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HUMAN SCIENCES RESEARCH COUNCIL

REQUIRED PHYSICAL INFRASTRUCTURE TO ATTAIN THE VISION OF THE NSI: SECONDARY SCHOOL EDUCATION COMPONENT

"Hands on and Minds On"

Study commissioned by the National Advisory Council for Innovation

Vijay Reddy with Neloufar Khan

November 2006

CONTENTS

EXECUTIVE SUMMARY

Mathematics and science are key areas of knowledge and competence for the development of an individual and the social and economic development of South Africa in a globalising world. However, performance in the key areas of mathematics and science is poor by international, regional and national assessment standards. There are many reasons for poor performance in mathematics and science for the majority of schools: poverty, historical legacies. poor infrastructure, lack of qualified teachers, poor teaching and learning cultures, lack of facilities and resources for teaching. All these reasons are valid and require further investigation. **This research will focus on the facilities and resources needed for the teaching of the sciences at the senior secondary level. Providing physical science resources could be a leverage point to improve the teaching of and performance in this subject.**

The aim of this research is to,

(i) highlight international best practice of laboratory equipment and systems to support secondary school education from the perspective of entry into and optimal performance in tertiary level science and engineering courses and

(ii) provide a detailed survey of the generic items of equipment and systems available in the market together with an indication of their cost.

The scope of this research has been informed by the following:

(i) the literature review about international best practice will span the practices in both the developed and developing worlds,

(ii) as this is a limited budget project, the scope of this research proposal will be to examine the grade 10 Physical Sciences curriculum (which was implemented in 2006) and identify the resources needed for the effective teaching of the subject,

(iii) we will then identify the kinds of resources that are available in the market and their costs.

The data for this study was sought from the following sources: (i) Literature Review, (ii) Analysis of grade 10 Physical Science curricula and texts, (iii) Interviews (teachers, subject advisors, providers of equipment or services for Physical Science practical work), (iv) Visits to developers of equipment for Practical work, (v) electronic-mail and (vi) Internet Searches of equipment available and their cost for the teaching of science.

Internationally and locally there are debates about the facilities and resources needed to best promote the teaching of the sciences. Conventional wisdom has been that a laboratory, resources and equipment that constitute a laboratory are important for the effective teaching and learning of the sciences. The 'doing of science' is considered important for the teaching of sciences and the arguments for doing science relate to the development of the cognitive, affective skills domains. Recent debates indicate that this doing of science does not have to take place in a conventional laboratory. Developing countries, including South Africa, recognised that they would not be able to build a laboratory for each school and over the last thirty years there has been the development of low cost equipment which is packaged in the form of a kit and capable of enhancing concept development.

In discussing practical work and provision of resources for practical work we must remember that the teacher, the teachers subject knowledge, the number of students in a class, the teachers ability to manage practical work are all very important conditions for the effective use of resources in a classroom and school.

The South African society is characterized by high levels of poverty and vast inequalities, arising from the historical policy of apartheid. The UNDP report (2005) estimates that at least one third of the population are living on less than $2 a day. The consequence of South Africa's racial politics and poverty is that Africans are the poorest group and in African schools there are vast backlogs in the provision of basic infrastructure, learning materials and qualified teachers all of which affect science and mathematics participation and achievement. In the last ten years the government has attempted to improve the infrastructure and resources in schools previously designated for Africans but, according to President Mbeki, this is "unfolding at a much slower pace than envisaged". One quarter of schools (mostly African) do not have access to running water and about 45 per cent of schools do not have access to electricity ((Department of Education, 2001).

African schools are still located in the former areas where Africans were designated to live by the previous government and these continue as the poorest areas of the country. The state of African and ex-House of Assembly (White) schools is still different and located in areas which are socio-economically different.

In considering the resources needed for the teaching of the physical sciences we have found that the provisioning is more than the conventional laboratory and laboratory equipment. The 'doing of science' could happen using (i) Conventional Laboratories, (ii) Science Kits (Scientific Teaching Aids and Micro-Science Kits), (iii) Mobile Laboratories, (iv) Computer Software Simulations.

Science, because of the need for resources like a laboratory, is an expensive subject to teach. The South African School Register of Needs (2000)[1], indicates that of the 5513 secondary schools nationwide, one third (1869 schools) have a laboratory. There are a large number of schools without a laboratory and it would be safe to say that most schools without the laboratory are schools that were designated for African students in the apartheid state and is located in areas where the poorest groups of the population live. To improve the state of all schools in the country with a laboratory, will require a massive investment from the state.

The government has embarked on the Dinaledi initiative to improve mathematics and science education. This initiative involves targeting around 500 senior secondary schools in the country for intensive support in order to improve the quality of mathematics and science inputs leading to improved outcomes (participation and performance) from the educational system. The laboratory infrastructure audit for the Dinaledi schools reveals that 40% of these schools do not have a Physical Science laboratory, 50% do not have a Biology Laboratory and 58% do not have a General Science laboratory.

Thus a pivotal aspect for the learning of science as a basic experimental science, viz. laboratory work, and the chance to "play" with equipment, is available only in a very limited number of secondary schools, and with virtually no state support for the activity. If one looks at the huge backlogs of facilities, it is not possible in the short term to meet this backlog. This is something that many less resourced countries also face.

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[1] This information will be updated in the School Register of Needs (2006).

There is an acknowledgement of the importance of practical activities for the understanding of scientific concepts and because there is recognition that in many poorer countries and schools, it will not be possible to get a laboratory, there has been research around the development low cost equipment and kits. While the initial imperative for the development of this low cost equipment was financial, it is now found that many of the low cost equipment could be very effective for the teaching of the science concepts. Since 1976, the non-government sector (NGOs) had developed kits of science equipment to provide the resources for the teaching of the sciences. Some schools had been provided this equipment (either by private sector investment or by some provincial government departments). There is no documented evidence of how many schools have these resources, but there is anecdotal evidence that some schools buy this equipment from their own funds. In addition the anecdotal evidence suggests that teachers need support on how to use these resources and how to manage practical work in the classroom. There have also been initiatives, like the Mobile Laboratories, where individuals and private sector have worked to provide practical experiences for grade 12 students.

The key findings and recommendations from this study are:

Findings

1. South Africa's social and economic development is dependent on an educated citizenry and a skilled workforce. There is a low supply of suitably qualified mathematics and science students from the school system to enter the national science system. To improve the national system of innovation we must imprtove the quality of the schooling system as the school is the pipeline to the competitive sector.

2. There have been many initiatives (by government, NGOs, private sector and individuals) to improve mathematics and science teaching in the country. Many of these initiatives have looked at teacher development. There has been minimal research and engagements about practical work and ways to provision schools with resources and equipment to conduct practical work for science teaching. This study,

commissioned by NACI, is timely to stimulate debate about resources for science teaching and ways to resource schools.

3. Secondary schools have different levels of resources for the teaching of physical sciences. Conventional laboratories are expensive and with the levels of shortages in the country it is not possible to provide every school with a fully resourced laboratory in the short term. The international debates point to the importance of practical activities in science rather than only practical work (laboratory based).

4. South Africa, and many other developing countries, have been innovative and developed high quality equipment, packaged in a the form of a kit, for the teaching of sciences. The usage of the kits is not dependant on electricity, gas or running water hence making them suitable for diverse environments. In addition there are other less expensive ways to illustrate a concept.

5. We cannot separate provisioning of schools with science resources and equipment and from teacher development. For effective practical work and physical science investigations the teacher must be well qualified in the subject knowledge, be able to manage practical work in a reasonably sized class, be able manage equipment, ensure that there are mechanisms for the replenishment and maintenance of the resources.

6. Of the 5513 secondary schools nationwide, one third (1869 schools) have a laboratory. There are a large number of schools without a laboratory and it would be safe to say that most schools without the laboratory are schools that were designated for African students in the apartheid state and is located in areas where the poorest groups of the population live. To improve the state of all schools in the country with a laboratory, will require a massive investment from the state.

7. Since 1976, the non-government sector (NGOs) had developed kits of science equipment to provide the resources for the teaching of the sciences. Some schools had

been provided this equipment (either by private sector investment or by some provincial government departments).

8. In South Africa there is a shortage of skilled science teachers and therefore any provisioning intervention must include a mechanism for teacher development. Teachers need support on how to use these resources and how to manage practical work in the classroom. Any science provisioning initiative must include a plan for maintenance of equipment and replenishment of chemicals.

9. As indicated earlier, there is little research on this topic in South Africa. Suggested future research areas are: (i) more research on the impact of doing practical work on learning outcomes, attitudes and motivation of students; (ii) how teachers use practical work in their teaching, (iii) The SRN 2006 will provide information of infrastructure that exists (e.g. number of laboratories etc). This data should be mined to provide a more detailed picture for science teaching, (iv) We need more information about the usage patterns of resources in schools.

Recommendations

1. A science provisioning initiative must include government, NGOs, private sector and individuals (especially retired teachers). Presently, government capital expenditure budgets are directed to building schools, classrooms and capitalization of the FET colleges. With the many demands on the budget, the provision of resources for the teaching of the sciences is lower on the agenda of government. However, the private sector in South Africa has been involved and committed to education, especially science education and this could be an opportunity to harness their committment.

2. Retired teachers are looking for ways to use their science skills to plough back into the community in the proximity. The science provisioning initiative could provide an opportunity to bring back those skills to education.

3. A science provisioning initiative must build on and add value to existing initiatives. For example, link the intervention to Dinaledi schools, or locate the intervention in a node of development.

4. When considering private sector involvement in schools, before an intervention begins, schools must be operating at a certain threshold level and they must meet a minimal set of conditions. This will ensure that there is a partnership involving the school.

