of the graphs when they are compared. Instead of asking the learners to answer a number of questions, the learners would then be instructed to write a report on their findings using the word processor. Writing a report encourages the learners to strengthen their communication skills and the teacher is able to identify the strengths and weaknesses of the learners' understanding of the science concepts. This also allows the learners to work individually and it reduces the possibility of learners copying answers from other group members. The learners could also be given the opportunity to visit certain Internet sites. These sites would provide the learner with more information on the everyday application of the data that was collected. This could be included in the report.

Should this strategy be adopted, the learners would acquire the skills needed to participate actively in the Information Age and thereby contribute towards the mathematical and scientific skills that our country requires. This strategy also allows for additional teaching methodologies, other than authority-based teaching, to be used, and the learners would be able to identify areas where the science concepts are relevant to their everyday experiences. Teachers need to use these different strategies in their classrooms. TRAC SA can provide the necessary training to show teachers how this can be done.

6.9 SHORTCOMINGS OF THIS RESEARCH

I acknowledge the following as the main shortcomings of this research.

- This research contained a sample of learners that did not represent the demographics of the area in which this study was conducted. This sample contained only learners from previously disadvantaged communities. The results obtained during this research might have been different had a representative sample of learners been used in this study.

- I did not differentiate between higher grade (HG) and standard grade (SG) learners. This could have influenced the interpretation of the data collected because a possibility exists that only the HG learners' point(s) of view are reflected in this study. The opposite, or a combination thereof, could also be true.

- The worksheets, paper-and-pencil test and learner questionnaires were translated into English and Afrikaans. The learners were allowed to work in their language of choice. However, one group of learners who were Xhosa-speaking completed the above-mentioned activities in English. This could have negatively influenced their ability to provide the correct answers to the questions posed to them. This was not taken into account when the data was analysed.

- In section 3.4.2, I provided reasons for conducting classroom-based research at only two high schools. The results of this study might have been different had I visited more than two high schools.

6.10 CONTRIBUTIONS OF THIS RESEARCH

I believe that this research has made the following contribution to science education:

- This research provides an in-depth interpretation of the interaction of teachers and learners with the TRAC PAC.

- It also provides recommendations which, if implemented, could possibly contribute to the optimal use of the TRAC PAC.

6.11 QUESTIONS FOR FURTHER RESEARCH

The following two questions are posed for further research. These questions emanate from the analysis of the data and, if investigated, could contribute further towards the optimal use of the TRAC PAC.

- In section 6.5.1, I contended that learners' inability to perform certain basic skills hampered the optimal use of the TRAC PAC. This could be attributed to the fact that this research focused on only one interaction of different learners with the TRAC PAC. A question that should be investigated further is: "Would one reach the same conclusions, as in this research, if the same group of learners interacted with the TRAC PAC over a period of time?"

- The critical outcomes[125] are incorporated in the learning outcomes[126] which are specific for the subject Physical Science. This research was completed before these learning outcomes had to be implemented. It was not possible to consider these learning outcomes during this research. Does using the TRAC PAC enable the learners to master the Physical Science learning outcomes? This is another question that could stimulate further research.

6.12 CONCLUSION

The motivation for designing practical activities for use with the TRAC PAC was to encourage teachers to use it more regularly, thereby lightening their workload. After conducting this research, I believe that this strategy can be followed but it will not assure the optimal use of the TRAC PAC. The reason(s) for this statement is (are) given below.

In Chapter Two, I provided an insight into the challenges facing science education in South Africa. The following were mentioned:

- Currently South African mathematics and science learners perform poorly in matriculation examinations and international tests.

- The development of skills in learners is essential for them to be globally competitive.

- The South African education department has adopted an OBE approach.

[125] Refer to section 2.3.1.2.
[126] Refer to the National Curriculum Statement for Physical Sciences

The main findings of this research, which addresses the two research questions, are summarised.

Question one asked: "What were the practical realities experienced by teachers and learners when using the TRAC PACs at schools and at the TRAC laboratory"? This research has found that:

- Teachers agree that the TRAC PAC can definitely be used in Physical Science classrooms.
- Learners struggled to replicate the expected graph shapes.
- The activities were time consuming for both teachers and learners.
- When completing the activities, learners required regular assistance. Teachers also need assistance when using the TRAC PAC at their school because they lack the necessary confidence to use the TRAC PAC effectively.
- Learners have difficulty seeing the graphs as they appear on the computer screen in their classrooms because the screen is too small.
- Financial constraints limit the number of learners who visit the TRAC laboratory.
- The TRAC PAC is not used regularly in the classroom and one visit by a group of learners to the TRAC laboratory makes the experience a 'once off' event.

Question two asked: "What were the learners' experiences while participating in activities using a TRAC PAC, and how well did they perform in class after these experiences"? This research found that learners:

- lacked basic skills.
- enjoyed the experience.
- demonstrated an improvement in understanding of the concepts dealt with while they completed an activity worksheet
- were frustrated when the expected graph shape did not appear on the computer screen.
- performed poorly in a paper-and-pencil test.
- did not follow instructions.
- did not always participate fully in the activities.

These issues mentioned above must be taken into account when developing activities to be used with the TRAC PAC. I believe that the optimal use of the TRAC PAC is possible if TRAC SA designs a programme or a series of programmes that will address the skills shortages experienced by learners. There cannot be a 'one size fits all' approach. The outcomes of using the TRAC PAC need to be clearly spelt out. The integration with other computer applications must be realised. The TRAC PAC should not be used as an 'add on' technique, but should form part of the teaching and learning process. We need to develop and demonstrate the positive effects that different teaching and learning strategies have on the learners. At the same time, teachers must be provided with effective teaching strategies through appropriate training courses in, for example, classroom management skills. TRAC SA is in a favourable position to provide these services to the teachers and learners of South Africa.

BIBLIOGRAPHY

Adams, W.E. 1996. Science laboratory classroom environment in a South African College of Education. *South African Journal of Education,* **16**(3):123-128.

Addison, T.M. & Fridman, B.I. 1997. Towards introducing computers into the accounting curriculum in high schools: A pilot study. *South African Journal of Education*, **17**(4):157-160.

Alexander, R. & Robertson, B. 1997. Critical Issues Forum. *The Science Teacher*, **64**(3): 26-29.

Amend, J.R, Tucker, K.A, Larsen, R. & Furstenau, R.P. 1990. Drawing Relationships from Experimental Data: Computers Can Change the Way We Teach Science. *Journal of Computers in Mathematics and Science Teaching*, **10**(1):101-111.

Anslow, J. 1999. Just what is exciting physics? *Physics Education*, **36**(6):389-393.

Appel, M. & Appel, S. 1987. A critique of CAI: the case of SERGO. *South African Journal of Education*, **7**(4):278-282.

Barba, R.H. 1990. Problem Solving Pointers. *The Science Teacher*, **57**(7):32-35.

Barton, M.L, Heideman, C, Jordan, D. 2002. Teaching in Mathematics. *Educational Leadership*, **60**(3):24-28.

Barton, R. 1993. Computers and practical science: why isn't everyone doing it? *School Science Review*, **75**(271):75-80.

Barton, R. 1998. Why do we ask pupils to plot graphs? *Physics Education*, **33**(6):366-376.

Barton, R. & Rogers, L. 1991. The computer as an aid to practical science – studying motion with a computer. *Journal of Computer Assisted Learning*, **7**:104-113.

Baylor, A.L. & Ritchie, D. 2002. What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers and Education*, **39**(4):395-414.

Becker, H.J. 1993. Decision making about computer acquisition and use in American schools. *Computers and Education*, **20**(4):341-352.

Beichner, R.J. 1986. Using a Microcomputer for graphing Practice. *Journal of College Science Teaching*, **15**(6): 528-529.

Beichner, R.J, Wilkinson, L.K, Gastineau, J.E, Engelbrecht, P.V, Gjertsen, M.H, Hazen, M, Ritchie, L. & Risley, J.S. 1995. Hardware and Software Preferences. *The Physics Teacher*, **33**(5): 270-274.

Benn, K.R.A. 1989. Computer-assisted learning in South African Schools: mistakes of the past and hopes for the future. *South African Journal of Education*, **9**(4): 613-616.

Bisseker, C. 1999. Science and Maths teacher shortage now critical. *Financial Mail*, 7 May, 32-33,35.

Blignaut, J. 1997. World conference on computers in education: some thoughts on teacher education and training. *Informedia*, April, 10.

Borchers, C.A, Shroyer, M.G. & Enochs, L.G. 1992. A staff development model to encourage the use of Microcomputers in Science Teaching in Rural Schools. *School Science and Mathematics*, **92**(7):384-391.

Bork, A. 1984. The computer in education in the United States: The perspective from the Educational Technology Centre. *Computers and Education*, **8**(4):335-341.

Boschee, F. & Baron, F.A. 1994. OBE: Some answers for the uninitiated. *The Clearing House*, **67**(4):193-196.

Bradley, J.D. & Stanton, M. 1986. CAL: the Wits experience. *South African Journal of Science*, **82**(10):535-536.

Bradley, J.D. & Stanton, M. 1986. Bridging the gap between school and university in the physical sciences: a review of development and research at Wits. *South African Journal of Science,* **82**(10):534.

Brooks, J.G. & Brooks, M.G. 1993. *In search of understanding: the case for constructivist classrooms*. Alexandria, Virginia: Association for supervision and curriculum development.

Bross, T.R. 1986. The Microcomputer-Based Science Laboratory. *Journal of Computers in Mathematics and Science Teaching*, **5**(3):16-18.

Brown, A.J. & Dowling, P.C. 1998. *Doing Research/ Reading Research*. London: The Falmer Press.

Brummelhuis, A.T. & Plomp, T. 1993. Lessons from two dutch projects for the introduction of computers in schools. *Computers and Education*, **20**(4):333-340.

Brummelhuis, A.T. & Plomp, T. 1994. Computers in Primary and Secondary Education: The interest of an individual teacher or a school policy? *Computers and Education*, **22**(4):291-299.

Carson, S.R. 1997. The use of spreadsheets in science – an overview. *School Science Review*, **79**(287):69-79.

Chaisson, E.J. & Kim, T.C. (ed.). 1999. *The Thirteenth Labor*. Australia and Canada: Gordon and Breach.

Chion-Kenney, L. 1994. Negotiating the challenge of outcomes-based education. *The School Administrator*, September, 9-19.

Coetzee, S. 1999. " School Computer Labs – Expensive Windowdressing"? Millennium Minds Conference. Hyperlink. [http://archive.wcape.school.za/mm99/cd/conf99/proceedings/150/index.htm]. 5 February 2000.

Cohen, L. & Manion, L. 1994. *Research Methods in Education*. London and New York: Routledge Falmer. 4th Edition.

Cohen, L. & Manion, L. & Morrison, K. 2000. *Research Methods in Education*. London and New York: Routledge Falmer. 5th Edition.

Colburn, A. & Clough, M.P. 1997. Implementing the Learning Cycle. A gradual transition to a new teaching approach. *The Science Teacher*, **64**(5):30-33.

Collins, M. 1997. Developing & Running a WWW Biology Course. *The American Biology Teacher*, **59**(9):594-596.

Colyn, W. & Breen, C. 1989. Exploring action research: implications for teachers and researchers. *South African Journal of Education*, **9**(2):248-253.

Constitution of the Republic of South Africa. 1996. Act No. 108 of 1996.

Cox, A.M. & Craig, D.V. 1997. Action Research. Teachers studying teaching and learning in their own classrooms. *The Science Teacher*, **64**(6):50-53.

Cox, J. 1996. *Your opinion, Please! How to build the best questionnaires in the field of education*. California: Corwin Press, Inc.

Crowther, D.T. (ed.). 1997. The Constructivist Zone. *Electronic Journal of Science Education*, **2**(2):1-7. Hyperlink [http://unr.edu/homepage/jcannon/ejse/ejsev2n2ed.html]. 3 July 2001.

Dence, M. 1980. Towards defining the Role of CAI: A Review. *Educational Technology*, **20**(11):50-55.

Department of Education. n.d. A. Directory 102 Dedicated Schools Project for Mathematics and Science.

Department of Education. n.d. B. Institutional Profiles of 102 Dedicated Schools for Maths & Science. National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training.

Department of Education. 1996. National physical science syllabus.

Department of Education. 2000. Draft Intervention Strategy for Science, Mathematics and Technology Education. 11 September.

Department of Education. 2001 A. National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training, June.

Department of Education. 2001 B. Education in South Africa: Achievements since 1994, May. Hyperlink [http://www.education.gov.za/content/documents/294.pdf].

Department of Education. 2002. Revised National Curriculum Statement Grades R-9 (Schools): Overview, May.

Department of Education. 2003. National Curriculum Statement Grades 10-12: Physical Sciences.

Descy, D.E. 1997. The Internet and Education: Some lessons on privacy and pitfalls. *Educational Technology*, **37**(3):48-52.

DOE n.d. A: See Department of Education above.

DOE n.d. B: See Department of Education above.

DOE 1996: See Department of Education above.

DOE 2000: See Department of Education above.

DOE 2001 A: See Department of Education above.

DOE 2001 B: See Department of Education above.

DOE 2002: See Department of Education above.

DOE 2003: See Department of Education above.

Doerr, H.M. 1996. Integrating the Study of Trigonometry, Vectors, and Force Through Modeling. *School Science and Mathematics*, **96**(8):407-418.

Doherty, A. 1998. The Internet: Destined to become a passive surfing technology. E*ducational Technology*, **38**(5):61-63.

Doornekamp, B.G. 1993. Students valuation of the use of computers in education. *Computers and Education*, **21**(1):103-113.

Duguet, P. 1990. Computers in schools: National strategies and their extension to the international level. *Prospects*, **20**(2):165-172.

Edwards, M.G. & Weller, B.E. 1986. Compulab – Computing for the physical sciences teaching laboratory. *Computers and Education*, **10**(2):307-313.

Elliot, C. 1988. Spreadsheets in science teaching. *School Science Review*, **70**(251):87-93.

Escalada, L.T, Baptiste, H.P, Zollman, D.A. & Rebello, N.S. 1997. Physics for all. *The Science Teacher*, **64**(2):26-29.

Feuler, J. 1991. Graphing with computers in the physics lab. *The Physics Teacher*, **29**(2):126-127.

Forcheri, P. & Molfino, M.T. 1986. Teacher training in computers and education: A two year experience. *Computers and Education*, **10**(1):137-143.

Fourie, E. & Henning, E. 1996. The impact of computer literacy on community school teachers in South Africa. *Computers and Education*, **27**(3/4):151-156.

Fraenkel, J.R. & Wallen, N.E. 1993. *How to design and evaluate research in education*. New York: McGraw-Hill Inc.

Friedler, Y. & McFarlane, A.E. 1997. Data Logging with Portable Computers: A study of the Impact on Graphing Skills in Secondary Pupils. *Journal of Computers in Mathematics and Science Teaching*, **16**(4):527-550.

Garson, P. 1997. Will quality continue in the new curriculum? *The Teacher*, February, 5.

Gillies, A.D, Sinclair, B,D. & Swithenby, S. 1996. Feeling physics: computer packages for building concepts and understanding. *Physics Education*, **31**(6):362-367.

Govender, D. 1999. How do South African school teachers understand "educational technology"? *South African Journal of Education*, **19**(2):79-83.

Gustafson, K.L. & Watkins, K.E. 1998. Return on Investment (ROI): An idea whose time has come again? *Educational Technology*, **38**(4):5-6.

Hackbarth, S. 1997. Integrating Web-Based Learning Activities into School Curriculums. *Educational Technology*, **37**(3):59-71.

Hargis, J. 2000. The Self-Regulated Learner Advantage: Learning Science on the Internet. *Electronic Journal of Science Education*, **4**(4):1-7.

Haugland, O.A. 1999. Spreadsheet waves. *The Physics Teacher*, **37**(1):14.

Hawkridge, D, Kaworski, J. & McMahon, H. 1990. *Computers in Third-World Schools: Examples, Experiences and Issues*. Basingstoke: The MacMillan Press Ltd.

Hawkridge, D. 1990. Who needs computers in schools, and why? *Computers and Education*, **15**(1-3):1-6.

Helgeson, S.L. 1988. "Microcomputers in the Science Classroom." *ERIC Digest*. Hyperlink [http://www.ed.gov/databases/ERIC_Digests/ed309050.html]. 10 June 2001.

Henning, E. 1995. Qualitative educational research: soft or solid option? *South African Journal of Education*, **15**(1):29-34.

Herselman, M. & Britton, KG. 2002. Analysing the role of ICT in bridging the digital divide amongst learners. *South African Journal of Education*, **22**(4):270-274.