4. Scenarios for provisioning of resources for physical science

Scenario 1: *Providing laboratories to schools who do not have laboratories*
The perceptions of most schools are that a laboratory is the answer to effective science teaching. This, however, remains an idealistic and expensive solution. **If we consider that the approximate cost of the construction and provisioning of a laboratory is R1 million:**

- If every school in KwaZuluNatal is to have a laboratory, it means an additional 1175 laboratories needs to be built. This would cost the province R1175 million.
- If KZN Dinaledi initiative is supported, 61 laboratories need to be provided. This would cost R61 million.
- If every secondary school in the country is to have laboratory, it means an additional 3500 physical science laboratories have to be built. The cost will be R3500 million.
- If every Dinaledi school is targeted for support, 180 laboratories need to be provided. This would cost R180 million

The building of school laboratories is the responsibility of the Department of Public Works. If such an initiative is embarked upon the roll out of the initiative would be longer term. One could expect the building of 100 laboratories a year. It would be best to target the schools which have a record of good performance that is there is stable governance and a culture of teaching and learning. It would then make sense to start this initiative with in the Dinaledi schools in the first two years and using the same criteria of schools demonstrating sustained good performance of selecting those schools the building of laboratories.

Scenario 2: *Providing Science Kits to schools without laboratories*

Science kits are an economic and effective way for science teaching. As shown in the Costing and Provisioning chapter (chapter 4), **a school could be provided with a teacher demonstration table, the FET Physical Science Kit for teacher demonstration and say 6 sets of Electricity kits for group work for around R20 000.** This set of equipment would be used by the grade 10, 11 and 12 classes.

Private sector companies could select a set of schools in close proximity their business or where they draw their workforce from or within a node of development to provide the kits of equipment. In providing the kits it would be important to also include a budget provision for the school to train the teachers on how to use the kits, maintain the kits and replenish stocks of chemicals. In providing resources it is also important to have a set of pre-conditions that a school should meet before resources are committed to a school. This will ensure a greater chance of success in the utilisation of the resources.

If 3500 schools at present do not have a laboratory and the expectation is that in the next 5 years at least 500 more schools will have a laboratory, then there are still 3000 schools seemingly without resources. These schools should be targeted for the provision of kits.

The roll – out for the next 5 years is 700 schools a year. The initial cost of provision is 700 x R20 000 i.e. R14 million for the first year and an inflation linked increase for each of the subsequent five years.

There must be an additional budget to provide support to teachers to be trained on this usage of kits.

The school provisioning budget must then include a ring-fenced amount for teacher development and subsequent replenishment of stocks etc.

Scenario 3: *Providing Science Kits to Dinaledi Schools without laboratories*
The Dinaledi schools are receiving additional physical and human resources to improve participation and performance in mathematics and science among previously disadvantaged learners. **Sixty one (61) schools in KwaZuluNatal have indicated that they do not have laboratories.** Private sector could target to provide kits of equipment in these schools and thus further enhance the conditions for teaching and learning.

Scenario 4: *Providing schools with science computer simulation resources*
Computer simulations work best in an environment where there is a qualified science teacher (i.e. one having the requisite science knowledge) who could engage the students in discussions and learning. **This will involve an investment of R20 000 per school (hardware and software).** We would recommend that in following this route, teachers have to demonstrate their track record in teaching and this package be provided as an incentive.

Scenario 5: *Supporting individuals who have started local initiatives to introduce students to practical work.*
Individuals, (e.g. ex-teachers, retired subject advisors) who are interested to work with a group of schools (teachers and students) to demonstrate practical work, like in the Mobile Biology Lab should be supported. If private sector chooses to support this kind of initiative they should go into partnership with provincial departments of education.
Individuals should be encouraged to submit a business plan, which would indicate that they would provide assistance to teachers and students by bringing in the equipment to conduct practical work. They should service between 15 to 20 schools (say 400 – 600 learners), in especially areas far from big cities. In these business plans they should indicate that they would employ local matriculants as laboratory assistants. **The initial layout costs (for the vehicle and equipment) is between R150 000 to R200 000 and the running costs are R200 000 - R300 000 a year.**

5. Policy messages for the improved resourcing for Physical Sciences

Message 1

There is a silence in the discourses about educational performance about the learning of the physical sciences concepts. Science knowledge is cumulative and the learning of science concepts requires an experience base of the phenomena. In the national discussion and debates we need to shift from the broad statements about a quality education to direct statements about science knowledge and how learning can be facilitated. The *recommendation* is that the Minister, in his speeches introduces the ideas and examples of the experiences of school sciences and how this moves from the experience base to analytical knowledge base.

Message 2

We must improve participation and performance in the whole schooling system. School science is the responsibility of the Ministry of Education and the delivery of school science is responsibility of the provincial departments of education. Any initiative for the provision of resources for schools must involve a co-ordinated approach and relationship between the Department of Science and Technology and the National and Provincial Departments of Education and the Department of Public Works. It is *recommended* that the Minister of Science and Technology and Minister of Education sign a MoU for a joint project around the resourcing of schools for the teaching of the sciences.

Message 3

The learning of physical sciences requires students to experience the phenomena. This can be achieved through an experience in a laboratory or through using kits of equipment which have been packaged in a way to make certain concepts available. Most schools are either not resourced or under-resourced with science equipment. The provincial Department of Education is responsible for resourcing of schools.

Recommendation is that the Minister of Science and Technology, with the Minister of Education, initiates a meeting with provincial officials responsible for the delivery of school science, to discuss the plan for resourcing the schools. The plan for resourcing of schools must be accompanied with a plan for professional development of teachers, support for teachers doing practical work, maintenance of the equipment and setting up a system of accountability regarding the delivery of a quality education.

Message 4

There are different ways in which students could experience science – through science conducted in laboratories or using kits of equipment of accessing resources from around. The kits of equipment that are being developed in South Africa are both pedagogically and financially accessible and it is recommended that government departments consider these for the provision of experiences for learners.

Recommendation is that state departments look to placing kits of equipment on the list of requisitions from the state.

Message 5

There are massive backlogs in school resources. The provision of resources will have to be phased in. It is recommended that a strategic plan be developed for how the resources will be provided – i.e. is it Dinaledi schools first or schools linked to other initiatives? We do not recommend starting new initiatives for the driving of the resourcing for schools but rather this initiative is linked to present initiatives.

Message 6

One could construct a part of the resourcing initiative to involve the usage of retied skills. Like the DST has a programme to deploy the skills of unemployed graduates through an internship programme, it could build a register of retired and retrenched science teachers, especially those based in areas away from the main centres that could provide support to science teachers. They could be encouraged to be involved in a project like the Mobile Laboratory project. Such an initiative will require strong collaboration with the provincial ministry of education.

Message 7

The resourcing initiative could be used to stimulate private sector involvement. One could provide to potential funders a 'neat package' consisting of what resources and training they could provide to a school. The recommendation is that the Minister of Science and Technology stimulates such a discussion and 'sells' such a package to private sector.

6. Plan of action for the science provisioning initiative

1. *Laboratory provisioning plan*

Given the vast backlogs (3500 schools need laboratories) and the other school capital demands, plan should target to build 100 new laboratories a year. This will cost an additional R100 million a year (and in following years the cost are inflation linked). Given the cost, a decision has to be taken about which schools are first to be targeted. It would make sense to target the Dinaledi schools, where the school has shown a good record of passes and where there is assurance of a qualified teacher. This would probably be where there would be a higher return on the investment.

The laboratory provisioning plan will involve negotiations between the Department of Science and Technology, Department of Education, Department of Public Works with Treasury.

2. *Science Kit provisioning*

Laboratory provisioning will take a long time. Therefore there must be a *science kit provisioning strategy,* where kits of equipment are provided to schools. This initiative will involve the Department of Science and Technology, the national and provincial Department of Education and Treasury and it is an initiative that could involve a partnership between government and private sector.

The plan would be to provision 500 schools a year and given that there are 3500 schools to be provisioned, the roll-out will take 7 years.

The kit package that could be offered to schools will be a teacher demonstration table, the FET Physical Science Kit for teacher demonstration and six sets of Electricity kits for group work. This set of equipment would be used by the grade 10, 11 and 12 classes. The present cost of this kit is R20 000. In addition to the provision of the kits of equipment the strategy will include a plan for teachers to be trained on how to use of the kits of equipment and how to manage practical work in a classroom. The strategy will also include a 5 year plan for maintenance of the kits and the replenishment of chemicals and this component will involve an extra R5 000 per school.

The cost of the kit provisioning strategy is:

	Cost of Kits	Teacher support + kit maintenance	Total
Year 1	R14 million	R3.5 million	R17.5 million
Year 2	R16 million	R7million	R21 million
Year 3	R18 million	R 9 million	R 27 million
Year 3	R21 million	R12 million	R33 million
Year 4	R24 million	R16 million	R40 million
Year 5	R29 million	R20 million	R49 million

Schools would be selected by the provincial department of education on the basis of the readiness of the school to deliver a quality education.

Private sector companies could be encouraged to participate in the science kit provisioning strategy by sending them the names of schools in close proximity their business or where they draw their workforce from or within a node of development to 'adopt' that school and provide the kits of equipment.

3. *Supporting retired science professionals to start local initiatives to introduce students to practical work*

The Department of Science and Technology should spearhead an initiative to attract retired science professionals to set up a Mobile Laboratory to service between 15 to 20 schools (400-600 learners)..

The retired science professionals would be invited to a business plan, which would indicate the schools in a cluster that they would support by bringing in the equipment to conduct practical work. Initiatives proposed in areas away from big cities should be prioritised. The business plans would indicate the names of the schools in a cluster that would be supported, the plan for school visits and the plan to employ a local matriculant as laboratory assistant.

The initial layout costs (for the vehicle and equipment) is between R150000 to R200000 and the running costs are R200 000 - R300 000 a year. The Department of Science and Technology should set aside R10 million a year to co-ordinate and support this initiative. This is again an initiative that private sector could be interested in supporting. There would then be a partnership between private and the provincial departments of education.

ACRONYMS

CASME	Centre for the Advancement of Science and Mathematics Education
CASS	Continuous Assessment
DoE	Department of Education
Ex-DET	Ex Department of Education and Training (African Learners)
DST	Department of Science and Technology
EC	Eastern Cape
Ex-HoD	Ex House of Delegates (Indian Learners)
Ex-HoA	Ex House of Assembly (White Learners)
Ex-HoR	Ex House of Representatives (Coloured Learners)
FET	Further Education and Training
FS	Free State
G	Gauteng
GIS	Geographical Information Systems
HRD	Human Resource Development
HSRC	Human Sciences Research Council
IEA	International Association for the Evaluation of Educational Achievement
INSET	In-Service Education and Training
JIPSA	Joint Initiative on Priority Skills Acquisition
KZN	Kwa-Zulu Natal
L	Limpopo
LO	Learning Outcome
M	Mpumulanga
MEC	Member of the Executive Council for Education
NACI	National Advisory Council on Innovation
NC	Northern Cape
NCS	National Curriculum Statements
NGO	Non-Governmental Organization
NRF	National Research Foundation
NW	North West
OBE	Outcomes Based Education
Radmaste	Centre for Research and Development in Mathematics, Science and Technology Education
RNCS	Revised National Curriculum Statements
SA	South Africa
SAASTA	South African Agency for Science and Technology Advancement
SAASTEC	Southern African Association of Science and Technology Centres
SEP	Science Education Project
PSP	Primary Science Project
SET	Science Engineering and Technology
SRN	School Register of Needs
STA	Scientific Teaching Aids
TIMSS	Trends in International Mathematics and Science Study

UNESCO	United Nations Educational, Scientific and Cultural Organisation
VWSA	Volkswagen South Africa
WC	Western Cape

CHAPTER ONE

INTRODUCTION TO THE STUDY AND RESEARCH METHODOLOGY

INTRODUCTION

Mathematics and science are key areas of knowledge and competence for the development of an individual and the social and economic development of South Africa in a globalising world. Most South African citizens meet mathematics and science knowledge for the first and last time in the schooling system. Competency in these gateway subjects at a school level opens up opportunities for empowerment through an understanding of common technologies on which all depend and provides better access to tertiary education and higher skilled jobs and livelihoods.

However, performance in the key areas of mathematics and science is poor by international, regional and national assessment standards. The grade 12 mathematics performance is unsatisfactory and in particular, there is the concern about the small number of learners passing with higher grade mathematics. In 2002 there were 19 765 mathematics higher grade passes. Of this there were 4637 African learners who passed higher-grade mathematics (Perry and Fleisch, 2006. This number has increased to around 24 143 in 2004; 26 383 in 2005 and 25 217 in 2006. Mathematics higher grade passes indicates the pool of learners who could participate in further science and technical studies.

Analysis of matriculation participation trends shows that of the about half a million learners sitting for the matric examination, one third take physical science (around 150 000). Of those who offer physical science, one third take Physical Science at a higher grade level (50 000) and two thirds at a standard grade level (100 000). In addition to poor participation trends for Physical Science there is also poor performance in examinations of students taking physical science. Of those who sit for the Physical Science HG examination. half pass Physical Science at the higher grade level (around 25 000) and half of those who sit for the Physical Science SG examination, pass on the SG.

Performance across the educational system varies widely and performance scores of learners in schools belonging to the ex-racial groups illustrate this. The former racial departments of schools are located in communities with different socio-economic conditions. The areas where most Africans live and where most African schools are located still rank the lowest on the scale of socio-economic conditions. The lowest performance is in the African schools and this forms the majority of South African schools.

There are many reasons for poor performance in mathematics and science for the majority of schools: poverty, historical legacies, poor infrastructure, lack of qualified teachers, poor teaching and learning cultures, lack of facilities and resources for teaching. All these reasons are valid and require further investigation. **This research will focus on the facilities and resources needed for the teaching of the sciences at the senior secondary level.**

AIM, SCOPE AND DESIGN OF THIS RESEARCH

The aims of this research are to:

i. highlight international best practice in terms of laboratory equipment and systems to support secondary school education from the perspective of entry into and optimal performance in tertiary level science and engineering courses.

ii. provide a detailed survey of the generic items of equipment and systems available in the market together with an indication of their cost.

The scope of this research has been informed by the following:

i. The literature review about international best practice will span the practices in both the developed and developing worlds. The literature review will cover the debates about the activities which constitute 'doing' science, the impact of doing science on learning, the effect of different types of resources and equipment for doing science, the usage patterns relating to resources for sciences and the management of doing science in classrooms.

ii. As this is a limited budget project, the scope of this research proposal will be to examine the grade 10 Physical Sciences curriculum (which was implemented in 2006) and identify the resources needed for the effective teaching of the subject.

iii. We will then identify the kinds of resources that are available in the market place and their costs.

iv. We will use the KwaZuluNatal province to illustrate the intervention recommendations.

The design proposed for the research is:

First component is the literature review. The literature review will look at the work in the international arena - developed and developing world. In addition there have been initiatives for the introduction and promotion of practical work in South Africa and this research will be included in the review.

Second component: analysis of the grade 10 physical science curriculum to identify resources needed (equipment, teaching and learning materials).

Third component: We will start off with a web-based search of South African companies that provide resources and equipment. This would be followed by a search of companies/ organizations in South Africa that provide resources. These generic lists will then be generated. There will be a list provided for the resources needed for the teaching of grade 10 physical sciences, the organizations that could provide such equipment and the cost of the resources.

Fourth component: We will use KwaZulNatal Province as the example to illustrate how interventions can be effected to promote practical work and hence improved performance. The recommendations will be contextualized within the context of a stratified South African society.

RESEARCH METHODOLOGY

Data for this study was sought from the following sources:

- Literature Review
- Analysis of grade 10 Physical Science curricula and texts
- Interviews (teachers, subject advisors, providers of equipment or services for Physical Science practical work)
- Visits and e-mail communication to developers of equipment for physical science practical work
- Internet communication (Electronic-mail) with the owner of Experilab
- Internet Searches of equipment available and their costs.

Literature Review

The review included the literature on the following: (1) The teaching and development of science concepts in the classroom; (2) Importance of practical work in science; (3) Infrastructure available for the teaching of physical science (4) Differences in teaching science, and in particular practical work, in developed and developing countries and (5) Innovative ways to teach science in conditions of low resources.

Analysis of the Physical Science curricula and text

The Grade 10 Further Education and Training (FET) Physical Science curricula statements were reviewed. The learning areas, topic areas, time allocation and outcomes of the Grade 10 Physical Science Curriculum were noted. We also analysed the popular school science textbooks to see what textbook authors indicated as effective ways of teaching physical science.

Interviews

Interviews were conducted with: (1) Developers of the equipment used to teach Physical Science and (2) The Project leaders of the Mobile Biology and Physical Science Laboratories. Interviews were conducted on the premises of the developers. Interviews with project leaders of the Mobile Laboratories were conducted over the telephone.

Visits to premises of developers of practical work equipment

The researcher visited the premises of the developers of kits of equipment – i.e. Scientific Teaching Aids (in Pinetown, Durban) and of the Radmaste Microscience Kits (at Wits University).

Internet Search

We used the search engine Google, on World Wide Web, to access information about equipment developed in South Africa. This information included the availability and costing of the equipment.

VISION OF THE NATIONAL SYSTEM OF INNOVATION

South Africa is committed to and wants to invest in developing the National System of Innovation. The National Research and Development Strategy focuses on three core objectives:

- Enhanced innovation this refers to the process by which new products and services enter the market and the creation of new businesses is the engine of economic growth and wealth creation. Economic growth and wealth creation are based on innovation.
- SET human resources and transformation: there is a dire shortage of scientists and technically oriented people in the country. In order to ensure there are sufficient human resources in the country on a sustainable basis it is important that we increase the supply of suitably qualified graduates from the schooling system. This implies ensuring quality educational inputs and school and classroom environments that will facilitate high quality outcomes and outputs from the schooling system.
- An effective government science and technology system and infrastructure. The DST would be responsible for a regulatory framework affecting all institutions with research and development as a primary mandate.

While the focus of the National Advisory Council on Innovation (NACI) and the Department of Science and Technology (DST) is on 'big science', to ensure sustainability of the national system of innovation it is critical we look at the supply of suitably qualified science graduates from the school system. To ensure that this goal is achieved, one leverage point that could be used is the improved resources for the teaching of the physical sciences and thus improved teaching of science.

CHAPTER TWO

KEY DEBATES ABOUT PRACTICAL WORK AND THE TEACHING OF PHYSICAL SCIENCES

INTRODUCTION

This chapter will highlight the debates about the international best practices for the teaching of science practical work and the laboratory equipment and systems needed to support quality secondary school education so that more learners can achieve optimal performance in school and enter tertiary level science and engineering courses. Practical work has been applauded for its ability to enthuse, to illustrate phenomena and to enhance understanding. It has also been criticised and even condemned for its huge expense, its potential for conceptual confusion, its gender bias, and its power to encourage both teachers and pupils to behave badly (unethically) in the classroom. (Wellington, 1998: xiv). This chapter will outline the international debates, the responses by developing countries of facilitating practical work within the countries realities and looking at the history of practical work in South Africa.

INTERNATIONAL DEBATES ABOUT THE ROLE OF PRACTICAL WORK IN THE TEACHING OF PHYSICAL SCIENCE

Internationally and locally there are debates about the facilities and resources needed to best promote the teaching of the sciences. Conventional wisdom has been that a laboratory, resources and equipment that constitute a laboratory are important for the effective teaching and learning of the sciences. In other words the 'doing of science' is considered important for the teaching of sciences the question then is where does the 'doing' need to occur.

It is widely acknowledged that science operates through its processes. Therefore the teaching and learning of science needs to be characterised by focused emphasis on processes – i.e. experimentation, observations, collection of data, classification, analyses, making hypotheses, drawing inferences and arriving at conclusions. A very important mechanism by which to experience these processes is through practical work.

The 'doing of science' can take on many forms. There is the conventional experimentation (following the scientific method), investigations, fun experiments, demonstrations by the teacher to illustrate a concept. In this study we will refer to 'practical work' as the conventional laboratory based experiences and 'practical activities' as the many experiences that are used to enhance science teaching and learning.

The nature of science education and practical work has changed over time. The nature and role of science education and practical work is a function of its social, historical and technological context as well as the science and the scientific method itself. We need to look at where practical work has come from, how the laboratory has taken such a central position for the provision of high quality science teaching and the role it has in the future science education.