Hlynka, D. & Mason, R. 1998. PowerPoint in the Classroom: What Is the Point? *Educational Technology*, **38**(5):45-48.

Hodson, D. & Hodson, J. 1998. From constructivism to social constructivism: a Vygotskian perspective on learning and teaching science. *School Science Review*, **79**(289):33-41

Howie, S.J. & Hughes, C.A. 1998. Mathematics and Science Literacy of Final-Year School Students in South Africa. A report on the performance of South African students in the Third International Mathematics and Science Study (TIMMS). Human Science Research Council. Pretoria.

Hugo, F. 1999. Interview. Stellenbosch, 15 July.

Is computer literacy really necessary? 1999. *The educator's voice*, January, 9.

Jackson, R. & Bazley, M. 1997. Science education and the Internet – cutting through the hype. *School Science Review*, **79**(287):41-44.

Jansen, J.D. 1998. Curriculum Reform in South Africa: A Critical Review of Outcomes-Based Education [1]. *Cambridge Journal of Education*, **28**(3):321-332.

Jeevanantham, L.M. 1999. Towards 2005: proposals for curriculum change. *South African Journal of Education*, **19**(1):49-54.

Jensen, M.S. 1998. Finding a place for the computer in the introductory biology laboratory. *Journal of College Science Teaching*, **27**(4): 247-249.

Jimoyiannis, A. & Komis, V. 2001. Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion. *Computers and Education*, **36**(2):183-204.

Johansson, K.E. & Malmgren, T.G.M. 1999. Hands on CERN: an education project on the Internet using real high energy particle collisions. *Physics Education*, **34**(5):286-293.

Johansson, K.E. & Nilsson, C. 1999. Stockholm Science Laboratory for schools: a complement to the traditional education system. *Physics Education*, **34**(6):345-350.

Jones, R.C. 1986. Large scale implementation of a computer-based education programme for disadvantaged high school pupils at matriculation level. M.Ed thesis. University of the Western Cape.

Jones, T. & Clark, V.A. 1994. A computer attitude scale for secondary students. *Computers and Education*, **22**(4):315-318.

Julie, C, Manie, A, Meerkotter, D, Prodgers, R. & Reeler, D (ed.). 1990. Computers for transformation in education. University of the Western Cape.

Khan, M. 1999. Abandoned stepchild of education. *Cape Argus*, 6 May.

Khan, M. 2000. SA's number will be up if we do not master maths and science. *Sunday Times*, 5 March, 19.

Khan, M. & Volmink, J. 2000. Teaching and learning of Mathematics and Science within the context of lifelong learning. National Centre for Curriculum Research and Development. Department of Education.

Kaufman, R. (ed.). 1998. The Internet as the ultimate technology and panacea. E*ducational Technology*, **38**(1):63-64.

Kearsley, G. (ed.). 1998. Educational Technology: A Critique. E*ducational Technology*, **38**(2): 47-51.

Kellogg, D. 1993. Spreadsheet circuitry. *The Science Teacher*, **60**(8):21-23.

Kelly, G.J. & Crawford, T. 1996. Students' interaction with Computer Representatives: Analysis of Discourse in Laboratory Groups. *Journal of Research in Science Teaching*, **33**(7):693-707.

Kimball, N. 1995. "New playgrounds for learning." *TERC*. Hyperlink. [http://www.terc.edu/handsonIssues/spring_95/playgrounds.html]. 9 July 2002.

Kirkpatrick, H. & Cuban, L. 1998. Should We Be Worried? What the Research Says About Gender Differences in Access, Use, Attitudes, and Achievement with Computers. *Educational Technology*, **38**(4):56-61.

Krajcik, J.S, Arbor, A. & Layman, J.W. nd. "Microcomputer-Based Laboratories in the Science Classroom." *Research Matters – to the Science Teacher*. Hyperlink. [http://www.educ.sfu.ca/narstsite/publications/research/microcomputer.htm]. 7 March 2001.

Kudlas, J.M. 1994. Implications of OBE. *The Science Teacher*, **61**(5):32-35.

Lam, T. 1995. “Probing Microcomputer-Based Laboratories.” *TERC*. Hyperlink. [http://www.terc.edu/handsonIssues/spring_95/playgrounds.html]. 9 July 2002.

Lamont, A.G. 1993. Using spreadsheet simulations to teach electricity concepts at secondary school level: A case study. M.Ed thesis. University of Pretoria.

Landa, L.N. (ed.). 1998. Methodological Drawbacks of Current Educational Software and Suggestions for Radical Improvement Based on Algo-Heuristic Theory. *Educational Technology*, **38**(5):54-56.

Langhorn, M, Donham, J, Gross, J. & Rehmke,D. 1989. *Teaching with computers: A new menu for the ’90 s*. Oryx Press.

Lapp, D.A. & Cyrus, V.F. 2000. Using Data-Collection Devices to Enhance Students’ Understanding. *Mathematics Teacher*, **93**(6):504-510.

Laugksch, R.C. & Dunne, T.T. 2000. Predictors of scientific literacy of matriculants entering universities and technikons in the Western Cape. *South African Journal of Education*, **20**(2):96-108.

Lawler, C, Rossett, A. & Hoffman, R. 1998. Using Supportive Planning Software to Help Teachers Integrate Technology into Teaching. *Educational Technology*, **38**(5):29-34.

Leedy, P.D. 1993. *Practical Research*. *Planning and Design*. New York: Macmillan Publishing Company. 5th Edition.

Le Grange, L. & Reddy, C. 2000. Introducing teachers to OBE and EE: A Western Cape case study. *South African Journal of Education*, **20**(1):21-25.

Lehman, J.D. & Campbell, J.P. 1991. Microcomputer-Based Laboratories and Computer Newtworking in High School Science Classrooms. National Association for Research in Science Teaching Annual Conference, Lake Geneva, Wisconsin.

Lehman, J.R. 1994. Secondary Science Teachers' use of microcomputers during instruction. *School Science and Mathematics*, **94**(8):413-420.

Lemmer, E.M. 1992. Qualitative research methods in education. *South African Journal of Education*, **12**(3):292-296.

Lippert, R. 1989. *Computers in Science*. HSRC Report.

Lippert, R.C. (ed.). 1993. *Computer-Based Education and Training in South Africa*. Pretoria: Van Schaik.

Lynch, P. (ed.). 1994. *Upgrading and strengthening practical work in South African Schools*. University of Witwatersrand.

Maddux, C.D. & LaMont Johnson, D. 1997. The World Wide Web: History, Cultural context and a manual for developers of educational information based web sites. *Educational Technology*, **37**(5):5-12.

Maddux, C.D. (ed.). 1998. The World Wide Web: Some Simple Solutions to Common Design Problems. *Educational Technology*, **38**(5):24-28.

Marriemuthu, D. 1990. A study of the use of microcomputers in the teaching of physical science in secondary schools controlled by the house of delegates. M.Ed thesis. University of Natal.

Mascheretti, P, Massara, C.I, Borghi, L. & De Ambrosis,A. 1987. Computer simulation and laboratory work in the teaching of mechanics. *Physics Education*, **22**(2):117-121.

Mashile, E.O. & Mellet, S.M. 1996. Political and social factors related to secondary school pupils' attitude towards school. *South African Journal of Education*, **16**(4):223-226.

Mason, M. 1999. Outcomes-Based Education in South African Curricular Reform: A Response to Jonathan Jansen. *Cambridge Journal of Education*, **29**(1):137-143.

Mason, R. & Hlynka, D. 1998. 'PowerPoint' in the Classroom: Where Is the Power? *Educational Technology,* **38**(5):42-45.

McCulloch, D.W. 1980. The Uses of a Computer-Assisted Learning System in Principle and in Practice. *Educational Technology*, **20**(6):12-15.

McFarlane, A.E, Friedler, Y, Warwick, P. & Chaplain, R. 1995. Developing an Understanding of the Meaning of Line Graphs in Primary Science Investigations Using Portable Computers and Data Logging Software. *Journal of Computers in Mathematics and Science Teaching*, **14**(4):461-480.

McIntyre, D.R. & Wolff, F.G. 1998. An experiment with WWW interactive learning in university education. *Computers & Education*, **31**(3):255-264.

Mehl, M.C. 1991. Do we really need computer-based education in South Africa? *South African Journal of Higher Education,* **5**(1):11-14.

Merriam, S.B. 1988. *Case Study Research in Education. A Qualitative Approach.* San Francisco: Jossey-Bass Publishers.

Mestre, J. 2002. "Transfer of Learning: Issues and Research Agenda." *National Science Foundation*. Hyperlink. [http://www.nsf.gov/pubs/2003/nsf03212/nsf03212_1.pdf]. 4 September 2006.

Millar,R. n.d. *What is "scientific method" and can it be taught? Skills and Processes in Science Teaching*.

Milone, M.N. 1989. Classroom or Lab. How to decide which is best. *Classroom Computer Learning*, September,34-35,38-43.

Molitoris, J.J. 1992. Elementary and advanced computer projects for the physics classroom and laboratory. *Journal of College Science Teaching*, **22**(1):44-49.

Morse, R.A. 1993. Acceleration and net force: An experiment with the force probe. *The Physics Teacher*, **31**(4):224-226.

Morse, R.H. 1991. "Computer Uses in Secondary Science Education." *ERIC Digest*. Hyperlink. [http://www.ed.gov/databases/ERIC_Digests/ed331489.html]. 7 June 2001.

Munting, J. 1991. Problem areas for hands-on work in General Science in Std's 3 to 5. *South African Journal of Education*, **11**(3):152-157.

Nadelson, L. 1997. Online Assignments. Student web pages report results to the world. *The Science Teacher*, **64**(3):22-25.

Naicker, S. & Moll, I. n.d. How to teach in an outcomes based education system in SA: Some suggestions. Doing OBE Part 1. Western Cape Education Department.

Naidoo, P. & Savage, M. (ed.). 1998. *African science and technology education into the new millennium*: *practice, policy and priorities*. Cape Town: Juta.

Nakhleh, M.B. 1994. A review of Microcomputer-Based Labs: How have they affected science learning? *Journal of Computers in Mathematics and Science Teaching*, **13**(4):368-381.

Nathan, J. 1985. *Micro-Myths: Exploring the limits of learning with computers*. Minneapolis:Winston Press.

Niehaus, L, Myburgh, C.P.H. & Kok, J.C. 1996. South African high school teachers' personal beliefs and their ability to hold their own. *South African Journal of Education*, **16**(2):104-110.

Noll, E, Koehlinger, M, Kowalski, L. & Swackhamer, G. 1998. Investigating Coulomb's Law. Using a computer-linked camera to teach Coulomb's Law. *The Science Teacher*, **65**(1):46-49.

Oenoki, K. 1997. "Velocity". Hyperlink. [http://library.thinkquest.org/10796/ch2/ch2.htm]. 5 July 1999.

Ogunniyi, M.B. (ed.). 1999. *Assessment of Grades 7-9 Pupils' Knowledge and Interest in Science and Technology*. School of Science and Mathematics: University of the Western Cape

Osborne, R. & Tasker, R. 1985. *Introducing children's ideas to teachers*. Portsmouth:Heineman

Pelgrum, W.J. & Plomp, T. 1993. The worldwide use of computers: A description of main trends. *Computers and Education,* **20**(4):323-332.

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

Perkins, D.N. & Salomon, G. 1992. "Transfer of Learning." *International Encyclopedia of Education, Second Edition*. Hyperlink. [http://learnweb.harvard.edu/alps/thinking/docs/traencyn.htm]. 4 September 2006

Pickersgill, D. 1997. IT and science teaching – the past and the future. *School Science Review*, **79**(287):25-27.

Pisik, G.B. 1997. Is This Course Instructionally Sound? A Guide To Evaluating Online Training Courses. *Educational Technology*, **37**(4):50-59.

Prager, C. 1991. "Learning Centres for the 1990's". *ERIC Digest*. Hyperlink. [http://www.ed.gov/databases/ERIC_Digests/ed338295.html]. 10 June 2001.

Raphael, J. & Greenberg, R. 1995. Computers in Public Schools: Changing the image with image processing. *National Association of Secondary School Principals*, **79**(572): 90-97.

Redish, E.F, Saul, J.M. & Steinberg, R.N. 1997. On the Effectiveness of Active Engagement Microcomputer- Based Laboratories. *American Journal of Physics*, **65**:45-54.

Reeves, T.C. (ed.). 1998. Future Schlock, 'The Computer Delusion,' and 'The End of Education': Responding to Critics of Educational Technology. *Educational Technology*, **38**(5):49-53.

Retief, I.D. 1989. Computer-aided instruction and its implementation. *South African Journal of Education*, **9**(1):148-157.

Riche, B. & Dawe, S. n.d. "Using Microcomputer Based Labs and Simulations in High School Science." Hyperlink. [http://www.bishops.ntc.nf.ca/rriche/ed6620/microcomputer.html]. 18 July 2001.

Roberts, N. 1999. Approaches to Evaluating the Educational Use of Multimedia. Millenium Minds Conference, Cape Town, 29 September-1 October.

Rodrigues, S. 1997. The role of IT in secondary school science: An illustrative review. *School Science Review*, **79**(287):35-39.

Rogan, J.M. 2000. Strawberries, Cream and the implementation of Curriculum 2005: Towards a research agenda. *South African Journal of Education*, **20**(2):118-125.

Ronan, M. & Eliahu, M. 1997. Addressing students's common difficulties in basic electricity by qualitative simulation-based activities. *Physics Education*, **32**(3):29-35.

Rooney, K. (ed.). 2001. *Encarta Concise English Dictionary*. London: Bloombury Publishing.

Rowbotham, N. 1981. Using a microcomputer in science teaching. *School Science Review*, **63**(222):70-77.

Russell, D, Lucas, K.B. & McRobbie, C.J. 1999. "Microprocessor Based Laboratory activities as Catalysts for Student Construction of Understanding in Physics." Hyperlink. [http://www.aare.edu.au/99pap/luc99196.htm]. 18 July 2001.

Santos, L.M. & de Oliveira, M. 1999. Internet as a Freeway to Foster Critical Thinking in Lab Activities. Paper presented at 1999 NARST Annual Meeting. Boston, Massachussetts, 28-31 March 1999. Hyperlink. [http://www2.educ.sfu.ca/narstsite/conference/santosdeoliveira/santosdeoliveira.htm]. 7 March 2001.

SAQA 2000A: See South African Qualifications Authority below.

SAQA 2000B: See South African Qualifications Authority below.

SAQA 2001: See South African Qualifications Authority below.

Scanlon, E. 1997. Learning Science On-line. *Studies in Science Education*, **30**:57-92.

Schlafly, P. 1994. What wrong with outcomes-based education? *The School Administrator*, September, 26-27.

Schulze, S. 2000. Education and the Internet: perspectives and trends at South African universities. *South African Journal of Education*, **20**(3):248-252.

Selwyn, N. 1997. Students' attitudes towards computers: Validation of a computer attitude scale for 16-19 education. *Computers and Education*, **28**(1):35-41.

Selwyn, N. 2000. Researching computers and education – glimpses of the wider picture. *Computers and Education*, **34**(2):93-101.

Severn, J. 1999. Use of spreadsheets for demonstrating the solutions of simple differential equations. *Physics Education*, **34**(6):360-366.

Shroyer, M.G. & Borchers, C.A. 1996. Factors that support school change to enhance the use of Microcomputers in Rural Schools. *School Science and Mathematics*, **96** (8):419-431.

Sillitto, R. & MacKinnon, L.M. 2000. Going SPLAT! – Building a multimedia educational resource for physics learners. *Physics Education*, **35**(5):325-331.

Silva, A.A. 1994. Simulating electrical circuits with an electronic spreadsheet. *Computers and Education*, **22**(4):345-353.

Singh, P. & Manser, P.G. 2000. Effects of a shared vision on the attitudes of teachers towards outcomes-based education. *South African Journal of Education*, **20**(2) 108-114.

Smit, R. 1999. “Towards a more relevant science curriculum”: A qualitative analysis of aspects of the work of the MSRC Project. Unpublished MSc thesis, University of Witswatersrand, Johannesburg.

Snyder, H.D. 1990. Computer instrumentation and the new tools of science. *Journal of College Science Teaching*, **19**(3):171-175.

Solomon, J, Bevan, R, Frost, A, Reynolds, H, Summers, M. & Zimmerman,C. 1991. Can pupils learn through their own movement? A study of the use of a motion sensor interface. *Physics Education*, **26**: 345-349.

South African Qualifications Authority. 2000A. The National Qualifications Framework and Curriculum Development, May.

South African Qualifications Authority. 2000B. "The NQF and Curriculum 2005". Hyperlink. [http://www.saqa.org.za/html/nqf/docs/curricula2005.html]. 17 July 2001.