In the United Kingdom, Wellington (1998) demarcates the 100 year history of practical work in physical science into three phases:

- *Discovery approach phase*: this involved setting up the practical work so that students could be "a scientist for the day" and involved slogans like "I do and I understand." This approach bore many courses and curricula, most notably the Nuffield curriculum. This approach has been criticized largely for its distorted view of scientific inquiry-observations were presented as theory-free and the jump from experimental data to laws and theory was presented as an inductive process. This phase has been described as 'philosophically unsound and pedagogically unworkable."
- *Process approach phase:* Wellington (1998) describes this phase as a 'harmful period' for science education. This view of science was based on the myth that the skills and processes of science (observing, inferring, predicting etc) could be divorced from the knowledge base (i.e. laws and theories of science). Processes were dis-embedded from their context and content, learnt and taught separately, in the hope that they could be transferable to other contexts.
- *Practical work by order:* This phase is characterized by the National Curriculum legislation which decreed not only what content was to be covered in science education, but the approach to be taken in practical and investigative work. This was

criticized by teachers who were forced to implement and assess this rigid model of scientific inquiry.

While we take the incorporation of practical work and activities for the teaching and learning of science as a given, when a group of teachers[2] were asked about why practical work is done, they indicated (with surprise) the following as possible reasons (Wellington, 1998:6):

- to back up theory;
- to make theory more visual and accessible to kids:
- to give experience - seeing is believing;
- to bring science to life;
- to develop manipulative and practical skills;
- to develop an inquiring mind;
- to keep kids quiet,
- to make boring topics more fun.

In addition (Ware, 1992) notes that the rationale for school based practical work in science is to provide 'correct explanations' or a 'solid foundation'. The assumption in this view is that practical work makes it easier for students to understand and retain concepts and facts of science. Thus practical work is seen as a means to nurture 'scientific skill development', enabling the students to become 'self explainers' therefore allowing them to understand the manner in which scientific knowledge is accumulated.

The Trends in International Mathematics and Science Study (TIMSS 2003) asked 8^{th} grade students and teachers of the 8^{th} grade classes, in 50 countries, about the activities conducted in classrooms which are related to scientific investigations. The table below provides the international set of responses of students and teachers about which activities occurred in half or more of their lessons.

[2] A sample of forty-eight science graduates about to embark on a teaching career.

Table 2.1 Student and Teacher Responses to Activities Related to Scientific Investigations in classrooms in TIMSS 2003

	Student Responses(%)	Teacher Responses %)
Watching the teacher demonstrate an experiment or investigation	64	38
Designing or planning experiments or investigations	49	31
Conducting experiments or investigations	57	54
Working in small groups on experiments or investigations	59	57
Writing explanations about what was observed and why it happened	66	61
Relating what is being learned in science to our daily lives	57	76

Wellington (1998) condenses the arguments for practical work into three key areas of why practical work is conducted in schools. These categories are (1) Cognitive arguments, (2) Affective arguments and (3) Skills arguments. The core of each argument and the counter argument to them is noted:

- *Cognitive Arguments:* Here it is argued that practical work has the potential to improve students understanding of science. Practical work promotes conceptual development, hence enabling learners to 'visualise' the laws and theories of science. In addition this process of 'visualization' helps to verify or affirm theory. The counter argument is that practical work can confuse as easily as aid understanding ('I do and become confused'). It is also argued that theory is needed before the experience so that one can make sense of the experience. However there might be a good argument for doing practical work after teaching and discussing theory.
- *Affective Arguments:* Argued in this perspective is that the implementation of practical work in science education serves to motivate and excite learners hence generating interest and enthusiasm. In simple terms practical work helps to 'make it stick'. This is generally accepted as true, except that the stress and pressure around doing of the practical work could lead to some students being 'turned off' by practical work especially when something goes wrong or when they cannot see the point of doing it.
- *Skills Arguments:* The crux of this position postulates that practical work develops manipulative or manual dexterity skills. In addition, practical work promotes the

development of transferable skills, for example, observation, measurement, prediction and inference. In a broader sense, these are said to possess general application and vocational value. While there is evidence for the transfer of manipulative skills, the evidence is mixed with respect to transfer of other skills.

Recent evidence in the science education literature raises questions about what we have believed to the value of practical work. Authors like Osborne (1998), Millar (1998) all caution that the centrality of the laboratory has led to an over-emphasis on practical work and authors like Barton (1998) and Baggot (1998) argue that one needs to look at other mechanisms, like Information Technology and Multi-Media, to provide suitable experiences for learners to make sense of the science concepts. The literature also cautions about the learning expectations from doing science and that sometimes there is 'noise' in doing science and we need to carefully consider the impact of learning by doing.

PRACTICAL WORK IN SCIENCE EDUCATION IN DEVELOPING COUNTRIES

In the 1980s and 1990s, there had been research and writing, internationally, about practical work in science teaching. There were also debates about the nature, role, function and availability of practical work in developing. Since practical work (and at that time this meant laboratory work) was considered important for the learning of science, ways were sought to ensure that developing countries could also access practical work. In 1985, UNESCO published a book entitled *Low cost equipment for science and technology education*. There have been subsequent studies commissioned by the World Bank (Musar, 1993; Ware, 1992) and by the International Institute for Educational Planning (Lewin, 1992; Ross and Lewin, 1992; Calloids, Gottlemann-Duret and Lewin, 1997) around practical work for the teaching of school science.

Musar (1993) presents case studies for the development of science and low cost science equipment in Zimbabwe (ZimSci which developed science kits for primary and lower secondary education), SriLanka (MiniLabs for secondary schools), Colombia (where Multitaller at Universidad del Valle had designed science centres to provide science education for students for 10 schools) and India (where the Electronics Group at the University of Delhi developed low cost, sophisticated equipment for the higher education levels).

Ware (1992) analysing the status and issues for secondary school science in developing countries in the late 1980s and early 90s, discusses the role of laboratory work, which was still considered as an essential component of secondary school science classes. She cautions that one should not see the problems associated with implementing laboratory work to result solely from inadequate facilities. In many cases she found that "laboratories are used as regular (expensive) classrooms, equipment remains on the shelf unused to prevent breakage or broken equipment remains un-repaired, consumables are not re-supplied, and teachers are not shown how to use and repair equipment. Many of these problems are, at least partly, a consequence of teacher insecurity with the subject matter, and a failure to include adequate teacher professional development in the implementation plans". (pg. iv).

Ware (1992) makes the following recommendations with regard to laboratory instruction:

1. There is a need to redefine laboratory instruction in all countries. Given the poor utilisation of laboratory facilities and equipment in many countries, it would be a waste of money, time and effort to continue to support the construction and provision of traditional laboratory facilities without a careful review of proposed projects.
2. Laboratory instruction is an important component of science learning and should be retained in some fashion. Low cost equipment of a sufficiently high standard for use in school laboratories can be produced locally.
3. Teachers do not have the time to make simple equipment themselves and should not be expected to do so.
4. Teachers should be provided with the skills of how to maintain equipment.
5. Laboratory skills should be included in examinations as part of the continuous assessment part.

Cailloids et al (1997) concurs with Ware on the role of laboratory instruction. It would seem that the traditional laboratory based science may be 'over-engineered' to indicate the value that is placed on the thinking skills that it can promote. Notwithstanding the evidence that teaching in a conventional laboratory-based environment does not produce the expected learning gains, many schools and countries still see the provision of a school laboratory as a pre-requisite for effective learning. The power of perceptions! Active engagement with the problems of the physical world is part of everyday experience and a way for students to learn the science concepts. However this will only happen with a knowledgeable facilitator or teacher. To ensure effective science teaching and conceptual development there are many other lower cost alternatives like demonstrations, videos and simulations.

Ross and Lewin (1992) outline the development of low cost kits to teach science concepts. Although the drivers for the development of low cost equipment has been the economic constraints facing developing countries, the recent trends in curriculum development and the concerns about the pedagogical benefits of laboratory work have also prompted developers and policy-makers to look at low cost, low–noise equipment. The science kit can be categorised as low cost equipment. Science kits can contain varying amounts of material and could be produced locally or are imported. The key feature seems to be that a science kit comprises a pre-selected collection of items designed to illustrate particular scientific principles, usually linked to published curriculum material, sometimes containing tools for assembly, and generally boxed in such a way as to serve as a store cupboard for items in the classroom or home (Ross and Lewin, 1992: 14).

Both economic and educational advantages have been claimed for science kits. The danger of the science kits is that centrally produced science kits could reflect a particular image of science, that it could provide a packaged science allowing only for the demonstration of simple and idealised phenomena. Ross and Lewin note the following pedagogical reasons for promoting the use of low cost equipment:

- Provide simplified and more relevant science learning experiences;
- Promote the use of technology to improve living conditions;
- Make science education more attractive and enjoyable;
- Overcome psychological barriers to using equipment.

The additional advantages of low cost science kits are:

- Make it easier to store and order equipment;
- Support hands-on approach and child-centred teaching;
- Maximise the interaction between equipment and course;
- Overcome the lack of laboratory facilities in remote schools;
- Improve the management of science lessons;
- Ease equipment shortages caused by rapid expansion.

While there has been some literature about practical work (especially by the donor agencies) and activities in developing countries in the early 1990s, there seems to be less literature in the late 1990s and 2000s.

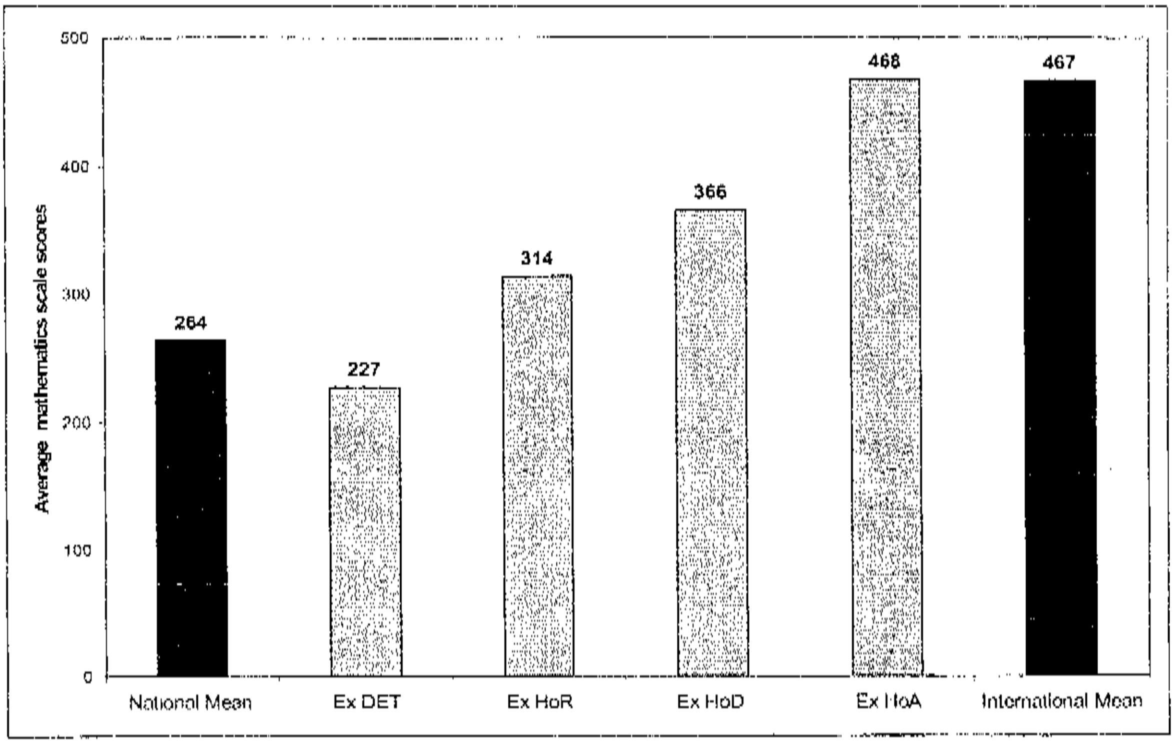
DEBATES ABOUT PRACTICAL WORK IN SOUTH AFRICAN SCHOOL SCIENCE

The South African society is characterized by high levels of poverty and vast inequalities, arising from the historical policy of apartheid. The UNDP report (2005) estimates that at least one third of the population are living on less than \$2 a day and 11.1% are living on less than \$1 a day. The consequence of South Africa's racial politics and poverty is that Africans are the poorest group and in African schools there are vast backlogs in the provision of basic infrastructure, learning materials and qualified teachers all of which affect science and mathematics participation and achievement.

In the last ten years the government has attempted to improve the infrastructure and resources in schools previously designated for Africans but this is "unfolding at a much slower pace than envisaged" (Mbeki 2005). One quarter of schools (mostly African) do not have access to running water and about 45 per cent of schools do not have access to electricity ((Department of Education, 2001). African schools are still located in the former areas where Africans were designated to live by the previous government and these continue as the poorest areas of the country. The state of African and ex-HoA schools is still different and located in areas which are socio-economically different.

Performance is differentiated by the previous department of education that a school belonged to. Under apartheid, education was administered separately and unequally to the different racial groups. It is important to include an analysis of performance of learners in schools categorized by ex-racial departments of education. This categorisation gives an indication of performance of schools operating within different conditions (like infrastructure, management and governance, educational culture, resource base and socio-economic status of learners). African schools are located in areas where most Africans live and this is characterized by high levels of poverty and unemployment. Ex-House of Assembly schools are located in areas where, previously, White households were located and these areas are, generally, in better socio-economic conditions. South Africa participated in TIMSS 2003 and came last of 50 countries. The disaggregated scores of learners in schools, categorized by ex-racial departments in TIMSS 2003 are provided in Figure 1, and gives an indication of disparities of performance. There are big differences in the average scores of learners who attend the different school types.

Figure 1: Average TIMSS 2003 mathematics scale scores of learners from the different school types



South Africa has an overall poor performance in mathematics and science achievement and the achievement scores in different school type are reflective of the inequalities in the country. The government, parents, communities, private sector and other actors face tremendous challenges in trying to improve the quality of education.

Within this environment then, let us look at practical work and practical activities in the teaching and learning of physical science. The South African debates about the place of practical work and investigations in the physical science classroom partly mirror the phases that occurred in Britain. In the last decade there has been large scale and radical curriculum reform in South Africa. In the old curriculum (NATED 550) all learners took general science and mathematics up to the end of grade 9 year. In grade 10, learners could choose to enroll for mathematics, physical science or biology. This curriculum was content driven and the content to be taught was specified for teachers.

The NATED 550, Physical Science Curriculum (adopted pre-1994) acknowledges the importance of practical work. The purpose of the practical work was seen as *'being a* *scientist for a day'*. In the ex-House of Assembly (for White learners) and the ex-House of Delegates (for Indian learners) schools practical work was taken seriously because it was assessed and the assessment mark contributed to the final examination mark. These schools were equipped with laboratories and generally, a well qualified teaching corp. Practical work was not assessed in the ex Department if Education and Training (for African learners) and ex House of Representatives (for Coloured learners) schools. These schools generally did not have laboratories or equipment for the teaching of science.

A new curriculum was prepared for the country and in 1998, C2005. based on an outcomes based education (OBE) philosophy was introduced to schools. The new curriculum meant a shift to a learner centred approach to teaching . The new curriculum was criticized for the under-specification of content and lack of structured resourced materials for teachers since they departed from the traditional content-based approach. In addition there was an over-emphasis on the *processes* involved in science and mathematics and an under-emphasis on basic knowledge and skills.

In 2000 the Minister of Education set up a Review Committee to consider the feasibility of implementing C2005. The Review Committee recommended a revision of Curriculum 2005. This led to a process of streamlining and strengthening the curriculum and in 2002, the Revised National Curriculum Statements (RNCS) were produced. The RNCS (2002) provided greater structure for teachers to organize their classroom activities.

The National Curriculum Statements for the Further Education and Training (FET) phase was implemented at the grade 10 level in 2006. This new curriculum will be implemented in grade 11 in 2007 and grade 12 in 2008. One of the learning outcomes for the subject, Physical Sciences, in the FET phase is "scientific inquiry and problem solving in a variety of scientific, technological, socio-economic and environmental contexts." The assessment standards for this learning outcome includes, conducting an investigation, interpreting data to draw conclusions and solving problems. The practical activities are embedded in the process of teaching science. An analysis of the textbooks, based on the new curriculum, reveals that the authors have provided many examples of practical activities which the teacher can easily organise and learners can do. We need further investigations about the kinds of practical activities that teachers undertake in their classrooms.

In South Africa in the last thirty years, because of the recognition that good performance in science is important for the development of the country there have been many non governmental organization (NGO) initiatives which had highlighted 'practical work and experimentation.' Post 1976, private sector increased its involvement in education through non-governmental organizations, and supported NGOs like the Science Education Project (SEP), Primary Science Programme (PSP) and CASME who all offered INSET programmes which promoted the 'doing of science' as a way of improving the teaching and learning of science. Each of these projects then developed innovative and accessible equipment to illustrate the science concepts. SEP, working with the then Scientific Teaching Aids, developed the first kits of equipment for science teaching in South Africa. These kits were developed for teaching science at the grade 8 to 10 level. The PSP worked with STA to develop kits for the grade 5 to 7 level and CASME worked with teachers at the grade 10-12 level. The Radmaste Centre at Wits University has developed micro chemistry and micro-science kits for the teaching of sciences.

In each of these projects the NGO work involved development of low cost equipment, working in schools on an intervention programme which involved teacher development. In addition to the provision of equipment there were teacher development workshops on how to use the equipment, how to integrate practical activities into class teaching, how to manage practical work in a classroom, how to maintain the equipment and how to ensure the replenishment of the stocks.

An International Panel appointed by Department of Science and Technology, National Research Foundation, South African Institute of Physics, in their report *Shaping the Future of Physics in South Africa* (2004) commented

> As far as the Panel could ascertain, most schools do not have physics (or science) laboratories. Some schools do have items of equipment, but there is no state funding to provide for maintenance or purchase of equipment. A few isolated schools still have state-funded posts of laboratory assistant, but it appears that they are being phased out. And there does not appear to be any formal training course available to produce qualified school laboratory assistants for the future.

In the late 80s and early 90s there had been vibrant discussion and debate about practical work and practical activities for the teaching of school sciences. Presently, with the many other demands of the state and the departments of education, there is a silence around these issues. This discussion needs to be again brought to the fore if we are discussing the concerns about mathematics and science performance. This report and the discussion that ensues could contribute to strategies of how to improve the quality of science teaching and hence the outcomes of science teaching. In the recent years there have been small scale studies conducted by Masters and doctoral students on implementing practical work in schools, but there have been no national initiatives around practical work in the country.

CONCLUDING COMMENTS

It is acknowledged that practical work and activities have moved on from a 'hands on' approach to a 'minds on' approach. Internationally there are concerns raised about what happens in laboratories and the learning gains from laboratory experiences. However the perceptions, from places that do not have the facility, is that good science teaching requires a laboratory.

We need to couch the discussion about practical activities rather than practical work. The discussion about the practical work and practical activities, needs to be understood within the context of teacher knowledge and competencies – i.e. we need link infrastructure development with human resource development.

CHAPTER THREE
THE PHYSICAL SCIENCES CURRICULUM

INTRODUCTION

In the new school curriculum, up to Grade 9 (end of General Education and Training Phase) natural science is a mandatory subject for all learners. At the beginning of Grade 10, learners can make a choice of the selection of subjects for the subsequent three years of schooling.

The challenges to attain the vision of the national system of innovation are massive and the analysis and provision of the physical infrastructure must be seen within the context of the national participation and performance challenges. In this chapter we will outline the requirements of the new national curriculum for the FET phase and in particular outline the content basis of the Physical Sciences curriculum.

THE FURTHER EDUCATION AND TRAINING (GRADE 10-12) CURRICULUM

In 1997 the country introduced a new curriculum, underpinned by a philosophy of an outcomes based education. The NCS were first developed for the General Education and Training phase. From 2006, new national curriculum statements were introduced for the FET phase. The FET curriculum is designed to shift away from the traditional pedagogical divide between academic and applied learning, theory and practice and knowledge and skills. The new curriculum plans to move towards a more balanced learning experience that makes provision for flexible access to life long learning, higher education and training and productive employment in myriad occupational contexts.