South African Qualifications Authority. 2001. "The National Qualifications Framework: An Overview". Hyperlink. [http://www.saqa.org.za/html/nqf/overview01.html]. 16 July 2001.

Stager, G. 2000. Portable Probeware: Science Education’s next Frontier. *Curriculum Administrator*, **36**(3):32-35.

Steyn, P. & Wilkinson, A. 1998. Understanding the theoretical assumptions of outcomes-based education as a condition for meaningful implementation. *South African Journal of Education*, **18**(4):203-208.

Stewart, M. 1998. Promoting resource-based learning in HE physics: tales from the resource centre. *Physics Education*, **33**(6):385-392.

Stewart, M.F. & Gregory, J.R. 1997. Production of a multimedia CAL package in basic physics. *Physics Education*, **32**(5):332-339.

Steyn, P. & Wilkinson, A. 1998. Understanding the theoretical assumptions of outcomes-based education as a condition for meaningful implementation. *South African Journal of Education*, **18**(4):203-208.

Swain, L. 1998. "Using the Periodic Table". Hyperlink. [http://www.can-do.com/uci/lessons98/Periodic.html]. 5 July 1999.

Swain, P.A. 1997. The iodine-clock reaction – a spreadsheet simulation to test. *School Science Review*, **79**(287):81-85.

Sykes, J.B. (ed.). 1982. *The Concise Oxford Dictionary*. Oxford: Clarendon Press. 7th Edition.

Tebbutt, M. 1997. Word processors in science teaching – why? *School Science Review*, **79**(287):91-99.

Thiagarajan, S. 1998. The Myths and Realities of Simulations in Performance Technology. *Educational Technology*, **38**(5):35-41.

Thoennessen, M. & Harrison, M.J. 1996. Computer-assisted assignments in a large physics class. *Computers and Education*, **27**(2):141-147.

Thomas, R. & Hooper, E. 1991. Simulations: An Opportunity We Are Missing. *Journal of Research on Computing in Education*, **23**(4):497-513.

Thornton, R.K. & Sokoloff, D.R. 1990. Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics*, **58**(9):858-867.

Tinker, R.F. 1981. Microcomputers in the teaching lab. *The Physics Teacher*, **19**(2):94-105.

Tinker, R.F. 1987. Educational Technology and the Future of Science Education. *School Science and Mathematics*, **87**(6):466-476.

Tobin, K.G. & Capie, W. n.d. Teaching Process skills in the middle school. *School Science and Mathematics*, 590-599.

TRAC South Africa. 1997. Annual Report.

TRAC South Africa. 1998. Annual Report.

TRAC South Africa. 1999. Annual Report.

TRAC South Africa. 2004. "Welcome to the TRAC South Africa webpage". Hyperlink. [http://www.trac.sun.ac.za].

Trumper, R. 1997. Learning Kinematics with a V-Scope: A Case Study. *Journal of Computers in Mathematics and Science Teaching*, **16**(1):91-110.

Trumper, R. & Gelbman,M. 1997. Investigating power, work and effective values in an AC resistive circuit through a microcomputer based laboratory. *Physics Education,* **32**(6):408-414.

Trumper, R. & Gelbman, M. 2000. Investigating electromagnetic induction through a microcomputer-based laboratory. *Physics Education*, **35**(2):90-95.

U.S. Department of Education. 2000. "Teacher use of computers and the Internet in Public Schools." *National Centre for Education Statistics*. Hyperlink. [http://nces.ed.gov].

van der Linde, H.J, van der Wal, R.W.E. & Wilkinson,A. 1994. Practical work in science teaching in developing communities. *South African Journal of Education*, **14**(1): 48-52.

Venter, I.M. & Blignaut, R.J. 1996. Approach to computer literacy education in a Third World setting. *Computers and Education*, **27**(1):23-29.

Viall, J. 2003. Education gets wrong outcome. *Cape Argus*, 19 November, 14.

Vieyra, P. 1993. The influence of computers on teachers' and pupils' attitudes and performance: A case study. M.Ed unpublished thesis. University of Pretoria.

Waghid, Y. 2000. Qualitative research in education and the critical use of rationality. *South African Journal of Education*, **20**(1):25-29.

Waghid, Y. 2001. Is Outcomes-based education a sufficient justification for education? *South African Journal of Education*, **21**(2):127-132.

Wagner, D.L. 1994. Using digitized video for motion analysis. *The Physics Teacher*, **32**(4):240-243.

Ward, M. & Newlands, D. 1998. Use of the Web in undergraduate teaching. *Computers and Education*, **31**(2):171-184.

Weiss, A. 1999. Crisis looms as science teacher numbers fall. *Cape Argus*, 28 April.

Weller, H.G. 1996. Assessing the Impact of Computer Based Learning in Science. *Journal of Research on Computing in Education*, **28**(4):461-486.

Wellington, J. 1999. Multimedia in science teaching: friend or foe? *Physics Education*, **34**(6):351-359.

Wilcox, K.J. & Jensen, M.S. 1997. Computer Use in the Science Classroom: Proceed with Caution! *Journal of College Science Teaching*, **26**(4):258-264.

Wilkinson, A.C. & Strauss, J.P. 1998. The applicability of an investigative technology-enhanced approach to the natural sciences in secondary schools in the Free State. *South African Journal of Education*, **18**(4):251-258.

Wilkinson, F.J, Reuter, M.A. & Kriel, C.F. 1987. An analysis of the problems experienced by teachers of physical science in some developing states within the South African context. *South African Journal of Education*, **7**(1):47-52.

Williamson, P. & Waker, P. 1990. Computers in Education '90. A report to the Executive Director: Education, Cape Education Department.

APPENDIX A - QUESTIONNAIRE FOR TEACHERS

TRAC SA RESEARCH PROJECT

TEACHER QUESTIONNAIRE

INSTRUCTIONS:

1. The aim of this questionnaire is to gather information on:

- the classroom realities when performing practicals
- the organizational, administrative and financial implications when taking learners to an educational resource away from the school environment
- teachers' computer literacy skills and qualifications.

2. Please be assured that all information gathered will be regarded as strictly confidential.

3. It is important that YOUR PERSONAL VIEWS are expressed.

4. Please circle or √ or write in the appropriate places.

5. Please do not fill in the columns on the right hand side that is meant for the computer.

6. **I thank you for your time and effort spent in completing this questionnaire.**

Trevor Daniels

PERSONAL BACKGROUND

1. a) Gender: ………………………….

b) Age:………………………. (years)

2. a) Highest academic qualifications: ………………

b) Highest professional qualifications: ……………

c) Highest pass achieved for the following subjects:

i) Mathematics ………………………………..

ii) Physics …………………………………….

iii) Chemistry ………………………………...

d) If your major subjects were other than those listed above in 2 c), please indicate them below:

…………………………………………………

TEACHING EXPERIENCE

1. Years of teaching experience: ……………………………

2. Years teaching Physical Science at high school: ………..

CLASSROOM EXPERIENCE

1. Complete the following table on the number of learners in ***your physical science classes.***

Grade	Total No. Learners	No. Classes	No. Learners in each class
10			
11			
12			

2. The following is a list that indicates the practical work to be completed by matriculants as prescribed by the Western Cape Education Department 1996.

   Please indicate, by means of a tick (√) in the appropriate box below, which of the following is done in class:

   [L]: indicates that the learner should perform the practical

   [D]: indicates that the teacher should perform the practical as a demonstration

	YES [L]	**YES [D]**	**NO**
a) Investigate the acceleration produced by a constant force acting on a given mass. [L]			
b) Investigate the relationship between acceleration and force. [L]			
c) Investigate the relationship between acceleration and mass.[L]			
d) Determine “g” by free fall. [L]			
e) Investigate the conservation of momentum. D]			
f) Investigate electric field pattern. [D]			

	YES [L]	YES [D]	NO	
g) Demonstrate the force between parallel current carrying conductors. [D]				
h) Investigate the quantity of work done. [D]				
i) Investigate the factors that affect the rate of reaction.[L]				
j) Investigate the effect of concentration on equilibrium.[D] Investigate the effect of temperature on equilibrium.[L]				
k) Investigate the common ion effect. [L]				
l) Prepare a standard solution of oxalic acid. [L]				
m) Standardise a base using oxalic acid. [L]				
n) Standardise an acid using a base. [L]				
o) Investigate the metal displacement of zinc with copper sulphate.[L]				
p) Investigate the reaction between copper ions and zinc when they are not in contact. [D]				
q) Investigate the reaction of an alkane and an alkene with a solution of bromine.[D]				
r) Preparation of ethanoic acid[D]				
s) Preparation of ethyl ethanoate [D]				

3. Please answer the following question relating to the practicals that you perform in class (Where you have indicated **YES [L]** OR **YES [D]** in question 2 above.)

Do you have at your school all the necessary apparatus and chemicals needed to perform the practicals successfully?

YES …….   NO…….

If NO , please explain briefly where you obtain the necessary apparatus and chemicals.

…………………………………………………….

…………………………………………………….

…………………………………………………….

4. When conducting practicals in class, do(es):
(Please tick √ the appropriate box.)

	YES	NO
a) the students perform them individually or in groups.		
b) you rearrange the seating arrangements of the class.		
c) you set up the apparatus before the students enter the class.		
d) you have a lab assistant to assist with the practicals.		
e) you have a separate classroom in which to conduct the practicals.		
f) you have a separate room in which to store the equipment used in the practicals.		
g) you have to clean up the classroom and store the equipment which was used.		
h) your classroom have security measures in place (e.g. Armed Response)		

5. Refer to question 3 above.
The following is a possible list of reasons for the practicals you were unable to complete.
Please tick (√) the appropriate box.
You may tick more than one box.

a) Don't have the necessary equipment

b) Too much time is required to perform the practicals

c) Classes are too large

d) Don't understand how the practical works

e) Disciplinary problems when conducting practicals

f) Don't have a suitable room (venue) with suitable furniture (tables, chairs, etc.)

g) Don't have the correct facilities (running water, electricity, etc.)

h) Results or data obtained from practicals are not convincing or worthwhile to perform. The learners do not learn anything from the practicals.

i) Other (specify)…………………………………………..

………………………………..…………………………….

6. What do you recommend should be done to ensure that the prescribed practicals are completed by learners.(Taking into account that the State will *not* supply more teachers or funds.)

a) Scale down the content of the syllabus to be taught

b) Perform the practicals after school or on weekends or during the school holiday

c) Involve other institutions (NGO's)

d) Borrow apparatus

e) Other (please specify) ……………………………

……………………………………………………….

SCHOOL OUTINGS

1. How often do you take your grade 12 learners away from school on educational outings per year.

Never	1-5 times	6 –10 times	11-more times

If you have indicated Never, please explain briefly why they never go on outings.
(*and proceed to question No.9*)

………………………………………………………………..

……………………………………………………………….

……………………………………………………………….

2. Which is the most common destination for school outings?
Please tick(√) the appropriate box.

a) lecture	
b) revision classes	
c) practicals	
d) exhibitions	
e) other (please specify) ………………………………..	

3. Who makes the travelling arrangements?

………………………………………………………………

4. How much time is spent making the arrangements?

………………………………………………………………..

5. What happens to your other classes should you take a group of grade 12 learners away from school?

………………………………………………………………

……………………………………………………………...

6. Who finances these outings? Please tick (√)

a) the learners pay 100% of the travelling expenses	
b) the school pays 100% of the travelling expenses	
c) the cost is shared 50: 50 between the learners and the school	
d) Sponsorship is obtained	
e) Other: (please specify)………… …………………………………	

7. Explain briefly what procedure is followed when taking learners away from school?

…………………………………………………………

…………………………………………………………

…………………………………………………………

8. List the disadvantages in taking learners away from school.

………………………………………………………….

………………………………………………………….

…..……………………………………………………….

9. In your opinion, which of the 2 options indicated below would you prefer? Explain briefly your choice.

a) An NGO setting up the apparatus in a centre close to your school (within a 5 km radius) for your learners to complete the prescribed practical activities.

b) Your lab is fully equipped, at your school's expense, for you to complete the practical activities in class.

……………………………………………………………

……………………………………………………………

…………………………………………………………..

COMPUTER LITERACY

1. Do you own a personal computer?

YES …….   NO ……

2. On a rating of 1 to 10, how confident are you in using a computer?
(1= not confident ; 10 = extremely confident)
Please circle the appropriate number.

1 2 3 4 5 6 7 8 9 10

3. Would you use a computer in your Physical Science classroom?

YES …….   NO ……

Supply a reason. …………………………………..

……………………………………………………

4. Which of the following computer applications do you use? Please tick (√) the appropriate box. You may tick more than one box.

a) Internet

b) CD ROM

c) Spreadsheets

d) Word processors

e) Other (please specify) ………

……………………………….

THANK YOU VERY MUCH FOR YOUR TIME

TREVOR DANIELS

APPENDIX B - LEARNER QUESTIONNAIRE

INSTRUCTIONS:

1. Do not write in the boxes on the right hand side.

2. It is important that your personal views are expressed.

3. Please tick (√) or write in the appropriate places.

4.Thank you for your time and effort.

1. Gender: ……………………………………..……..

2. Age: …………………(years)

3. Grade: …………………………………………….

4. How many learners were in your group?

   ……………………………………………………….

5. What role did you play in the group?
   Please tick (√) the appropriate box. You may tick more
   Than one box.

   a) Read instructions

   b) Set up the apparatus

   c) Record observations

   d) Use the mouse to click "start"

   e) Other (please specify)………

   ………………………………

6. Did you understand the instructions?

   ………………………………………………………..

7. What were your experiences?

a) Did you enjoy it?

YES ………. NO ……….

b) Were you frustrated while performing the practicals?

YES ……… NO ……..

If you have answered YES, please complete the following

When?…………………………………….

Which section of work?

………………………………………………

c) Please indicate any other experiences while performing the practicals

……………………………………………………..

8. What dialogue occurred between the group members? Please tick (√) the appropriate box

a) argued most of the time	
b) could not reach agreement	
c) agreed on everything	
d) one learner knew all the answers the rest of us just wrote down the answers.	
e) other (please specify) …………………………………	

<u>I THANK YOU FOR YOUR TIME AND EFFORT</u>

APPENDIX C - GRADE 12 PAPER-AND-PENCIL TEST

Please answer the following questions.

1. In Activity 2, you investigated the relationship between the acceleration and the mass of the trolley. In your own words, explain what conclusion could be reached.

   ………………………………………………………………………………………

   ………………………………………………………………………………………

2. Which variable remained constant?

   ………………………………………………………………………………………

3. In Activity 3, explain in your own words what conclusion can be drawn from the relationship between the resultant force and acceleration.

   ………………………………………………………………………………………

   ………………………………………………………………………………………

4. In Activity 5, which investigates free-fall, answer the following questions.

   A. Complete the following sentence.

   During free-fall the acceleration ………………………..

   B. Why does the acceleration have a negative value?

   ………………………………………………………..

   C. At the turning point of the ball, what was the

   (i) acceleration ………………………………………….

   (ii) velocity ……………………………………………..

APPENDIX D - GRADE 11 ACTIVITY ONE WORKSHEET: REFERENCE POINTS AND DIRECTIONS

Experiment file: **ref1.exp & ref2.exp**
Verwysing1.MBL & Verwysing2.MBL

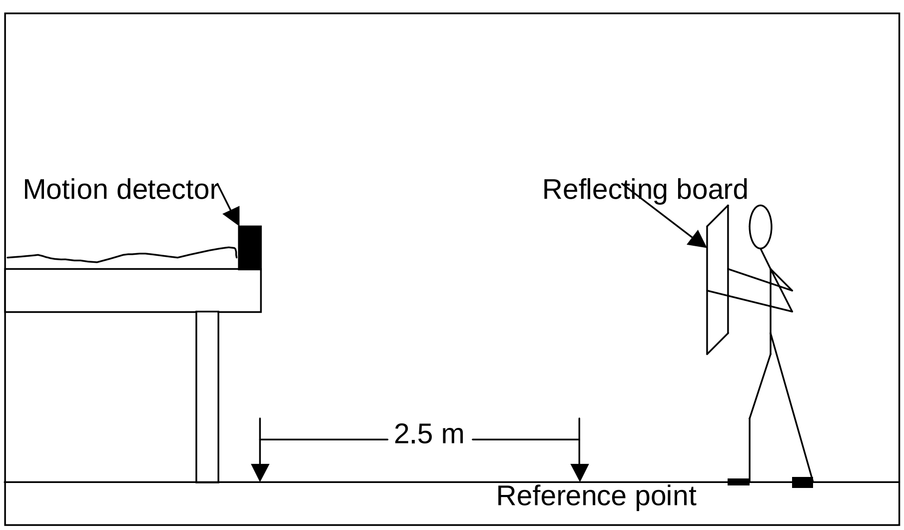
When you have completed this experiment you should be able to:

- Understand and explain the terms "Reference point" and "Reference direction".
- Interpret and simulate the movement displayed on a displacement-time graph.
- Explain how the choice of reference direction influences the shape of a displacement-time graph

Important definitions

Reference point: Point or position from which displacement is measured.
Displacement: Length and direction of the straight line drawn from the reference point to the ending point (of motion).
Reference direction: Direction in which displacement from the reference point is taken as positive.