The NCS for the FET phase offers 29 subjects. These are:

- 11 official languages of which there has to be a First Additional Language and a Second Additional Language
- Mathematics; Mathematical Literacy; Physical Sciences; Life Sciences
- Computer Applications Technology; Information Technology
- Accounting; Business Studies; Economics
- Geography; History; Life Orientation; Religious Studies
- Consumer Studies; Hospitality Studies; Tourism

- Dramatic Arts; Dance Studies; Design; Music; Visual Arts
- Agricultural Sciences

Of these subjects the following are compulsory:

- 2 Languages: First and Second languages
- Mathematics or Mathematics Literacy
- Life Orientation

A learner then chooses at least three other subjects from the above list.

THE PHYSICAL SCIENCES CURRICULUM

The subject Physical Sciences focuses on investigating physical and chemical phenomena through scientific inquiry. By applying scientific models, theories and laws it seeks to explain and predict events in our physical environment. This subject also deals with society's desire to understand how the physical environment works, how to benefit from it and how to care for it responsibly. The subject develops competencies in the following three focus areas:

- Scientific inquiry and problem solving in a variety of scientific, technological, socio-economic and environmental contexts;
- The construction and application of scientific and technological knowledge; and
- The nature of science and its relationship to technology, society and the environment.

The study of Physical Sciences aims to contribute to the holistic development of learners in the following ways:

- Giving learners the ability to work in scientific ways or to apply scientific principles which have proved effective in understanding and dealing with the natural and physical world in which they live;
- Stimulating their curiosity, deepening their interest in the natural and physical world in which they live;
- Developing insights and respect for different scientific perspectives and a sensitivity to cultural beliefs, prejudices and practices in society;

- Developing useful skills and attitudes that will prepare learners for various situations in life (e.g. self-employment and entrepreneurial ventures);
- Enhancing understanding that technological applications of the Physical Sciences should be used responsibly towards social, human, environmental and economic development in South Africa.

In addition to stipulating the outcomes that have to be achieved, The NCS provides the Assessment Standard for each of the Learning Outcomes of Physical Sciences.

Table 1: Learning Outcomes of Physical Science

Learning Outcome (LO)	Assessment Standard
LO 1: Scientific inquiry and problem-solving skills The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.	**Conducting an investigation** Plan and conduct a scientific investigation to collect data systematically with regard to the accuracy, reliability and the need to control one variable. **Interpreting data to draw conclusions** Seek patterns and trends in the information collected and link it to existing scientific knowledge to help draw conclusions. **Solving problems** Apply given steps in a problem-solving strategy to solve standard exercises.
LO 2: Constructing and applying scientific knowledge The learner is able to state, explain, interpret and evaluate, scientific and technological knowledge and can apply it in everyday contexts	**Recalling, stating and discussing prescribed concepts** Recall and state basic prescribed scientific knowledge. **Explaining relationships** Express and explain prescribed scientific theories and models by indicating some of the relationship of different facts and concepts with each other. **Applying scientific knowledge** Apply scientific knowledge in familiar, simple contexts.
LO 3: The nature of science and its relationships to technology, society and the environment The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the	**Evaluating knowledge claims** Discuss knowledge claims by indicating the link between indigenous knowledge systems and scientific knowledge. **Evaluation the impact of science on human development** Describe the interrelationship and impact of science and technology on socio-economic and human

quality of socio-economic, environmental and human development.	development. **Evaluating the impact of science on the environment and sustainable development** Discuss the impact of scientific and technological knowledge on sustainable local development of resources and on the immediate environment.

It is clear from the expected Assessment standards that there is an expectation of learners, in the grade 10-12 phase, to undertake practical work and investigations.

THE GRADE 10 PHYSICAL SCIENCES CURRICULUM

The core learning areas of the physical science curriculum has the following foci: two modules with a chemistry focus; three modules with a physics focus and one module with an integrated focus.

The table below provides information of the topics covered in the Grade 10 physical sciences curriculum by knowledge area, type and percentage time allocation.

Table 2: The Physical Sciences Curriculum by Knowledge Area, Type and Time Allocation

Knowledge Area	Type	Time allocation (%)
Matter and Materials	Integrated	25.00
Systems	Chemistry	18.75
Change	Chemistry	18.75
Mechanics	Physics	12.50
Waves, Sound and Light	Physics	12.50
Electricity and Magnetism	Physics	12.50

PHYSICAL SCIENCES LEARNING MATERIALS

Analysis of a range of physical science textbooks for students and teacher guides reveal that the textbooks are written in a way to incorporate practical work and investigations. The authors provide students and teachers with examples of both simple investigations with everyday/ easily accessible apparatus and investigations involving specialized physical science equipment. Performing the experiments and conducting the investigations is dependent on the teachers' familiarity of subject matter knowledge and ability to manage practical work in the classroom. Thus learning material for conducting practical work exists.

A TEACHER'S INCORPORATION OF PRACTICAL WORK INTO PHYSICAL SCIENCES TEACHING

Given the above knowledge, assessment standards and practical work expectations of the curriculum, the following table indicates the interpretation by one teacher of how practical work is conducted to achieve the outcomes of the curriculum. The teacher teaches in a semi-rural, church run school. There are no laboratory facilities at the school. The teacher is qualified in physical sciences and is very innovative[3] about the use of practical activities for her teaching. She has teaching kits, micro-science kits, science computer simulations and has bought easily accessible equipment. She incorporates this into her teaching repertoire.

[3] At the moment she is studying for a PhD on practical work.

Table 3: Example of Physical Science Practical Activities by Knowledge Area, for one teacher

Section	Practical work	Apparatus
Motion Gravity Energy	Learners tabulated data from computer simulated experiments and analyzed the data by critically evaluating logic statements about the data aimed at making learners formulate generalizing statements about the relationships between various concepts	Crocodile Clips: Physics Using frames from simulations, frozen and printed out.
Waves	Teacher demonstration using: (i) Computer Simulations (mainly), (ii) slinky springs, (iii) STA Light Kit, (iv) Optic Fibre Ornament Learners guided to make and explain observations	Crocodile Clips: Physics Laptop, Data Projector Slinky Springs, STA Light Kit, Optic Fibre 'Ornament'
Chemistry (Introduction)	Teacher demonstration of various chemicals: (i) Elements, (ii) compounds, (iii) mixtures	Various Chemicals and glassware, spirit burner etc.
	Some fun reactions to capture interest and introduce some commonly met chemicals	Especially S, Fe, Fe + S, FeS (for making classification clear).
	Learner 'investigations': 'What's in the box?': (Introduction to the Atom)	Fun reactive elements/ compounds e.g. Mg+HCl, $Na+H_2O$, $Fe+O_2$, $Mg+O_2$, $S+O_2$
	Teacher Demonstration: How small? (Introduction to the Atom and Molecules) $KMnO_4 + H_2O$	$KMnO_4$, Beakers, Water
	Learner Demonstration: Can you divide? Electrolysis of water	Micro-Chem Kit for Water Electrolysis : Combo Plate, NaOH, water, cell, straw, 2 paperclips, wire.

Electrostatics	Learners charge their rulers and pick up pieces of paper Teacher Demo: Use Sellotape to demonstrate need for 2 types of charge Use Balloons to demonstrate attraction, repulsion, polarization Learners use charged capacitors to classify substances according to electrical conductance	Rulers, Paper, Sellotape, Balloons, String, Water and + & - Rods (from STA batteries, capacitors, various materials)
Circuits	Teacher demo: Effect of Potential Difference (PD) increase on Current Strength (I). Learner investigation: (Groups of 4) Effect of Resistance (R) on Current (I) Effect of Resistance Ratios on PD ratios across resistors	Home made circuit boards (made from chip board, screws and washers) Resistors, Screwdrivers Wire, Cells, Multimeters Electronics kits from A1 radio
Magnetism	Learner Investigation: (groups of 4) Demonstrate truth of various premises in an argument which learners are required to complete; include making a simple compass.	Magnets, pins, iron filings, plotting compasses, needle, wire, nail, cell, leaf, water puddle, and bowl.
Motion	Learner data collection and representation (Groups of 4): Calibrate bag-with-hole-in as a 'ticker timer' Move in manner assigned to group while holding dripping bag (Acceleration positive/ negative/ constant high velocity/ constant low velocity) Tabulate and graph data [displacement (s)-time (t)] Pool data from all groups and generalize about s-t graphs for various types of motion.	Plastic bags, water, Stop watches, Measuring tapes

CHAPTER FOUR

PROVISIONING AND COSTING OF PHYSICAL RESOURCES FOR PHYSICAL SCIENCE

One of the aims of this research is to "provide a detailed survey of the generic items of equipment and systems available in the market together with an indication of their cost" (Terms of Reference). As we have indicated in chapter Two (*Key Debates about Practical Work and the Teaching of Physical Sciences)*, in view of the socio-economic conditions, apartheid history and stratified South African society and the debates about the value of practical work for motivation, interest and learning, we would like to discuss the provisioning as more than the conventional laboratory and laboratory equipment.

In this chapter we will discuss the physical resources needed and available for conducting practical work and activities as follows:

1. Conventional Laboratories;
2. Science Kits (Scientific Teaching Aids and Micro-Science Kits)
3. Mobile Laboratories
4. Computer Software Simulations
5. Equipment for Fun Science

1. CONVENTIONAL LABORATORIES

For many teachers and students, the idea of teaching of the sciences involves stepping into a well equipped laboratory that is generously stocked with the necessary apparatus, tools and chemicals and having a laboratory assistant. That is the situation in many resourced countries and some of the well resourced schools in South Africa. In most developing regions of the world, much like South Africa, this is not possible.

Science, because of the need for resources like a laboratory, is an expensive subject to teach. In more resourced countries the availability of facilities and resources is less of a problem than in less resourced countries. In trying to determine the needs in South Africa with respect to laboratory infrastructure, let's look at the school audits (e.g. school Register of Needs) that were conducted about infrastructure.