Experimental set-up for experiment
Set up the experimental equipment as in the diagram below.



Reference Point

1. Place the motion detector on a chair or a stand with enough room in front of it.
2. Measure a distance 2,5m from the sensor and mark the point with chalk on the floor.
3. Do not move the sensor now.
4. The point will serve as the reference point for the experiment.

Part I

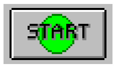
1. Prepare the computer for data collection by opening the appropriate experiment file.
2. If you are using the **MPLI-programme**, then open the following experiment file.
   - Open the file **ref1.exp**.
   - Collect your experimental data by pressing **Start**.

3. If you are using the **LabPro or Universal Lab Interface**:
   - Open the folder ***Physics with Computers***.
   - Then open the first experiment file, **Reference1.MBL**
     (For the second part of the experiment, open the file **Reference 2.MBL**)
   - The vertical axis will display displacement in meter
   - The horizontal axis will time in seconds.
   - Collect your experimental data by pressing Collect.

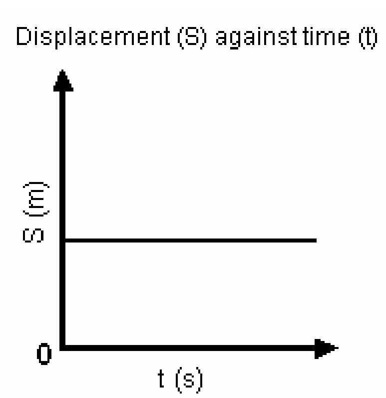
Interpretation of graphs

The following are examples of Displacement vs... Time Graphs.

1. Discuss the motion displayed by each graph.
2. Try to imitate the movement displayed in each graph by letting one person move in front of the sensor.
3. Click on Start to record the movement.
4. Give a short explanation of the movement next to each graph.



A.



Description of movement

____

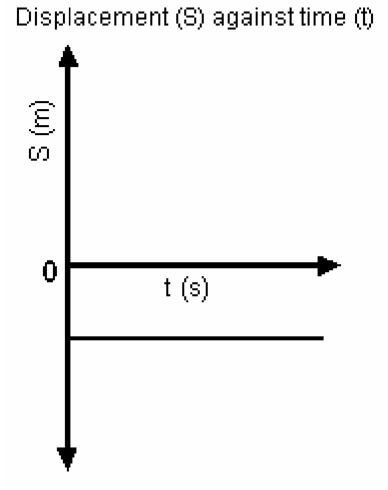
____

____

____

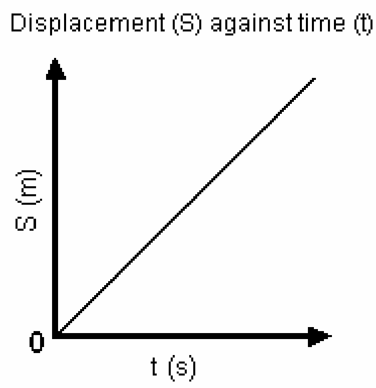
____

B.



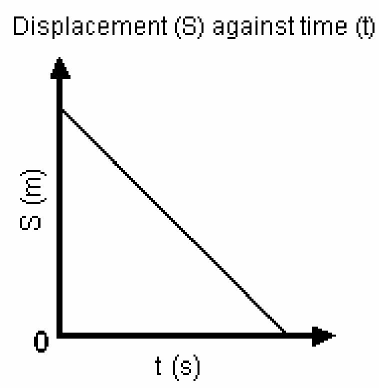
Description of movement

C.



Description of movement

D.

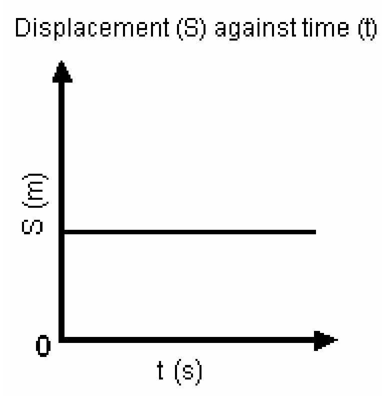


Desription of movement

Part II

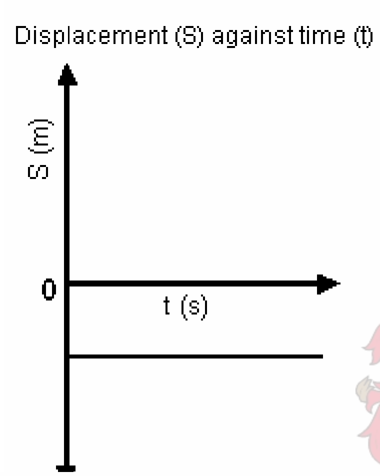
1. Open the file **ref2.exp** in the MPLI programme.
2. The mark on the floor is still the reference point, but movement **towards** the sensor is now taken as positive.
3. Imitate the graphs below again by simulating the motion.
4. Explain the motion.

A.



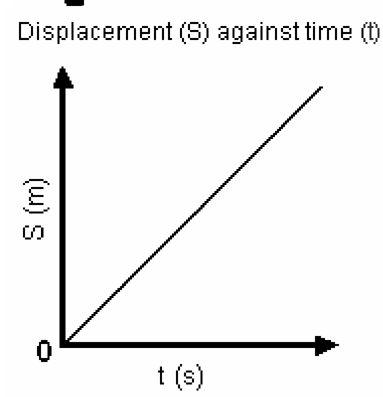
Description of movement

B.



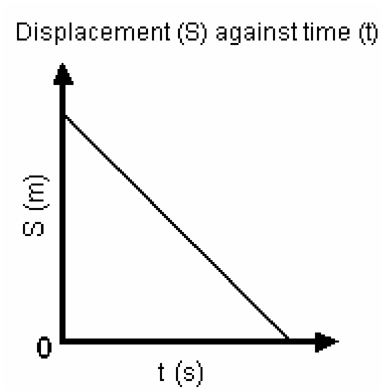
Description of movement

C.



Description of movement

D.



Description of movement

APPENDIX E - GRADE 12 ACTIVITY 2 WORKSHEET

ACTIVITY 2

THE RELATIONSHIP BETWEEN MASS AND ACCELERATION

Name: ………………………………

Grade: ……………

Date: ………………….

Experiment file: **newtone2.exp**
Newton2E.MBL

When you have completed this experiment you should be able to:

- Explain how the mass of an object influences its acceleration.
- Explain the relationship between mass and acceleration graphically.
- Explain the relationship between mass and acceleration mathematically.
- Use the relationship to solve problems.

Important Definitions

Weight: The force with which a body is pulled towards the centre of the earth. F_w=mg

Resultant Force: The single force which has the same effect as all the original forces exerting on a body.

Acceleration: The rate of change in the velocity of a body.

Experimental set-up for experiment
Set up the experimental equipment as in the diagram below.

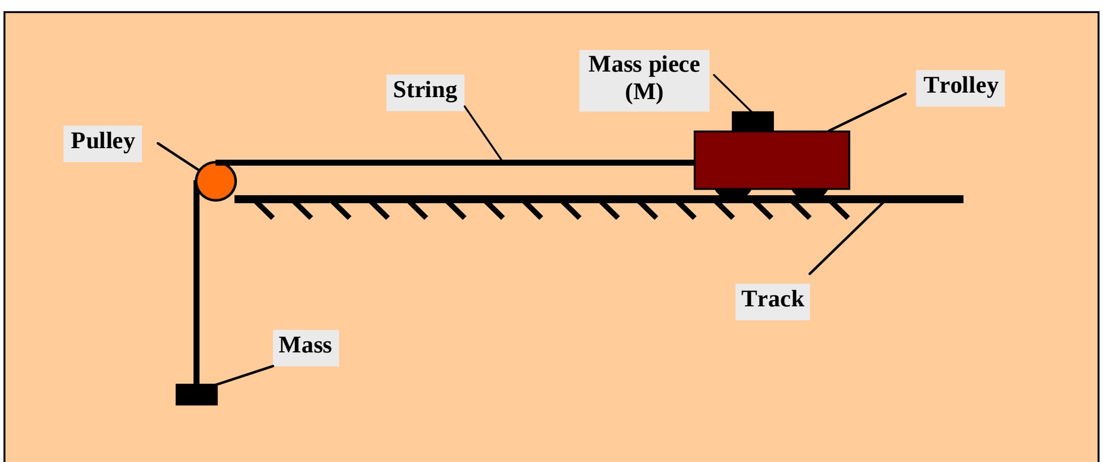


Figure 1.Experimental Setup

Procedure

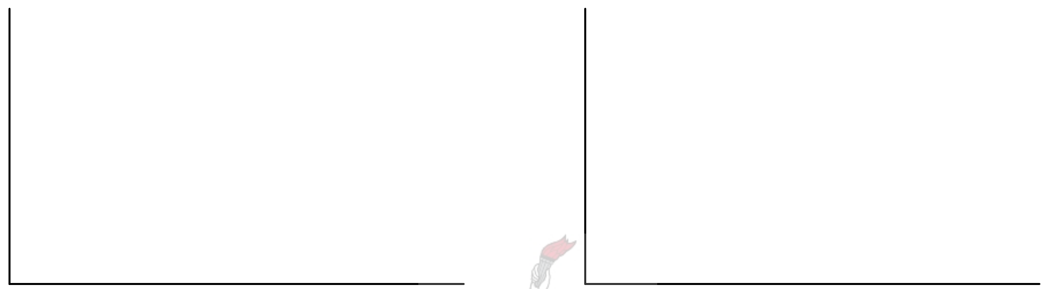
Discuss these questions in groups before continuing with the investigation.

1. We are investigating the acceleration of a moving system in this experiment. Name the parts of the system.

____

____

2. Make use of the following axis and draw rough sketches, which represent Newton's II Law. Label the axes clearly.



3. We are trying to establish the relationship between two variables in this investigation. Name the two variables.

____

____

4. All other quantities must therefore be kept constant during the investigation. Name the variables that should be kept constant.

____

____

5. Give a reason why the physical quantity in question 4 should be kept constant.

____

____

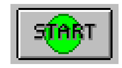
6. In the experiment the force is kept constant and the mass is changed. How will these conditions be maintained through the whole experiment?

____

____

Work in small groups to carry out the following instructions.

1. Open the file **newtone2.exp** in the **MPLI programme.**

- Weigh the trolley ______________________kg
- What is the mass of the system? _______________________kg
- Attach the string to the trolley and place the trolley at the top of the track.
- Simultaneously release the trolley and click on **START**. 

- If the results look reasonable, click on **DATA** then click **STORE LATEST RUN.**
- Place mass-pieces on the trolley to increase the mass of the trolley. Write down the total mass of the trolley and
  the mass pieces. ______________________________kg
- Repeat the experiment twice. Increase the mass pieces every time.
- Write down the total mass of the trolley and mass pieces of the other two runs.

  ______________________________kg

  ______________________________kg
- Display all the graphs on one axis. Make use of different colours to distinguish between the graphs.

2. If you are using the **LabPro or Universal Lab Interface**:

- Open the folder ***Physics with Computers***.
- Then open the experiment file, **Newton2E.MBL**
- The vertical axis will display acceleration in m/s^2, etc.
- The horizontal axis will time in seconds.
- Collect your experimental data by pressing .

A typical example of the experimental graph is as follows:

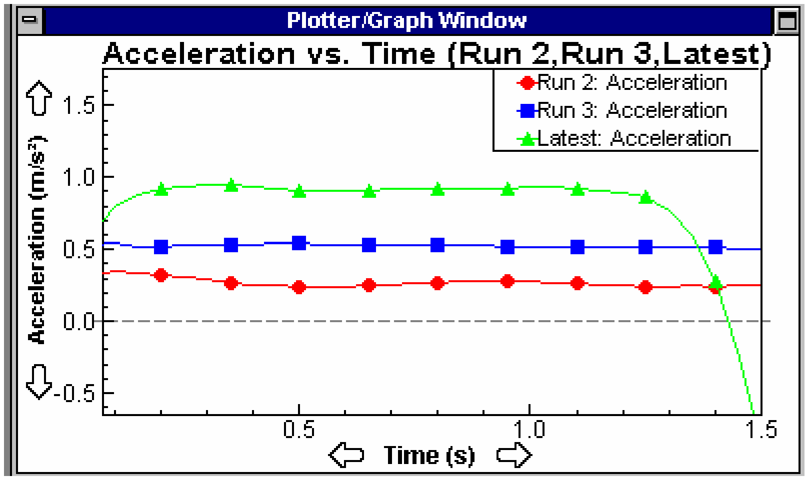


Fig. 2: The graph of acceleration vs... time

Analysis of results

You should try to answer these questions on your own. Should you experience any problems ask your teacher for assistance.

1. Make use of the graph on the screen of the computer and determine if the change in mass of the system influences the acceleration.

____

____

2. Determine the magnitude of the constant force that is exerted on the system.

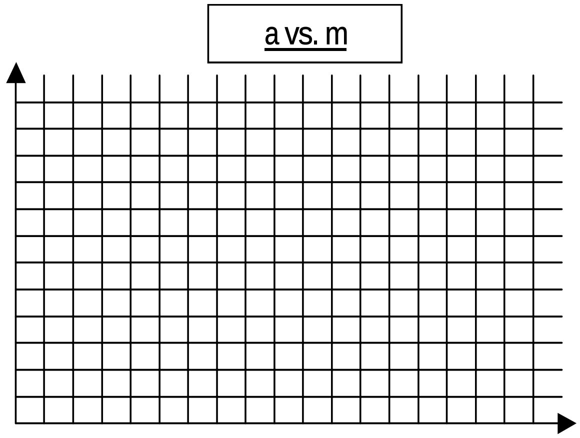
____

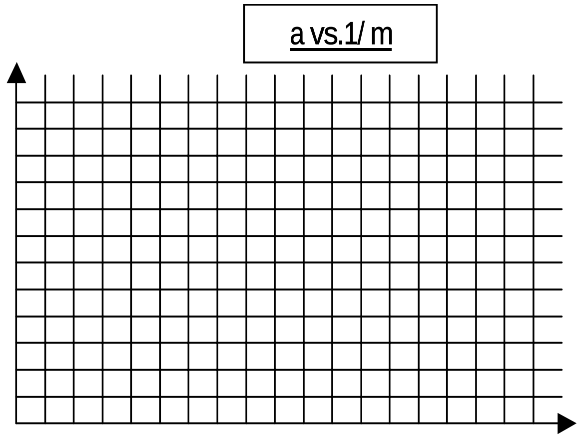
____

3. Complete the following table.

Run	a (ms^{-2})	m (kg)	1/m kg^{-1}
1			
2			
3			

4. Use the above information and plot graphs of **a vs... m** and **a vs... 1/m**.





5. Determine the gradient of the graph of **a vs... 1/m**.

____

____

6. Discuss the form of the two graphs.

____

____

7. Explain the relationship which exists between the mass and the acceleration of a body.

____

____

8. Express this relationship as a mathematical equation.

____

____

APPENDIX F - GRADE 12 ACTIVITY THREE WORKSHEET: THE RELATIONSHIP BETWEEN RESULTANT FORCE AND ACCELERATION

Experiment file: **newtone2.exp**
Newton2E.MBL

When you have completed this experiment you should be able to:

- Explain how the acceleration of an object changes when the resultant force acting on it increases or decreases.
- Express the relationship between resultant force and acceleration graphically.
- Express the relationship between resultant force and acceleration mathematically.
- Use these relationships to solve problems.

Important Definitions

Weight:	The **weight** of a body is equal to the product of its mass and the acceleration of gravity. W=mg
Resultant force:	A single force that exerts a force equal to all the other forces on a body
Acceleration:	The rate of change in the velocity of a body.

Experimental set-up for experiment
Set up the experimental equipment as in the diagram below.

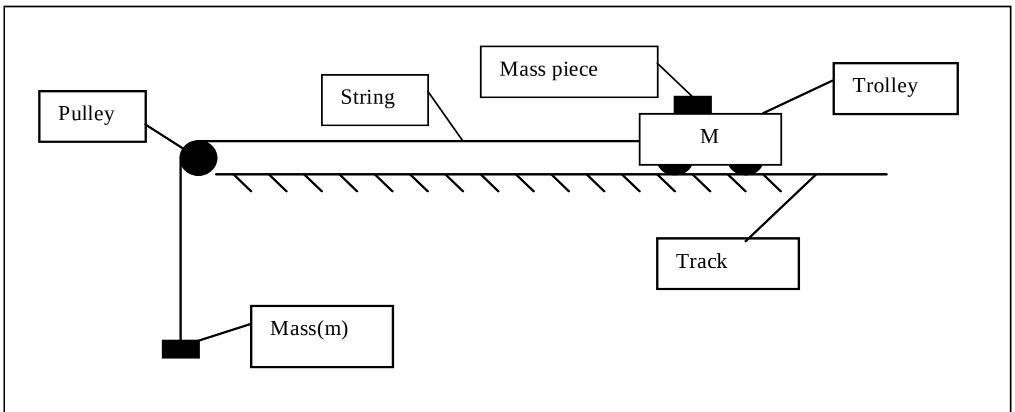


Figure 1.Experimental Set-up

Discuss these questions in small groups or as a class before you continue with the investigation.

1. You will perform an experiment that investigates Newton II law. Name all the variables which are applicable to this law.

2. We are trying to establish the relationship between two variables in this investigation. Name the two variables.

3. The other variable must therefore be kept constant during the investigation. Name the variable.

4. You will be investigating the acceleration of a moving system in this experiment. Name the parts that form of this system.

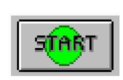
5. You need to supply a resultant force to cause the system to accelerate. How will you establish the resultant force?

Now work in small groups to carry out the investigation.

Procedure

1. Open the file **newtone2.exp** in the **MPLI programme.**
- Attach one mass to the end of the cord and tie the opposite end to the trolley. Pass the cord over the pulleys and pull the trolley up the slope so that the mass lies just under the pulley. Place the remaining mass pieces on the trolley.

2. Simultaneously release the trolley and click on START to collect data.



- If the results look reasonable, STORE DATA (*Click on DATA, then STORE LATEST RUN*). Otherwise repeat the run.
- Take the mass pieces off the trolley one by one and attach them to the nylon cord as well. Allow the trolley to run down the slope after each new addition, and STORE the results if they look reasonable. Ideally, you should collect three sets of results, using different sets of mass-pieces to create the accelerating force.

• Display your graph sets so that they all appear on the same sets of axes. Use different colours to represent the different runs.
3. An example of a graph of three runs is displayed below.

If you are using the LabPro interface, follow the following instructions.

1. Open the folder ***Physics with Computers***.
   - Then open the experiment file, **Newton2E.MBL**.

2. A graph of acceleration *vs*... time will be displayed
3. Click Collect to begin data collection.
4. The program will stop at the end of data collection.
5. An example of a graph of three runs is displayed below.

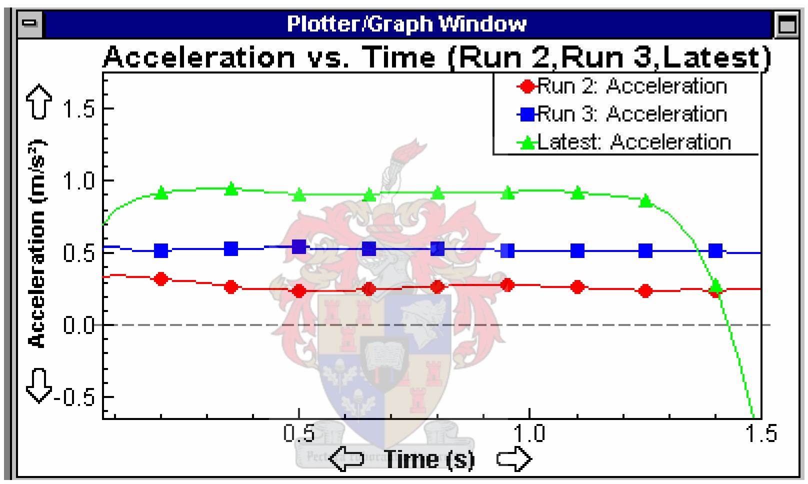


Fig. 2: The graph of acceleration vs... time

Analysis

You should try to answer these questions on your own.

The graphs you produced should be similar to the shapes of these shown above.

1. Explain why the <u>acceleration-time</u> graphs are straight-line graphs <u>parallel to the x-axis</u>.

____

____

2. How does the acceleration of the system change for each consecutive run?

3. What did you do with the mass-pieces to cause the change in acceleration?

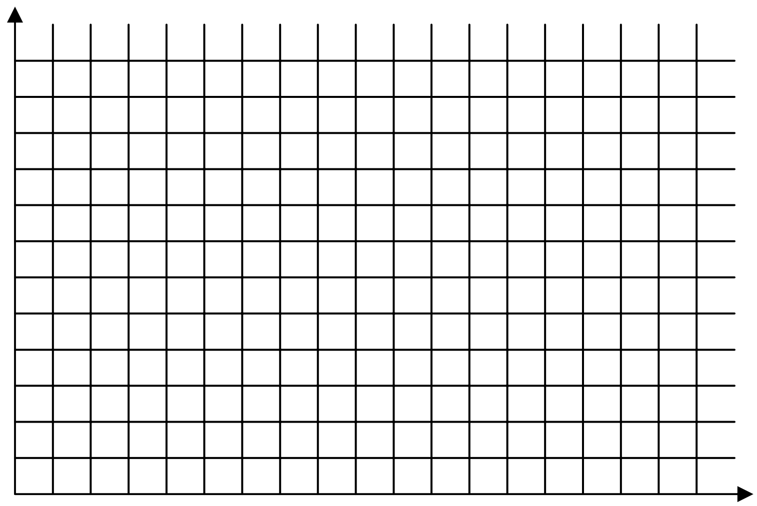
4. What effect did the answer given for question 3 have on the resultant force acting on the system?

Now measure the force that was applied for each run.

5. Complete the table below. Fill in the force that you measured for each run. Look at your graph and obtain the average acceleration for each run.

Run	Measured force (N)	Acceleration (m/s^2)
1		
2		
3		

6. Now plot a graph of force against acceleration on the set of axes below.



7. Describe the shape of this graph.

8. Explain briefly in words the relationship, which exist between resultant force and acceleration that is illustrated by the above graph.

9. Represent the relationship mentioned in question 8 as a mathematical proportionality.

APPENDIX G - GRADE 12 ACTIVITY FIVE WORKSHEET: INVESTIGATION OF FREE FALL AS A SPECIAL CASE OF PROJECTILE MOTION

Experiment file: **freefall.exp**
Freefall Motion.MBL

When you have completed this experiment you should be able to:

- Define and explain the terms **displacement, velocity** and **acceleration**
- Distinguish between the displacement-time -, velocity-time and acceleration-time graphs of projectile motion.
- Explain the relationship between displacement, velocity and acceleration.
- Express the relationship between the displacement, velocity and acceleration graphs.
- Explain what happens to the three variables at the **turning point.**

Important Definitions

Displacement (s): The magnitude and direction of the straight line drawn from the reference point to the object.
Velocity (v): The rate of change in displacement.
Acceleration (a): The rate of change in velocity.
Turning Point: A point where a change in direction of movement takes place.

Experimental set-up for experiment
Set up the experimental equipment as in the diagram below.

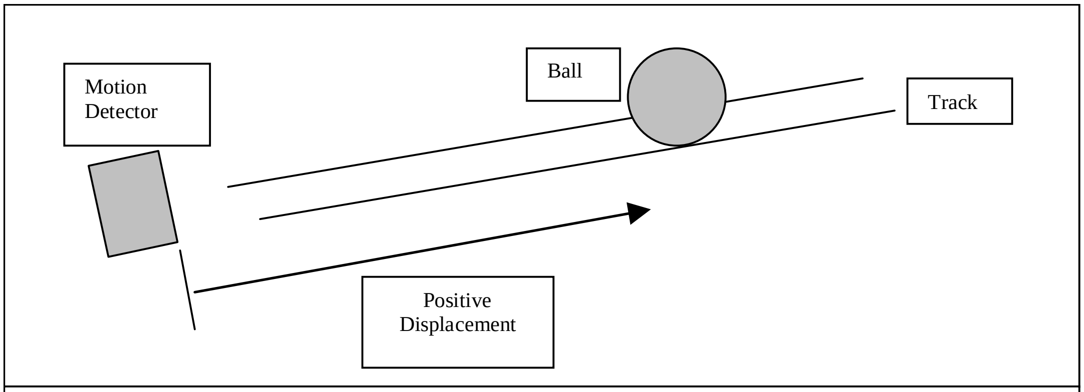
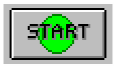


Figure 1: Apparatus for Free Fall Experiment.

Procedure:

Simulate free fall motion by rolling a ball up and down an incline to measure displacement, velocity and acceleration.

1. The apparatus and TRAC sensors are already calibrated to measure displacement away from the sensor as positive. See Figure 1.
2. Roll the ball up the incline and click on the **Start** button immediately.



3. Wait for the graph to be plotted on the screen.
4. Repeat the experiment until a smooth graph is obtained.

5. If you are using the **LabPro or Universal Lab Interface**:
   - Open the folder ***Physics with Computers***.
   - Then open the experiment file, **Freefall Motion.MBL**
   - Graphs of displacement -, velocity - and acceleration vs.. time will be displayed.
   - Collect your experimental data by pressing .

Graphs similar to the following ones should be obtained.

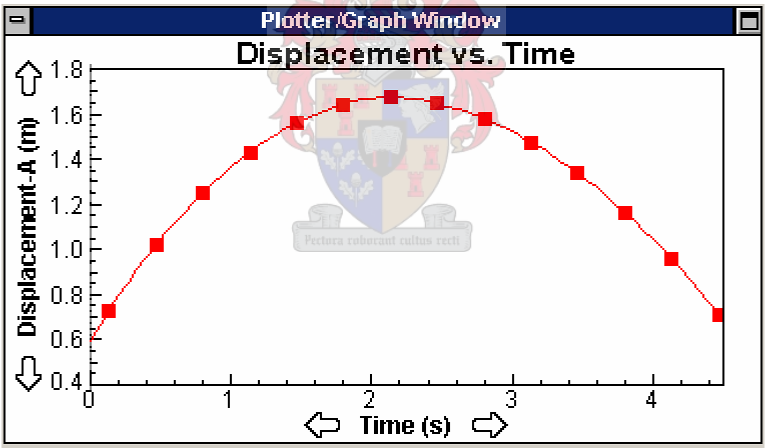


Fig. 2: Displacement vs.. Time graph.

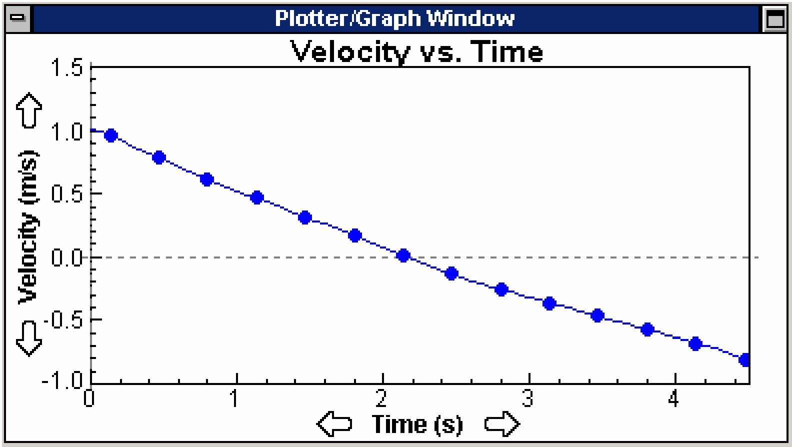


Fig. 3: Velocity vs.. Time graph.

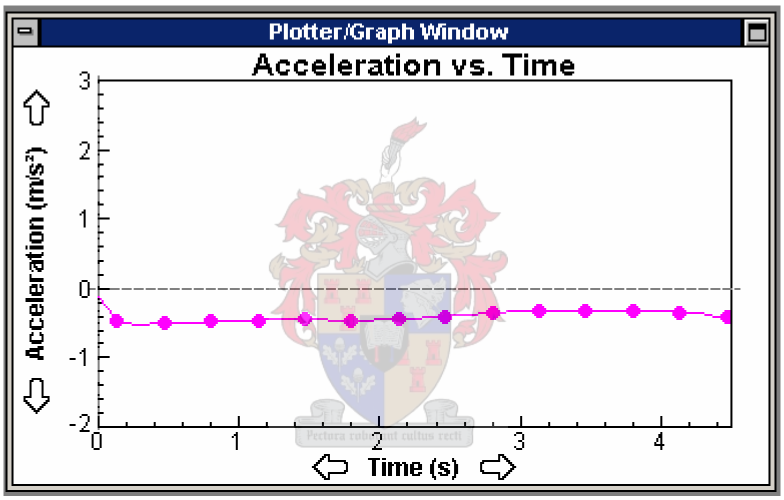


Fig. 4: Acceleration vs. Time graph.

Use the graph on the screen to answer the following questions:

Part I

1. Draw a vertical line, on the printed graph, at time $t_1 = 0.5$ s. Or use the **examine** icon on your screen. Determine and record the displacement and velocity at this time from your experimental results.

t_1	0,5s
s_1	
v_1	

2. Indicate the turning point on the printed graph and draw a vertical line through it. Determine and record the time, displacement, and velocity at the turning point from your experimental results.

t_2	
s_2	
v_2	

What do you conclude? ____

3. Indicate by means of a vertical line on the graph, a time later than time t1 at which the displacement is the same as at time t1. Determine and record the time, displacement, and velocity at this time from your experimental results.

t_3	
s_3	
v_3	

What do you conclude?____

4. What shape do we expect for the **acceleration-time** graph? How does this compare to the experimental results?

5. Determine from the graph the value of the **acceleration**. Is the value negative or positive?

6. Determine the gradient of the **velocity-time** graph. Compare this value with the value determined in question 5.

Examine the displacement-time graph.

7. What shape does the **Displacement / Time** graph have?

8. In what direction does the ball move when the velocity is positive?

____

9. In what direction does the ball move when the velocity is negative?

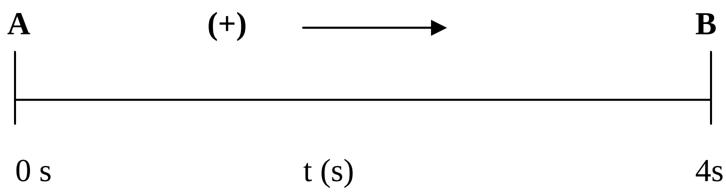
____

10. What happens to the ball at the point where its velocity is zero?

____

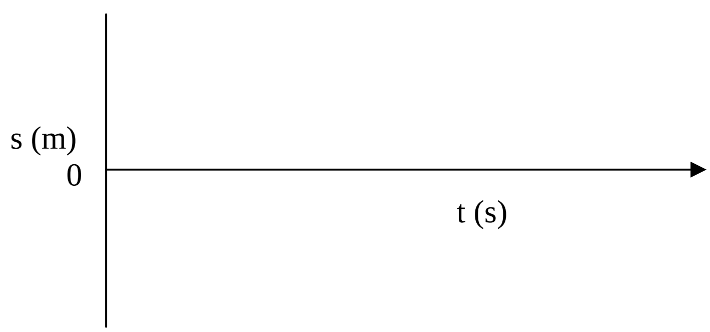
APPENDIX H - GRADE 11 PAPER-AND-PENCIL TEST

1. A car travels at <u>constant velocity</u> from point A to point B in 4 s. Point A is the reference point with a value of 0 and the direction from A to B is taken as <u>positive.</u>



Draw a ***Displacement/time*** graph that represents the displacement of the car.

2. Consider the same question as in question 1 with point A being the reference point, **but** the direction from B to A is now **positive.** Draw a ***displacement/time graph*** that represents the displacement of the car.



APPENDIX I - INTERVIEW WITH A GRADE 11 TEACHER AT THE TRAC LABORATORY

Researcher: "What do you think have been your learner's experiences at the TRAC laboratory?"

Teacher: "*It has really been an exciting experience for the learners. They are concerned that they will not get another opportunity to perform practicals again because even though we have a science lab, we don't have enough equipment and chemicals so they got a good opportunity to do some experiments with the computer. We have a computer lab at school but are not using it at the moment. A qualified teacher is using the lab to give computer lessons after school. You could see the learners struggling to use the mouse*".

Researcher: "What do you, as the physical science teacher, want from an educational centre such as the TRAC laboratory?"

Teacher: "*It must benefit my learners, the group work; they must be allowed to think for themselves. It must offer work that is related to the science syllabus and a place where they can build knowledge. The use of facilities that is not available in our school. The learners must have 'hands on' experience at the centre*".