Table 4.1 Schools with physical science laboratories in 2000 (SRN 2000)

	Schools with laboratory		Schools without laboratory		No response		Total
Province	Number	%	Number	%	Number	%	
EC	208	23.6	101	11.5	571	64.9	880
FS	176	66.7	13	4.9	75	28.4	264
GP	431	83.2	13	2.5	74	14.3	518
KZN	359	24.8	186	12.8	904	62.4	1449
MP	112	34.1	6	1.8	210	64.0	328
NC	44	66.7	6	9.1	16	24.2	66
NP	209	15.0	287	20.6	896	64.4	1392
NW	168	54.4	40	12.9	101	32.7	309
WC	160	52.1	10	3.3	137	44.6	307
National	**1867**	**33.9**	**662**	**12.0**	**2984**	**54.1**	**5513**

The caution with respect to reading the audit is that there was a great deal of missing data in the survey[4]. However it would be safe to say that, of the 5513 secondary schools nationwide, one third (1869 schools) did have a laboratory. The physical science infrastructure is different in the different provinces: in the Northern Province, only 15% of the schools indicated that they had a physical science laboratory, a quarter of KwaZuluNatal and Eastern Cape schools and one third of Mpumulanga schools indicated that they had laboratories. There are a large number of schools without a laboratory and it would be safe to say that most schools without the laboratory are schools that were designated for African students in the apartheid state and is located in areas where the poorest groups of the population live. To improve the state of all schools in the country by providing a laboratory, will require a massive financial investment from the state.

It is not possible to improve the school infrastructure with the provision of a laboratory, ensure human resource provision with a qualified teacher and ensure a culture of teaching and learning in every school immediately. Therefore there is a need for targetted interventions. In South Africa, the government has embarked on the Dinaledi initiative to improve mathematics and science education. This initiative involves targeting around 500 senior secondary schools in the country for intensive support in order to improve the quality of mathematics and science inputs leading to improved outcomes (participation

[4] A more comprehensive audit of schools is presently being conducted and it is expected that the report will be published mid 2007.

and performance) from the educational system. A laboratory infrastructure audit for the Dinaledi schools is noted in the table below.

Table 4.2: Laboratory Availability in Dinaledi Schools

Province	Number of Schools	No Biology Labs	No General Science Labs	No Physical Science labs
EC	53	36	33	31
FS	25	17	10	12
GP	79	29	36	23
KZN	113	70	81	52
LIM	47	30	34	32
MPU	31	13	20	10
NC	10	1	5	0
NW	35	16	21	14
WC	40	5	13	6
TOTAL	**433**	**217**	**253**	**180**

Again, we see that in the schools that have been targeted for interventions to improve the performance in mathematics and science at the senior secondary level, there is a shortage of laboratories. A pivotal aspect for the learning of science as a basic experimental science, viz. laboratory work, and the chance to "play" with equipment, is available only in a very limited number of secondary schools, and with virtually no new state support for the activity. If one looks at the huge backlogs of facilities, it is not possible in the short term to meet this backlog. This is something that many less resourced countries also face.

Cost of Laboratories

Whilst there is no information about the exact amount of money required to build up a new laboratory in a school, the average suggested cost is around R500 000. Generally, if a school wants to build a laboratory this will be seen as part of a package – i.e. a biology and physical science laboratory in an administration block. The initial infrastructure costs are high and the laboratory would need equipment and chemicals. This is an expensive route - one that many schools in the country may not be able to take.

2. SCIENCE KITS

As indicated in the literature review, there is an acknowledgement of the importance of practical investigations for the understanding of scientific concepts and because there is recognition that in many poorer countries and schools, it will not be possible to provide a laboratory, there has been research around the development low cost equipment and kits. While the initial imperative for the development of this low cost equipment was financial, it is now found that many of the low cost equipment could be very effective for the teaching of the science concepts. In this section we will discuss the kits made by Scientific Teaching Aids and distributed by EduTrade and the Microscience Kits which had been developed by the Radmaste Centre at Wits and now distributed by Somerset Educational Equipment.

Science kits can be a cost effective, affordable and effective means for providing a 'hands on' experience for students for practical work in physical science. In addition, the science kits could also function to overcome the psychological barriers teachers may have in the use of science equipment.

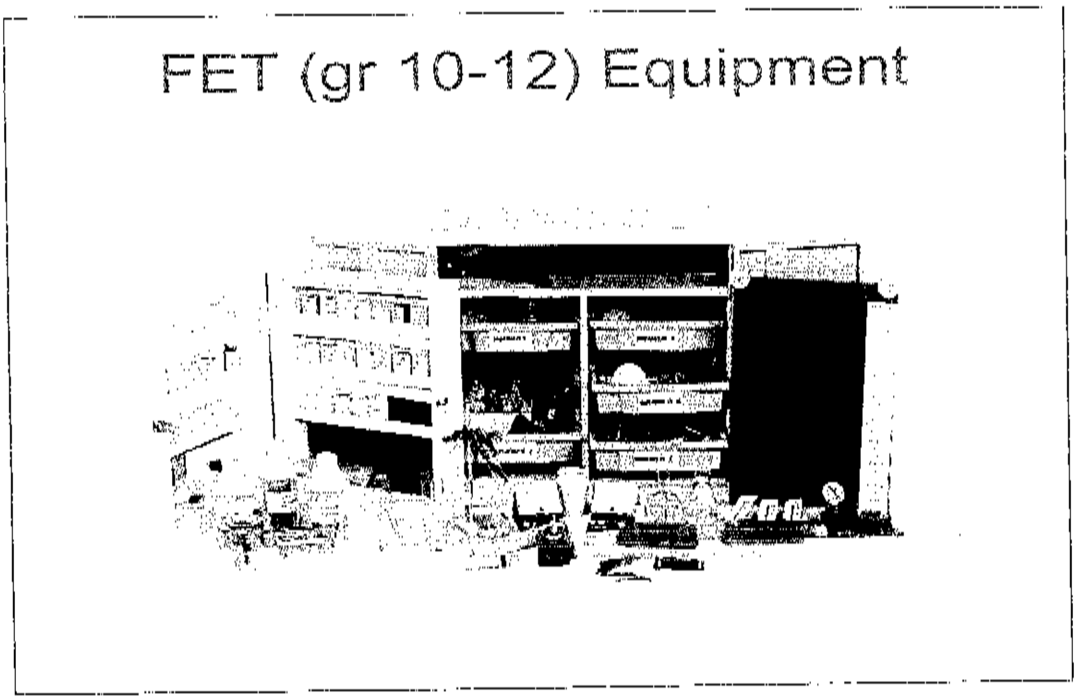
2.1. Kits from Scientific Teaching Aids (STA)

STA began manufacturing low cost equipment, packaged as a kit in the 1970s. These kits were developed in partnership with science NGOs who sought ways to improve the educational quality in black, and especially African, schools. STA has expanded into a much bigger business and develops kits of equipment for physical sciences and biology and for the different phases of the schooling system. The usage of the kits is not dependant on electricity, gas or running water hence making them ideal for rural, farm and the formerly disadvantaged classrooms and schools

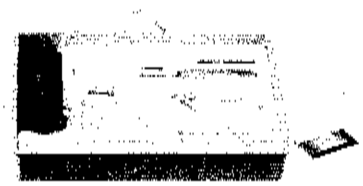
One of the kits developed by STA is the Physical Science Kit for the FET phase (Grades 10-12). The kit is contained in a lockable metal cabinet with topic trays that include:

i. Mechanics Kit
ii. Waves, Sound and Light Kit
iii. Magnetism and Electromagnetism Kit
iv. Electricity Kit and
v. Chemistry Kit.

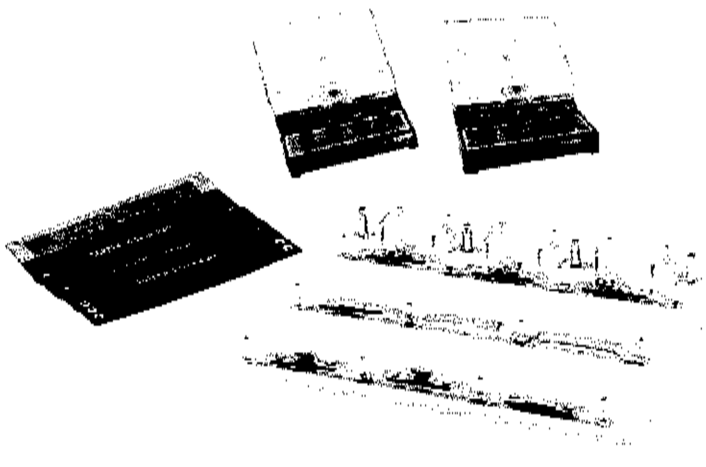
In addition, the kit includes all Grade 10-12 chemistry apparatus (beakers, pipettes etc). To aid effective teaching and demonstration the kit includes a set of worksheets that offers guidance to the teacher and student. Appendix 1 provides the list of contents of the kit. The FET kit is designed for teacher demonstration and has one set of all the equipment and chemicals needed. A school may purchase the FET Physical Science Kit and sets of extra, say, Light or Electricity Kits for group work. Recognising that many schools do not have the appropriate spaces for conducting practical work, STA has also developed Teacher Demonstration Tables. The following set of pictures illustrates the Teacher Demonstration Kit, the component kits and the Teacher Demonstration Table.



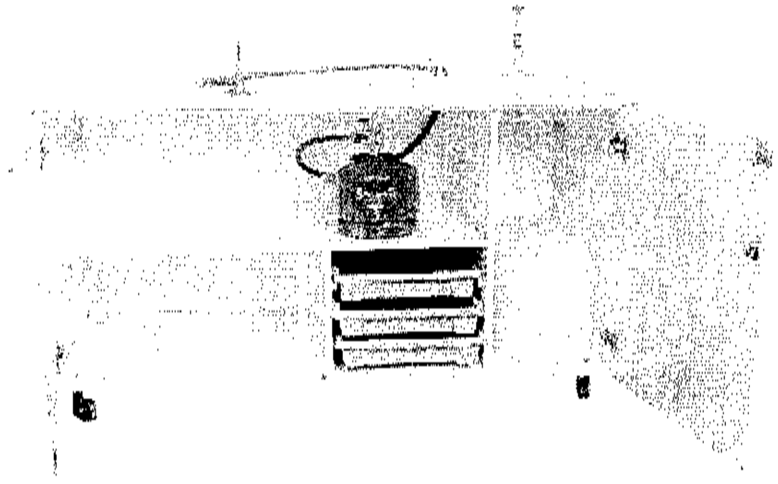
Light kit



Electricity kits



STA/ Edutrade
Teacher demonstration table



Cost of provision of FET / STA kits to a school

If a school did not have any equipment for the teaching of senior secondary science they could start off with the following basic sets of equipment.