Researcher: "Which factors could prevent you from bringing students to an educational centre again?"

Teacher: "*Financial problems. The school and parents simply do not have money to pay for transport to take learners away from school*".

Researcher: "Who should pay for transport to the TRAC laboratory?"

Teacher: "*Transport costs are expensive. Our school cannot afford it and it would be appreciated if the centres can assist the schools with transport*".

Researcher: "If TRAC where to give you one of these computers, would you be able to use it in your classroom?"

Teacher: "*Yes. It might be problematic because we have a security problem at school. With 50 learners in the class I will have to divide them into groups. Since one can only have about 5 learners in a group, I will need 10 groups. This will be problematic because there will not be enough time to complete the activities. This implies that I may have to use time in the afternoon or Saturday classes. If there is a facility that can accommodate 20 learners at one time, then it would be a big help*".

At the end of the interview the teacher thanked TRAC SA for helping the learners to learn using the computer. The teacher said that many of them had never used a computer before and ended by saying "*It was really exciting*".

APPENDIX J - INTERVIEWS WITH GRADE 11 LEARNERS AT THE TRAC LABORATORY

Four learners were interviewed. These were their responses.

Researcher: "Have you been to the TRAC laboratory before?"

Learner 1: "*No*".

Researcher: "Do you have any previous computer experience?"

Learner 1: "*Not so much. I did a course with PROTEC at school*".

Researcher: "Does your school have computers?"

Learner 1: "*Yes, but it is for Grade 12 only*".

Researcher: "Did you enjoy the session at the TRAC laboratory today?"

Learner 1: "*Yes, I did*".

Researcher: "What did you enjoy about the session today?"

Learner 1: Became very excited. "*Working with the computers and working with the group. I learned a lot about the computer. Also the things we do in class we did here on the computer. Using the computer made the work seem quite easy*".

Researcher: "Did you understand the work?"

Learner 1: "*Yes I did. I think because you helped us most of the time*" (Referring to the researcher).

Researcher: "What did you not enjoy about today?"

Learner 1: "*Nothing. I enjoyed it*".

Researcher: "How do the practicals done in the TRAC lab differ from those done in the classroom?"

Learner 1: "*It is different because in school there is no space and also no computers and some apparatus*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner 1: "*The lab*'.

Researcher: "Why?"

Learner 1: "*Here is someone to help you. At school there is no space to do practicals*".

A second interview was conducted with a different learner.

Researcher: "Have you been to the TRAC laboratory before?"

Learner 2: "*No. It is my first time*".

Researcher: "How regularly do you get to use a computer?"

Learner 2: "*I don't have a computer at home. We don't get to use the computers at school, as there are very little computers. I attended a course at the University during one school holiday. That was the last time I used a computer before today*".

Researcher: "How do you feel about the visit to the laboratory today?"

Learner 2: "*I enjoyed the session. It was fine. I particularly enjoyed working in a group*".

Researcher: "Do you think you understand the work done here today?"

Learner 2: "*Yes*".

Researcher: "What did you not enjoy about today's session?"

Learner 2: "*Nothing. I enjoyed it*".

Researcher: "How do the practicals done in the TRAC laboratory differ from those done in the classroom?"

Learner 2: "*Here we touched things. At school we don't do things, we don't touch things. We are only given paper and we only write*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner 2: "*I would prefer the lab. Here you* (the researcher) *explain to us, there is lots of apparatus*".

Researcher: "Do you think there is a place for computers in the physical science classroom?"

Learner 2: "*Sure. I think it is good to have in the class and that all schools should have computers in their science classroom. It is what we need since everything now is done on computers and it is helpful to understand the work*".

A third learner was interviewed.

Researcher: "Have you been to the TRAC laboratory before?"

Learner 3: "*No. It is my first time*".

Researcher: "Did you use a computer before today?"

Learner 3: "*Yes. Only once with the SAILI programme*".

Researcher: "Did you find working with the computer difficult?"

Learner 3: "*No. At first I thought it was going to be difficult but after you* (myself) *explained and the fact that we worked in a group showed me that it was actually easier and I enjoyed it a lot*".

Researcher: "What did you enjoy about today?"

Learner 3: "*Completing the practical with the use of the computer. I would use the computer to do practicals rather than the way we do practicals in class which is boring because all we do is talk about the practical but with the computer we get to see the graph, the acceleration graph, the lines formed so much that it becomes a part of you and you feel that you are doing something and it makes me excited*".

Researcher: "What did you not enjoy about today?"

Learner 3: "*The fact that maybe this will be the last time that I will get to use a computer again*".

Researcher: "How do the practicals, done in the TRAC laboratory, differ from those done in the classroom?"

Learner 3: "*It is very different because we don't often get to do practicals. We always write and teacher explains to us. You* (myself) *did explain to us and then we saw it happen. Now we are able to do practicals ourselves so that we can really have a vision of it when we are writing or preparing for the exam*".

Researcher: "Does the school have science equipment?"

Learner 3: "*Yes, very little and we do not get to use it*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner 3: "*I would definitely go with the lab. Have access to all equipment. Can handle the computer. Get to see the lines on the computer. Work in groups and there is lots of space*".

A fourth learner was interviewed.

Researcher: "Did you visit the TRAC laboratory before today?"

Learner 4: "*No. This is my first visit*".

Researcher: "What were your experiences at the lab today?"

Learner 4: "*I enjoyed it tremendously. The fact that we could perform practicals is exciting because we get to do very little practicals at school*".

Researcher: "How do the practicals done in the TRAC laboratory differ from those done in the classroom?"

Learner 4: "*We do practicals at school but the apparatus is not enough for everyone. When we do get the opportunity to perform a practical in class, then everything is done so quickly/rushed because the time allocated at school to complete a practical is usually not enough. We then do not have enough time then to understand the practical. Here at the lab time was set-aside for us to complete the practicals. Teachers* (the researcher and the research assistant) *are available to assist us with any difficulties that we experience and the whole experience was enjoyable. Here we were given the opportunity to repeat the practical if we got it wrong but in the class if the practical is not done to standard/ correctly, then we don't actually benefit from it. More than enough time* *is available to complete the practicals here at the lab, but in class our time is limited to complete the practicals because when the school bell rings we stop and have to go to the next class*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner 4: "*I would prefer to perform the practicals in the lab. It gives me exposure and experience to work in a lab. When I leave school, I might get the opportunity to work in a lab. I will then feel hesitant and insecure around the apparatus and will not feel confident in handling the apparatus (including the computer). I might just be asked by a lecturer – why don't you know how to use the apparatus, were you not taught this at school, were you never in a lab before? I would therefore recommend that practicals be performed in a lab because it is 'lekker' to work in a lab, one builds up experience and one learns about the rules to be followed when working in a lab*".

Researcher: "Are you computer literate?"

Learner 4: "*Although, I do not have a computer at home, I have attended computer courses on Saturday's where we learned programs such as Excel. I would not consider myself to be an expert around a computer but I am also not afraid to be in front of a computer. I do consider myself to be computer literate. It is important that one is computer literate in today's world as everything makes use of computers and one needs to be computer literate if you are seeking employment after you have left school*".

Researcher: "Do you think a place exists for the computer in the physical science classroom?"

Learner: "*Yes. If it will make me understand the work better as has happened here today, then it will be welcome in the classroom*".

Researcher: "Any additional comments from your side?"

Learner 4: "*Alles was goed genoeg*".

APPENDIX K - INTERVIEWS WITH GRADE 12 TEACHERS AT THE TRAC LABORATORY

A. First teacher interview

At first, the teacher was nervous about the interview since the school arrived at the TRAC laboratory an hour and fifteen minutes later than expected. After the teacher had settled down I started the interview session by asking the following questions.

Researcher: "What do you, as the physical science teacher, want from an educational centre such as the TRAC laboratory?"

Teacher: "*I want the centre to offer exactly the same practicals that are prescribed in the syllabus. Therefore, the practicals must be syllabus related and cover the same content that is covered at school. I must be able to contact the centre to book the venue so that the students can complete the practicals at the same time when the work is done at school. It must also offer continuous evaluation activities that must subscribe to the regulations as set down by the education department. These activities need to be marked*".

Researcher: "Which factors could prevent you from bringing students to an educational centre again?"

Teacher: "*The students must have 'hands on' experience. They must be kept busy. The activities must make the students think about what they are doing. Many centres simply offer a "walk through" exhibition. This will not motivate me to bring the students to a centre again. There needs to be 'control' over the students. They must not run around or wander around a centre*".

Researcher: "What problems do you experience when conducting practicals at school?"

Teacher: "*Time is a limiting factor. The first priority is to complete the syllabus. The time allocated per period in a school day is never constant. The environment at school is very dynamic*. *Problems arise at school that requires urgent attention and consequently the times allocated for each period is usually reduced. Therefore, a practical activity usually takes a few days to complete. This confuses the students since finality was not reached on the aim of the practical and they usually forget what it is that the practical is about*".

Researcher: "What other problems are you experiencing in the Physical Science classroom?"

Teacher: "*Many students are struggling to grasp abstract concepts taught in class. Too much time is spent in trying to reinforce these concepts. This results in losing valuable time and this then forces one to rush to complete the remainder of the syllabus before the September examinations. At our school, physical science is a compulsory subject. You will find that a drama student also does physical science. It is not their favourite subject and they tend to neglect it*".

I thanked the teacher for her valuable input.

B. Second teacher interview

A second teacher was interviewed on a different day when this teacher accompanied the grade 12 learners to the TRAC laboratory.

Researcher: "What do you, as the physical science teacher, want from an educational centre such as the TRAC laboratory?"

Teacher: "*The learner must feel that it was worth their while to visit the centre. I do not want to struggle to get them to come a second time again. I do not want a situation to arise where I have to force them to come by threatening them with the fact that it is compulsory because it is going to form part of their continuous evaluation mark. The experience must benefit the learners and they must feel that they have learned. One must be open to explore new things that will assist the learners to understand the subject better*".

Researcher: "Which factors could prevent you from bringing students to an educational centre again?"

Teacher: "*Financial costs. The arrangement at our school is that the school pays half of the transport and the learners have to pay the other half. In many cases the learners cannot afford it and then we don't go anywhere. The learners were really relieved when they heard that they did not have to pay for today's visit to the lab*".

Researcher: "Should learners be expected to pay an entrance fee together with paying for transport to the lab, how will this affect your plans in bring learners to the centre in future?"

Teacher: "*It will definitely make my task more difficult because our school is situated in a poor community and learners simply do not have the money to pay for this. This will probably depend on the number of times that I take the learners to the centre. I have had the experience in the past of taking learners to UWC. In the beginning they also paid for the transport and the learners attended every week. When the funding dried up and we were told to pay for our own transport, immediately everything fell flat and stopped. The school made an attempt to pay half of the transport costs while the learners were to pay the other half but after 2 to 3 weeks we had to stop because learners simply could not afford it. The financial implications place a huge role in bringing learners from a poor community to these centres. You definitely have learners who are eager to attend but then you also have learners who definitely don't have the money. If the arrangement is made that we can bring the learners once a term, then maybe we can bring all the learners with. The problem with that is that there will then be too little time available in the year to complete all the required practicals*".

Researcher: "What if you take off a whole day from school to complete all the practicals?"

Teacher: "*That has implications, especially for the grade 12 learners. The other teachers are concerned about losing time with their learners as they teach other classes as well and a class that leaves school regularly will eventually fall behind with their work. Fortunately, today, the learners have only missed the last two periods of the day. Teachers will be willing to give a whole day off to a class to attend a session like this but only once in the year. Not even once a term. The other implications are that other teachers have to invigilate my other classes and they are not too eager to agree to this*".

Researcher: "What are the planning implications when taking learners away from school?"

Teacher: "*Transport arrangements. I will first have to inform the principal and get his permission for learners to leave the school. I will then have to inform the teachers that teach the class that the learners will be absent on a certain day. The learners have to complete an indemnity form. Contact the transport company and determine the cost and inform the learners of their financial contribution. Then I will have to first collect the money. This can take a while to do. Because the learner struggles to pay for the transport, the learner tends to develop a negative attitude towards excursions in the future and they tend not to want to participate*".

Researcher: "What happens to the other learners that you teach when you leave the school to bring your grade 12 learners to the TRAC laboratory?"

Teacher: "*The system at our school is that each learner is assigned to their guardian teacher. This is problematic because the teacher already has large classes and now more learners enter the class and the learners do not take the subject. Therefore a teacher does not want to contribute to this situation happening regularly and one tries to keep it to a minimum. One does this so as not to increase the workload of the teachers and one does not want to fall behind with the workload of the other classes. This implies that one has to find ways of catching up with the time one has lost with these classes. The grade 12 learners don't mind staying after school, but the grade 11 – 9 learners do not understand the seriousness of the situation and they tend not to stay after school. These problems will make me tend not to want to take the learners away from school too frequently. Being the only physical* *science teacher has other implications as well. I tend to get involved in lots of other projects as well e.g. IMSTUS, FENCES, TRAC, SUNSTEP, etc. Making these arrangements as well to take learners there*".

Researcher: "I have been informed that you have a TRAC PAC at your school as well. Tell me how you get to use the TRAC PAC in you class. What are the advantages and disadvantages?"

Teacher: "*Our school has a computer lab it is not well resourced. It is being upgraded so that all the computers will be networked. At this point, the computers are just standing on there. The TRAC PAC is in the computer lab on a trolley. Learners do not use the TRAC PAC (who do not take science) because it is not loaded with the programs that are available on the other computers. When I want to use the TRAC PAC I will then take my learners to the computer lab. I have an advantage in that it is always ready for use. I do not have to carry it to the lab and set it up and dismantle it when I'm done. This would have discouraged me. I can just go into the lab and use the TRAC PAC. We are fortunate in that the lab is properly secure. It has its burglar bars and alarm system linked to an armed response. Possibility of theft is reduced to a minimum*".

Researcher: "How often do you get to use the TRAC PAC?"

Teacher: "*A problem that we have at school is that there is always an emphasis to complete the syllabus. No matter how eager one is to complete all the practicals, one eventually falls behind with the syllabus content. So I try to use it as often as is possible. I have already taken the grade 12 and grade 11 physical science learners to the lab to use the TRAC PAC. A problem that I have experienced is that the periods of 50 minutes each* *is too short and one has to then carry on with the practical the following day. So if I have to compare the 2 situations (TRAC PAC in school vs.. TRAC laboratory). If they use the TRAC PAC at school over a longer period of time, then they can complete the practical activity. This arrangement does not take a lot of my time and not a lot of my periods either. Because the TRAC PAC is available at school, I can use it to reinforce certain concepts that the learners are experiencing problems with, while I am teaching. I do not have to wait until I have completed a section and then only after a certain period of time take them to the TRAC laboratory to reinforce certain concepts. My experience is that the use of the TRAC PAC definitely helps the learners to grasp certain concepts quickly. It can also be argued that a learner will grasp the concept if he/she gets to use the TRAC PAC at the TRAC laboratory, after the teacher has taught it. It is much more beneficial if the learner gets to use the TRAC PAC when he/she comes into contact with the concepts and not to wait for time to pass before using the TRAC PAC to reinforce those concepts. My experience has shown me that if the learners grasp the concepts, I get to complete the syllabus content much quicker and that I get to complete much more work as well, if I compare this to last year when we did not have the TRAC PAC. Because we use the TRAC PAC I can definitely see the difference that it makes. This is the advantage of this arrangement*".

Researcher: "Should TRAC PACs be placed in schools or should they be placed in a laboratory? What would you recommend?"

Teacher: "*It is a difficult choice to make. If all schools are given a TRAC PAC, it is questionable whether all schools will use it. It all depends on the teacher and what he/she gets to do with the TRAC PAC. The advantage of the laboratory setup is that learners are forced to work in groups. A possible reason for the teacher not using the TRAC PAC at school is* *that he/she does not feel confident using the program. To combat this problem would be to empower the teacher so that the teacher feels confident and wants to use the TRAC PAC. His/her enthusiasm will result in the teacher exposing the learners to the TRAC PAC. To answer the question (even though I would not like to make a choice), I would be swayed to having the TRAC PAC at school because I am familiar with the TRAC program, I feel confident using the TRAC PAC. The ideal situation would obviously be to have both setups i.e. TRAC laboratory and a TRAC PAC at school. The TRAC LAB has its advantages for the teacher who does not feel confident in using the TRAC PAC. Not much effort is required on the side of the teacher to bring the learners to the TRAC laboratory. Some teachers even have a problem in accompanying the learners to such a venue, but this can be addressed by having assistants at the laboratory leading learners through the practicals. The problem with this again is that teachers do not get to see the development of concepts by their learners and wants to be a part of this development. Another advantage for me is when one starts with a concept like Newton II, it is a wonderful experience to see a learner grasp a concept immediately when he/she does the practical. This makes a difference in how the learner remembers this concept. Another advantage in bringing the learners to the TRAC laboratory is that it will save on time in terms of giving the learners the opportunity to complete practicals for their continuous evaluation mark. When the TRAC PAC is used at school with only one computer, we get one set of readings and all the learners take note of these readings that makes everything happen quickly. With continuous evaluation learners have to be busy on their own and obtain their own readings so that will help if they come to the TRAC laboratory*".

Researcher: "Low number of learners taking Physical Science as a subject. What is your view on this?"

Teacher: "*The grade 10 learners start on average with 40 learners in class. When they reach grade 12 the total number of learners has dropped to below 20. The reason for this is that many learners fail both Maths and Physical Science and consequently fail the grade, even thought they pass other subjects such as Biology well, and do not come back the following year to repeat the subjects but choose other subjects. Many learners are not able to make the distinction that Maths and Physical Science requires hard work. The same amount of effort that they use to pass subjects like Biology they also apply to Maths and Physical Science and definitely fall short. Maybe one has to address the pass requirements or the syllabus. We are fortunate that many programs are available to our learners for Maths and Physical Science, but at the end of the day it will only be successful, if the learners are prepared to do he necessary hard work. I don't know how to bring about the change in the way the learners do things. I think that the experience that the learner gets at primary school is vitally important. Many teachers at primary school are not confident in teaching Maths and Physical Science. This attitude rubs off on the learners and the learner comes to high school with a negative attitude towards the subject and the learners know that they do not have to choose the subject again in grade 10. At primary school it is terrifying to hear that there is not so much emphasis on literacy and numeracy anymore. The result is that we are getting many more learners at the high schools that have difficulty in reading with comprehension. Many learners are choosing the subjects in the business stream and those that take Physical Science in grade 10 do so because they are told about the importance of taking the subjects when they are in grade 9*".

I thanked the teacher for his insight and willingness to participate in the interview.

APPENDIX L - INTERVIEWS WITH GRADE 12 LEARNERS AT THE TRAC LABORATORY

<u>Learner A</u>

Researcher: "Did you enjoy the experience at the TRAC laboratory?"

Learner: "*For me it was not helpful*".

Researcher: "Please explain".

Learner: "*I need to understand how the velocity is calculated. I need to know what values to use. I understand the work better if I do the calculations myself. The shape of the graphs must not just appear on the screen. I need to understand why a particular shape graph is obtained*".

Researcher: "Did you experience any problems while conducting the practical activities?"

Learner: "*Not actually. A teacher was always available to assist with any problems that we had*".

Student could not identify any problems even though her group experienced problems.

Researcher: "Are there any other comments that you would like to make?"

Learner: "*Even though I did not find it useful, I still enjoyed it. I think that it can be useful for others students*".

Researcher: "Please explain what you mean when you say it can be useful for other students".

Learner: "*Maybe, they will understand the work because they are not like me that need to understand*".

Learner B

Researcher: "Did you enjoy the experience at the TRAC laboratory?"

The learner was hesitant to respond negatively, but his expression showed that he was merely being polite. After a brief silence the learner responded:

> "*There is something missing. I cannot put my finger on it. When you enter the lab the students' attention must be grabbed. This is not happening here. Students want to see fascinating things happen. Students must be allowed to explore*".

Researcher: "What would you recommend?"

Learner: "*I don't know. Maybe seeing computer simulations. Get to use the Internet*".

Researcher: "What problems did you experience while busy with the activity?"

Learner: "*When using the computer there needs to be clear guidance. Maybe a 'Help section' that the student can click on that will explain certain concepts. We did not understand what was meant by 'gradient'. Group work was a problem. One person knows all the answers. The rest of us became bored*".

Researcher: "Do you have any further comments that you wish to make?"

Learner: "*I know that we, the students, must know our work and this is not the case here today*".

Learner C

Researcher: "What were your experiences regarding the session at the TRAC laboratory here today?"

Learner: "*I enjoyed it very much. I have learned lots of things here today that I would not have learned at school. Example with the acceleration vs.. time graph I did not get to see the graph like I saw it here. At school all the learners are present around the computer and one does not get the opportunity to ask questions. Here at the TRAC laboratory I can ask someone to explain to me and show me again the graph if I do not understand it. To work in a group was great, we could help one another if someone did not understand. I could learn through making mistakes. At school there is no time to learn through making mistakes*".

Researcher: "Is there anything that you did not enjoy about the session today?"

Learner: "*No. I enjoyed everything and will like to come again*".

Researcher: "How do the practicals done in the TRAC lab differ from those done in the classroom?"

Learner: "*Because we have a TRAC PAC at school, it does not differ much from what is happening here at the TRAC laboratory. Everything is the same as at school. The only difference is that at the TRAC laboratory there are more computers so more learners are busy with the practical whereas at school there is only one computer so all learners are present around the computer. At school, the teacher will be at the computer with 2 or 3 learners assisting him with the setup of the apparatus while the other learners are mere spectators*".

Researcher: "If you had a choice, would you prefer to perform the practicals in the classroom or in the TRAC laboratory?"

Learner: "*I would prefer the TRAC laboratory. I am given the opportunity to perform the practical and so learn though the process. In the class I am merely observing and I think that I am not learning much*".

Learner D

Researcher: "Did you enjoy your experience at the TRAC laboratory today?"

Learner: "*Yes, the practicals are interesting*".

Researcher: "What about the practicals do you find interesting?"

Learner: "*The fact that we get to work with computers is fascinating and 'lekker'*".

Researcher: "Do you think that you have learned anything here today?"

Learner: "*I have learned a lot e.g. to describe the movement of an object using the computer*".

Researcher: "How do the practicals done in the TRAC laboratory differ from those done in the classroom?"

Learner: "*In the classroom it is not done so practically as it is done here. Our school does not have access to all the apparatus. I think our school has a shortage of apparatus*".

Researcher: "Have you done these practicals at school?"

Learner: "*Yes, but not with the computer, only with the ticker-timer*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner: "*I would prefer to perform the practicals in the lab*".

Researcher: "Do you think other learners will also prefer to complete the practicals in the laboratory?"

Learner: "*Yes, definitely*".

Researcher: "What did you not like about this session today?"

Learner: "*The time is definitely too long*".

Researcher: "What amount of time would you suggest should the learners be busy in the lab at any one time?"

Learner: "*One hour*".

Researcher: "What would you recommend should be done if a school wants to complete more than two practicals?"

Learner: "*Keep it short. The school can always make arrangements to visit the lab on another day*".

<u>Learner E</u>

Researcher: "What did you enjoy and not enjoy about today's activities?"

Learner: "*I felt that I learned a lot*".

Researcher: "What specifically do you think you have learned?"

Learner: "*Newton's Laws*".

Researcher: "Were there any problems that you experienced, anything specifically that you did not understand?"

Learner: "*Not actually*".

Researcher: "The use of the computer to perform the practicals, was it difficult?"

Learner: "*No, it was easy*".

Researcher: "How do the practicals done in the TRAC laboratory differ from those done in the classroom?"

Learner: "*The teacher lets us read about the practical before we perform the practical at school. We do not have access to this type of apparatus. Group work is also followed at school*".

Researcher: "*What do you enjoy about group work*?"

Learner: "*You get to hear learner's opinions*".

Researcher: "But doesn't this lead to different answers? How do you manage to come out to the same answer?"

Learner: "*Discuss together*".

Researcher: "If you had a choice, where would you prefer to perform the practicals? In the classroom or in the TRAC laboratory?"

Learner: "*In the lab. All the apparatus to perform the practical activity is readily available*".

Researcher: "*What can you tell me about the time spent at the laboratory today*?"

Learner: "*We had more time to complete the practicals here today than what we normally have time for at school. We don't always get to complete the practicals during the allocated 50 minutes per period at school. We are then sent home to complete the practical and return it the next day to school*".

APPENDIX M - INTERVIEWS WITH GRADE 11 TEACHERS AT THEIR SCHOOLS

TEACHER 1

Researcher: "Briefly, please provide some background information about your teaching career".

Teacher: "*I started teaching in 1984 after completing my B.Sc degree at UCT and completed my teaching diploma, while teaching. I have been teaching physical science to grades 10, 11 and 12 at the same school since 1984*".

Researcher: "When and how did you get to hear about the TRAC programme?"

Teacher: "*I received an invitation from the TRAC organiser to attend their introduction to the TRAC programme at Stellenbosch. I went along with twenty other teachers and it was there that they decided that we would be given a TRAC PAC*".

Researcher: "Why did you decide to remain with the TRAC programme?"

Teacher: "*Initially when I received the invitation I thought that it would be something interesting to do. It is another resource that I could use within the classroom. When I saw the TRAC PAC I though that my learners would be interested in the TRAC PAC and that it would really motivate my learners. It will also show them another way of collecting data for the investigations that they are doing. We are in a global world where our learners are exposed to IT (information technology) all the time and they should be given that kind of exposure within the classroom. It is for these* *reasons why I decided to accept the invitation and remain with the TRAC programme*".

Researcher: "When you accepted the invitation from TRAC, you went there with certain expectations. What did you think you would get from using the TRAC PAC in your classroom?"

Teacher: "*Initially I accepted the invitation because I like collecting different resources that I can use within the classroom. It was about seeing what TRAC could actually offer for my teaching and learning within the classroom. I thought that it would motivate my learners and it is just another way of teaching. I often get tired of the old traditional way of teaching, the transmission mode. Personally I need different ways of teaching a topic to the learner and this would just be another way that I could do a particular practical or investigations with my learners. So it was with these points in mind that I decided to use the TRAC PAC. So it was about another resource within the classroom, a different way of teaching within the classroom, trying to make the learners understand by showing them different ways of doing something so that they can understand the topic and about motivating the learners to do science and to get the grade 10's to keep doing science up until grade 12*".

Researcher: "Looking back, since accepting the invitation, did the TRAC PAC meet your expectations?"

Teacher: "*Yes, definitely. The learners really enjoyed using the TRAC equipment. They enjoyed using the computer to generate their data. It was something new for them to work with. Once I had set it up they would actually stay during interval to work all on their own. I did not have to plead with them to stay during interval to complete an activity. So in that way it did help with the stimulation and motivation of the learners. Secondly, there was now another resource that I could use to teach certain concepts such as* *force or acceleration-time graphs. I could then show the learners the traditional way of doing the practicals on these concepts and then the learners could compare. It was just another data collection method. In some ways it assisted with the understanding of concepts. It was easy to change a variable using the computer and the learners could then easily see the effect of the change. So it was then easier for the learners to get to grips with the concept that was being taught. The use of the TRAC PAC did assist with the process of teaching and learning in terms of making the understanding of concepts easier*".

Researcher: "I was going to ask you to comment on the advantages associated with having a TRAC PAC in your classroom. But you have clearly mentioned quite a few advantages, repeatedly. Would I be correct in summarising that you regard the following as being advantages of having a TRAC PAC in your classroom? The teaching and learning, stimulating learners, reinforcement of concepts and getting learners excited about physical science".

Teacher: "*Yes. Another advantage of using the TRAC PAC is that I could then use the grade 12 learners' practicals as part of their portfolios. I would then use at least 2 practical activities and present these as part of the grade 12 year marks that must be presented to the curriculum advisor*".

Researcher: "What are the disadvantages associated with having a TRAC PAC in your classroom?"

Teacher: "*You needed to be comfortable around the computer. I know very little about computers. So, initially it was quite intimidating setting it up, being alone with no one to assist you when something goes wrong. When busy with a practical activity and something goes wrong, and you do not feel confident, you lose a little bit of your self confidence in that process.*

Therefore, you need to be confident that you know how to work the programme for that particular investigation and that you know what to do when something goes wrong. If you don't have the necessary computer background, then that can be an intimidating factor. I would therefore call on the computer teacher at school to help me if something goes wrong. Another disadvantage is the time in preparing. It meant that you had to sit with the programme at school and you had to prepare what the learners had to do. That was time consuming especially if you have a full teaching day. I felt that I needed to be prepared before using the TRAC PAC with the learners. Another disadvantage is the issue of security around the equipment. This meant that I had to wheel the equipment out of a secure room on a daily basis and that can be very restricting when using the equipment because the classroom was not considered to be safe. At the end of each term it had to be packed up and taken down to the safe. At the beginning of each term I had to carry it from the safe back into the science laboratory. Another disadvantage is having a small computer screen that made it difficult for learners to see the screen. This was particularly obvious when I used the TRAC PAC with my sixty grade 12 learners. This meant that learners had to be divided into groups and these groups then had to rotate so that each group would eventually get to use the TRAC PAC. This resulted in quite a lot of time being used to complete a practical activity. In some cases it meant that learners had to complete the practical activity during interval, after school or in some cases even during the school holiday. Another disadvantage is that there were no effective assessment rubrics available and teachers do not have the time to develop their own assessment instruments. If I take an overview, the advantages always outweigh the disadvantages, that's why I continued using the TRAC PAC".

Researcher: "How often do you use the TRAC PAC in your classroom?" "Why?"

Teacher: "*That depends on the section of work to be covered by the syllabus. For grade 10, I would use it for sound, grade 11 for graphs and grade 12 for Newton's laws of motion. It could be that for one term I would not be using the computer. Completing these practical activities satisfied the departmental requirements and I never saw the use of the TRAC PAC as an 'add on'*".

Researcher: "Do you think that the TRAC PAC has a role to play in the physical science classrooms of South African schools?"

Teacher: "*Definitely. It is a brilliant tool for motivating learners and for making science fun and interesting. Learners get excited when you set up the TRAC PAC, it is not something that they are used to. Learners get to understand the concepts easier when I showed it to them on the computer. They get to see how the graph changes when a variable is changed and they get to understand the concept a whole lot quicker. It also has a role to play in compliance with policy requirements for continuous assessment. It can be used as a practical activity that grade 12 learners must complete for their portfolio requirements. What TRAC SA needs to do is to set up assessment instruments for those activities*".

Researcher: "What would motivate you to take your learners to the TRAC laboratory?"

Teacher: *What would motivate me is that I would actually have support and assistance. With the TRAC PAC at the school, you don't have the support and assistance from TRAC at your school. Nobody comes around to see if you know what you are doing and no one assists you at the school. At the TRAC lab you actually have the TRAC co-ordinators who would be able to assist you. The practicals are already set-up and people are there to assist if something goes wrong with the computer, because it does happen. At the lab you would have more computers available, you don't have that* *learners have to come during interval and after school to complete the practical activity because everyone can complete the activity at the same time. A disadvantage of the TRAC laboratory is that what happens at the lab is not integrated with the teaching and learning that takes place in the classroom at that particular point in time. You might have to wait to go to the lab after you had completed the work in class. Another aspect is that it contradicts the concept of continuous assessment where learners' complete six activities in one go. What are you saying about assessment actually being continuous? So that is a tension that one needs to address. Another disadvantage is the expense involved in bringing the learners to the laboratory. Where do I get the funding from to take sixty grade 12 learners from a disadvantaged community to Stellenbosch where the transport costs would be in the region of thirty rand per learner*"?

Researcher: "What advice would you offer to TRAC SA and to the teachers using the TRAC PACs, to ensure the optimal use of the TRAC PAC?"

Teacher: "*Make it part of the teaching and the learning. When doing sound, you make it part of your sound lesson. Don't see it as an 'add on' to your work, because then it could become a burden to you. Let it become part of the classroom activities. See it as a fun activity and you have to enjoy using it so that the learners also enjoy using it. You have to prepare thoroughly because things will go wrong and you have to be prepared for that. When things do go wrong, take that in your stride. Not to get too upset and then to put the TRAC equipment away in your storeroom never to be used again. Allow for things to go wrong and accept it, this is actually part of the fun in your science classroom. The noise levels of the learners definitely goes up when you use the TRAC PAC, allow this to happen. We are living in an age when information technology is important. We need to expose our learners to this technology in our science classrooms. It is not something that they simply use to play games* *with, or to type up their practical but that it is actually used for an investigation.*

For TRAC SA, it is extremely important to me that they conceptualise the worksheets. Making the worksheets and computer programme more user friendly. Teachers need to be re-trained constantly in terms of the computer programme and teachers need support in the classroom. Somebody from TRAC SA that could come out to the classroom at least for the first two lessons because it was quite nerve raking using the TRAC PAC for the first time on my own. If it is not possible to send someone to the school then TRAC SA could offer support in the form of a help desk that you could call while you are busy with an activity. TRAC SA could also set up assessment instruments for the worksheets. Teachers will tend not to use a worksheet if no assessment instrument is available. Expecting teachers to develop their own assessment instruments will not encourage teachers to use the worksheets simply because they do not have the time to do so. Therefore, TRAC SA will lessen the teachers' burden if they develop assessment instruments for the worksheets. Another aspect of these assessment instruments is that teachers will tend to use them if it complies with departmental policies".

TEACHER 2

Researcher: "Briefly, please provide some background information about your teaching career".

Teacher: "*I starting teaching Geography and General Science at this high school 18 years ago. The past 10 years I have been teaching physical science and I am at present the Head of Department for physical science*".

Researcher: "When and how did you get to hear about the TRAC programme?"

Teacher: "*About 2 years ago I received an invitation, while I was visiting an Expo, to attend a demonstration of the TRAC PAC. It was already at this Expo where I found this programme very interesting*".

Researcher: "Briefly, explain what this demonstration, which you were invited to, entailed".

Teacher: "*The demonstration took place over two days and I had to bring along another teacher from my school. The training that we received was merely to expose us to programme and all the teacher was expected to work with the computer, set up the different sensors, understand how to interpret the graphs and had to understand how to bring about changes to the existing graphs so that the teacher can adapt the graphs for the experiments that will be applicable in the classroom*".

Researcher: "When you accepted the invitation from TRAC, you went there with certain expectations. What did you think you would get from using the TRAC PAC in your classroom?"

Teacher: "*Currently, the workload of a physical science teacher is huge. Therefore, initially I was expecting that when using the TRAC PAC it would contribute towards reducing my workload when completing physical science practical experiments. My learners are expected to complete lots of physical science practical experiments, therefore I saw the use of the TRAC PAC as a solution to completing the practical experiments quickly and easily and for them to understand graphs easier*".

Researcher: "Looking back, since accepting the invitation, did the TRAC PAC meet your expectations?"

Teacher: "At this point in time, the use of the TRAC PAC at our school is working wonderfully".

Researcher: "Why do you still want to remain with the TRAC programme?"

Teacher: "*We have reached a stage where the world is experiencing change. Technological developments over the past couple of years have conditioned us into thinking that computer usage in the classroom is necessary and because of this I think that the TRAC programme is suited to be used in the classroom. Also, I think that because the learners can use the TRAC PAC on their own and that it can stimulate the learners are reasons why I wish to remain with the TRAC programme*".

Researcher: "Please comment on the advantages associated with having a TRAC PAC in your classroom".

Teacher: "*As mentioned in the previous question, the fact that learners are able to work alone, is a big advantage of having a TRAC PAC in one's classroom. I also believe that the graphs that appear on the computer screen are a great advantage over what was done in the past. It also makes the subject a lot more interesting for the learners who are growing up being exposed to computers all the time*".

Researcher: "What are the disadvantages associated with having a TRAC PAC in your classroom?"

Teacher: "*The limited time that a teacher has available for using the TRAC PAC is a great disadvantage because there are other skills that a learner is also expected to develop and the teacher cannot only use the TRAC PAC to develop all these skills. Another disadvantage is the issue of security. The* *necessary safety precautions need to be taken to secure the classroom and therefore also the TRAC PAC. In this case, the TRAC PAC is not stored in the physical science classroom, but in the computer laboratory which has the necessary safety precautions. It therefore becomes a great effort to collect the TRAC PAC in the computer laboratory, set it up in the physical science classroom, dismantle it after it has been used and take it back to the computer laboratory. This is one of the factors that contributes towards using the TRAC PAC only once per term with grade 10, 11 and 12 learners*".

Researcher: "How often do you use the TRAC PAC in your classroom?" "Why?"

Teacher: "*For each grade (10 to 12), I try to use it at least once per term*".

Researcher: "Will the placement of computers, in previously disadvantaged schools, together with the necessary infrastructure be enough to assist learners with the subject physical science?"

Teacher: "*No. Together with this we need to look at the bigger picture. Teachers need to be involved. At this point of time, our schools are experiencing a shortage of teachers who are computer literate. It involves much more than just placing the computers at schools. It requires complete training and usage thereof*".

Researcher: "What characteristics do you think a teacher should have, if the TRAC PAC is to be used effectively in the classroom?"

Teacher: "*Besides having a basic understanding of the physical science content, the teacher needs to be computer literate*"

Researcher: "What would motivate you to take your learners to the TRAC laboratory?"

Teacher: "*The fact that learners are able to experience the same concepts in a different setting is a great stimulation for learners and this would motivate me to take my learners to the TRAC laboratory*".

Researcher: "What advice would you offer to TRAC SA and to the teachers using the TRAC PACs, to ensure the optimal use of the TRAC PAC?"

Teacher: "*Try to use the TRAC PAC on a regular basis. It is very advantageous. One needs to determine if there are quicker and easier ways to complete the practical activities in order to save time. Another piece of advice would be to encourage learners to use the TRAC PAC on their own*".

Researcher: "If you could choose between having a TRAC PAC at your school or taking your learners to the TRAC laboratory, which option would you choose?"

Teacher: "*I would definitely choose to have the TRAC PAC in my classroom. Firstly, it saves money in term of travelling costs. Secondly, learners can conduct experiments on their own so that learning takes place*".

APPENDIX N - INTERVIEWS WITH GRADE 11 LEARNERS AT THEIR SCHOOLS

Three learners from two different schools were interviewed. I initially thanked all of them for participating in the interviews and allowing me to use an audio recorder. I guaranteed that their responses would be treated confidentially. These are their responses.

Learner 1

Researcher: "Did you enjoy the session today"?

Learner 1: "*Yes. It was very, very interesting and different and in the beginning I was very nervous and I did not know what to expect at first but after awhile I relaxed and realised that using this computer regularly can make the understanding of the work so much quicker and easier*".

Researcher: "What do you mean when you say that it was interesting and different"?

Learner 1: "*It was interesting to see how good technology has developed and how easy it is to get graphs to appear on the computer screen through your own movement. The graphs that appeared on the computer screen are different to the way we draw graphs during a normal lesson. Normally, the graphs are drawn on the board, we a given a piece of paper and we have to draw the graphs ourselves. Here, we were able to make our own graphs and we could see that the graph was really so. We could really see for ourselves that the graphs were real. It is not a case that our teacher says so, so therefore we must believe him. Here we could see for ourselves*".

Researcher: "Do you believe what see on the computer screen"?

Learner 1: "*Yes, because I saw it happen*".

Researcher: "Before you came to the front to demonstrate the shape of a particular graph, you were given an opportunity to have a discussion with the other learners in your group. What discussions took place"?

Learner 1: "*When we received our worksheet we first went through it and we realised that we had describe our movement for a particular shaped graph. As a result, we held a discussion which resulted in lots of different opinions and consensus was reached which helped all learners to understand what was expected*".

Researcher: "After the learners had completed the demonstration of a particular graph, everyone was given an opportunity to write down his or her own observations. Did this happen"?

Learner 1: "*Yes. We all wrote down our own answers*".

Learner 2

Researcher: "Please provide me a brief overview of your experiences this morning".

Learner 2: "*Yesterday when I was told by my teacher of our involvement in this research activity today, I felt a bit nervous because I was scared of the questions that were going to be asked and in case I did not know the answers to the questions then I would not raise my hand to answer the question. But when I saw that it involved the work that we had already done previously, I used my own knowledge to answer the questions. Therefore, I enjoyed it very much. I really enjoyed the change in the direction that influenced the shape of the graph and this helped me to understand the work. What I found particularly interesting was how* *someone could walk backwards but the graph actually goes up (Here the learner refers to graph C of part two)*".

Researcher: "Do you think that the one activity that we completed here today is enough to help you understand the work better"?

Learner 2: "*Yes, I think so. However, I think that some of my classmates still don't understand. Therefore, I think that we need to go to the computer room again and work on this together with more questions that could be set up by our teacher*".

Researcher: "What do you think is the advantage of this computer programme"?

Learner 2: "*To be able to share our experienced with other learners thereby motivate them to take physical science as a subject*".

Researcher: "What did you not enjoy about the session today"?

Learner 2: "*Nothing*".

Learner 3

Researcher: "Please provide me a brief overview of your experiences this morning".

Learner 3: "*I learned a lot more than I thought that I would learn this morning. The experience helped me to be able to answer the questions; therefore I think I learned a lot this morning*".

Researcher: "What experience are you referring to"?

Learner 3: "*I could see with my own eyes*".

Researcher: "Before you started with your demonstration, your group was asked to have a discussion. Initially, did you all have the same understanding of what was to be expected"?

Learner 3: "*No. They all had different views. For example, one learner said that movement must take place away from the sensor but others said that movement must take place towards the sensor*".

Researcher: "What did you then do in such a case. How did you know which movement to perform"?

Learner 3: "*We all agreed on one answer*".

Researcher: "Earlier you mentioned that you learned a lot. How does this differ from what normally happens in class"?

Learner 3: "*We are not able to see the shape of the graph of a particular movement*".

Researcher: "What did you enjoy about the session this morning"?

Learner 3: "*It was interesting to hear the opinion of other learners*".

Researcher: "What did you not enjoy about the session this morning"?

Learner 3: "*Nothing*".

I thank the learner for participating in the interview.

APPENDIX O - INTERVIEW WITH PROFESSOR HUGO

Researcher: "Who is Professor Hugo"?

Hugo: "*My personal background is that I have 40 years in Engineering work. In this period of time I have gone through four careers. I have been in construction, I have been a consultant, I have been in academics and I have been a researcher. So if you ask me who I am, it depends on which hat you want me to put on. I have had that background and from that perspective, I really have done field work. I have done design or execution work and I have been involved in actual training and of late I am also doing research which really is intertwined with a great part of my career. If I were to subdivide them, those were really the four facets of my career and I have landed up in a situation now, where this last one has extended more into the international scene. The extension of my career has actually been involved in international exchange and interaction with researchers and indeed providing a service with a research tool that I developed. It seems I am very close to getting a fifth career. I hope that helps you a little bit*".

Researcher: "Thank you. Please tell me why you chose to be associated with TRAC and how do you think the TRAC PAC can be used in improving the teaching and learning".

Hugo: "*What I want to explain to you is that with my international linkages, I serve on an education committee of the Transportation Research Board (TRB). The TRB is a subset of the National Science Foundation in the United States. They are involved in the Federal Highway Administration. It handles primarily a lot of research work and works together with other organisations such as the American Association of Highway and Transportation Officials.*

Now the TRB meets annually in January and roughly has some seven to nine thousand researchers meeting in Washington. It meets for some four or five days and discusses research and all aspects of transportation. It has, if I am right from memory, about two hundred and fifty committees that deals with all aspects of the field of transportation and one of those is the Education Committee and I sit on that committee as an international member. In the early 90's, at one of these meeting, I heard someone make a presentation on TRAC. It immediately prompted my mind and what I really do as part of my lifestyle up there is to continually explore and see what I can actually capture and bring across and build into this nation. It prompted me to say that this is something that we should get involved in.

At the time South Africa was still an underdog out there. It took me a couple of years to actually persuade the Board members to get into TRAC. To give you some background, though a little bit deeper than this, I simply asked "Can we get involved in this"? The response was that there are some eight organisations that were really parenting TRAC. These organisations included, amongst others, The American Society of Civil Engineers and the Society of Professional Engineers. At one of these meetings I put this request forward and at that time the director of TRAC, Allan Ship, requested a ballot. It was voted down. This was pre-1994. I did not give up too easily and kept on pursuing this matter. In early 1994, it was finally allowed. We then became the only international centre i.e. outside of the United States. TRAC has regional centres of which at the time there were some sixteen or seventeen. The agreement was that TRAC SA could become number seventeen and I brought it to South Africa. In the preparatory period I was loaned a MAC, small little MAC which I think is still around, to actually demonstrate the system and this MAC really started it all going and we haven't looked back.

I thought that this is one of the ways of bridging gaps and actually conveying science and mathematics or for that matter physics and mathematics principles which I am very convinced is one of the prime *methodologies of conveying some of these difficult concepts is by visually getting that information across. I think that the beauty of the tool is the visual concept that you have out there*".

Researcher: "As South Africans we are aware that our science and mathematics education is probably not the best in the world. In your opinion, how would you describe the general status of our science and mathematics education"?

Hugo: "*I think I must say that I am really disturbed and appalled at some of the things that I have been hearing, seeing and experiencing. It really started off when I was doing some career guidance. Taking the whole field of engineering, not just civil engineering, to schools highlighted the limitations experienced in these schools. I think it was really brought home when the university went to some schools to canvas learners to enter the engineering field that they would go to schools with some one thousand learners and find out that there wasn't even a physical science teacher. In some cases the physical science was poorly taught and we found that there were very many limits out there and this struck me as being not only a sore and sad state of affairs, but really something that if we haven't got the building blocks, then we are in trouble. So it means that unless we get to grips with that, we are not going to get off the ground and my fear is that we have so many gaps in the system that we just cannot stand still. I think it is appalling that we are in this state of affairs. So what worries me is that we have everything going for us, the options and possibilities. Why aren't we achieving, what is going on*"?

Researcher: "Do you think that there is a shortage of people interested in the field of science and its related disciplines"?

Hugo: "*I am sincerely of the opinion that not only is there a shortage, but everything that is happening out there is just exacerbating the problem. We have a severe shortage. It is my contention that we have a shortage but we also have a shortage of good people.*

We mustn't think that movement is equal to production. Movement might just be moving desks or rearranging desks on the titanic. I am a little bit worried that sometimes we think that there is somebody or a body in front of the class and that there is a solution. It is not quite that simple. My concern is that, yes, there is a shortage, but I think there are some people out there that can do it and also we have the potential for doing it. But unless we recognize and understand the problem, we are in deep water".

Researcher: "I am very curious about the last comment you made. You spoke about having somebody in front of a class of learners that may not mean much. How do you then classify or what do you think are the characteristics of a good science teacher"?

Hugo: "*I think it is clear, that in my experience over many years, you become comfortable in front of a group of people when only one main element is present. That is that you must be a master of the subject you are giving. If you stand in front of a group of people, whether you are giving a political speech or teaching a class, the only time you feel comfortable is when you know what you are doing. I therefore say that a characteristic of a good science teacher is that he or she should not only be knowledgeable, but should actually be eager to go beyond the pack that he or she is trying to lead. So the challenge out there is that you are going to find some smart kids and nowadays even more and the challenge is to stay ahead. There is nothing as embarrassing as not being ahead and I would believe that that in itself is a big challenge, because the youngsters of today are coming into the world being completely computer literate. This takes us to a position of where the characteristics of a future science teacher is just of* *necessity going to be, such a person must be totally computer literate and must be a master of it. So we land with a new animal out there. A new being that is not the science teacher of the past. The science teacher is going to be challenged of all the things of the past and the things of the future that makes it very tough for the good science teacher*".

Researcher: "What influence do you think the working conditions and the general conditions under which teachers operate have on the quality of service they deliver"?

Hugo: "*Well, I think that part of problem is that the very people we are talking about are not equipped to deliver services on a broader basis. The problem is that unless you meet the challenge on the broad base, out there you are going to have erosion of the very people you may have. So my concern is that you may make working conditions such that they are tolerable, they are such that a person can deal with the situation which they are in and they have got tools with which to do this. It is almost like saying that you can tie a person's hand behind his back and expect him to fight. You have got to make the conditions so that the individual can meet the challenges and I am not sure that the system is conducive to that. Unfortunately, I find this in many parts of the educational system, whether in the university or elsewhere, to get people to understand that all aspects of education are not strictly the same. Because the very basis of what the core of our business is out there is saying everything is equal. I am afraid that as long as you say that, you are then dealing with a situation where some people would say, well then if that is the truth, then I am going to look at the so called equal elements and I am going to choose the easiest partner and they just go the easy route. So unless there is recognition that it is not all equal, then you get into a situation where you don't allow market forces to grow. Unfortunately, many of the government systems don't allow market forces to work. The moment you say that everybody is* *equal, you get the reduction in numbers and the problem is that the private sector is not bound by these rules. So, the private sector then offers something better. Unless the conditions of a science teacher are brought to a point where they have not just all the tools, but comparative remuneration, you have a difficulty. Now you can live so much for unequal reward, but at the end of the day, if you have no butter to butter your bread, you will be willing to sacrifice something and if that hardship is then taken further and you have got a difficult subject to teach and you haven't got assistance or support, then you are in trouble.*

So, I am sure that other disciplines would come up and say that yes we also have a difficult task and I don't begrudge them making that statement. But I think that we have got to say that in the end we have got to have an understanding that you must also compare apples with apples. What is happening out there is that if the market forces are not allowed to act, then you will find a skewing of the system. The skewing of the system just simply means that there will be fewer and fewer of those just taking the harder route and that's it. So then you have got to look at other solutions".

I thanked the professor for taking the time to participate in the interview.