FET (gr 10-12) Science Kit (Teacher Demonstration)	R10 500
Teacher Demonstration Table	4 400
Light Kit (which could be used for group work) each	900
Electricity Kit (could be used for group work) each	500

2.2. MicroScience Kits

The initial development of the microscience approach focused on the needs of secondary school science, with a particular emphasis on chemistry. This development arose because chemicals that were used in laboratories were not only expensive, but was hazardous and polluting. According to UNESCO (2004) "providing practical experience in chemistry is a priority, but because chemicals are consumables, giving rise to high running cost and significant hazard and environmental impact, if used on the traditional scale. Thus by reducing the amount of chemicals used in experimentation, the micro-science kit also did away with the limitations associated with chemical use in the classroom. In addition to this benefit, there was no further need for expensive glass apparatus (beakers, glass, pipettes) as the kits make provision for items for manipulation. Furthermore there was a need to contribute to life skills development for all future citizens, as regards 'chemical literacy'". As noted by UNESCO (2004) this challenge has been met successfully. In doing so, the programme was able to stimulate interest in its application at other educational levels and other sciences.

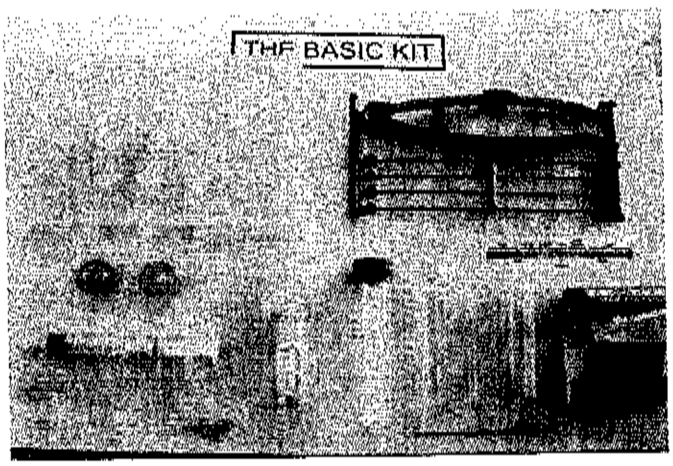
The chemistry micro-kits, developed by Radmaste, are manufactured by a South African company, Somerset Educational were tested in a variety of South African schools. Encouraged by the overwhelming response, RADMASTE, went on to develop kits for primary schools, and advanced kits for secondary schools and first year tertiary chemistry. The usage of the kits is not dependant on electricity, gas or running water hence making them ideal for the conditions in rural, farm and the formerly disadvantaged schools.

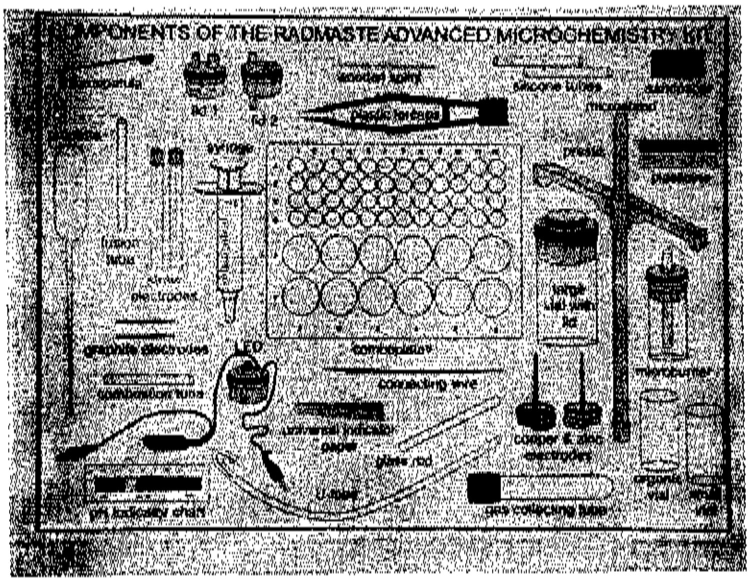
The Radmaste/ Somerset Micro-science Initiative have developed the following microscience kits for physics and chemistry:

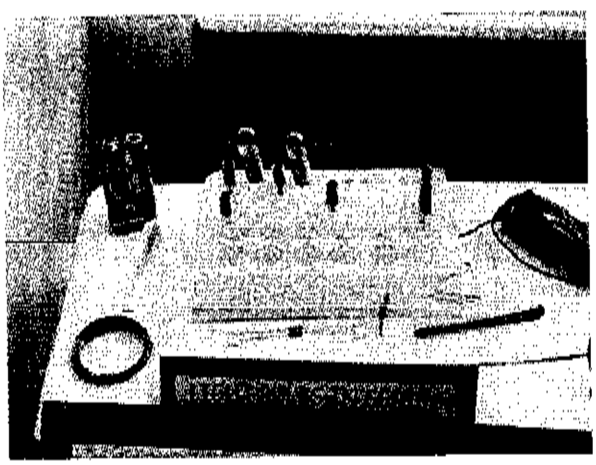
- Micro- Electricity and Magnetism Kit
- Micro-electricity Teacher Resource Guide ((Includes 4 Multimeters)
- Forces, Motion and Dynamics Kit and Manual ((Teacher Demo)
- Waves, Light, Sound and Optics Kit and Manual (Teacher Demo)
- Basic Microchemistry Kit
- Advanced Microchemistry Kit
- Chemistry Microburette Kit
- Organic Microchemistry Kit
- Combo Still Distillation Apparatus
- RADMASTE Advanced Microchemistry Teacher Resource Kit

Appendix 2 provides the complete list of micro-science equipment and Printed Resources for Physics and Chemistry and the prices of these. The pictures below are illustrations of the micro- science kits.

Radmaste/ Somerset microscience




…PONENTS OF THE RADMASTE ADVANCED MICROCHEMISTRY KIT
syringe
LED
glass rod
U-tube
gas collecting tube
copper & zinc electrodes



Cost of provisioning a school with microscience equipment and materials

Advanced microchemistry kit	R132
▪ For class of 10 groups	R1320
Micro-electricity and magnetism	R154
▪ For a class (10 groups)	R1540
Set of micro-chemicals (grade 10)	R825
Teacher guides	R330

3. MOBILE SCIENCE LABORATORIES

In our Internet searches about the provisioning of practical work for secondary schools students we came across the initiatives by individuals who provided practical experiences through a 'mobile laboratory' for grade 12 students. This initiative began when an individual, concerned that schools were not doing practical work with the students (either because the school did not have the appropriate equipment and the teachers were unable to conduct and manage the practical work) came up with an idea of purchasing a set of equipment for practical work and travelling with this set of equipment to schools in the area. When these co-ordinators visit the schools they work with the school teacher to set up practical work for the students and then manage the practical work session. The intention is to give the students the practical experience and for the teacher to gain experience in conducting and managing practical work.

3.1. Mobile Biology Laboratory

An ex-Model School teacher, Rhona Duncan, initiated a Mobile Biology Laboratory project. This project is a Rhodes University Outreach Project and is in its third year of operation in Grahamstown, Eastern Cape. The project is managed by a Steering Committee, which comprises 4 members from the Education Department at Rhodes University, Rhona Duncan and an associate. All finances are handled by the Rhodes University. This project is funded by private sector.

The staff on this initiative is the co-ordinator (Rhona Duncan), a Chief Laboratory Assistant and a laboratory assistant. These positions are typically filled by local matriculants.

The Mobile Biology Laboratory consists of a customised Volkswagen mini-bus to transport equipment. The VW mini-bus was sponsored by Volkswagen SA. The project also houses equipment, specimens and chemicals necessary for the teaching of senior secondary biology.

Operation of Mobile Biology Laboratory

At the beginning of each school term, the project co-ordinator organizes a meeting with schools in the area and teachers sign up for the visits to conduct practical work. According to the co-ordinator, attendance at these meetings is excellent. Typically, when a school has signed up for the demonstration of practical work, the mobile laboratory visits the school in the afternoons and the session takes an average of about 2 hours. The equipment is brought to the school in the customized VW kombi. The practical session is set up whilst the students have a glass of juice and biscuits. In the practical session, students work in groups of five, around a table, each with their own tray of equipment. The groups are given a printed procedure sheet which is a guideline to the practical work. In this time, four demonstrators (2 Mobile Lab teachers, the class teacher and the laboratory assistant from the Mobile Lab) move around the classroom to assist the students. Once the practical is completed, each learner is supplied with a 'take-home' sheet (or notes), that is directly related to the practical which they can file and use to study from for exams. The teacher is given a set of worksheets which they can give to students, collect and mark in their own time. The equipment is packed up at the end of the practical and taken back to a storeroom on Rhodes campus where it is washed and prepared for the next day.

In addition to conducting practical work, practical exams are also conducted when requested by teachers. A school receives an average of four visits per term for three terms, covering all 22 compulsory Grade 12 practicals. The Mobile laboratory service is offered after school hours and according to the co-ordinator is very well attended. During a year, approximately 450 students have participated in the project with an average attendance rate of 92%.

The Rhodes Outreach Project documents the following benefits of the project:

- One set of equipment services 8 schools,
- Every Grade 12 student gets hands-on practical experience,

- Teachers have a standardized and meaningful set of practical marks for each student in their class which is used for CASS submission,
- Students get the opportunity to improve their group-work skills,
- Deductive skills are improved,
- Teachers are being empowered to run their own practicals,
- A culture of after hours study is being encouraged.
- All 22 compulsory practicals covered are examined in the National Biology Examination so we expect these results to improve.

3.2. Mobile Physical Science Laboratory

A retired physical science teacher, Mr. Colin van Toeran, observed the initiative of the Mobile Biology Laboratory and decided to start such an initiative for Physical Science in Eshowe[5]. The Mobile Physical Science Laboratory was born out of the need to fill the gap in the lack of adequate infrastructure for the teaching of physical science in the area. Because of difficulties in accessing finds, the project took 3 years to get of the ground, and has only been running since August 2006. The project is supported by physical science subject advisors from the KwaZuluNatal Department of Education. The project is funded largely by the Shuttleworth Foundation. Monthly reports are submitted for their evaluation of the project.

Operation of the Physical Science Laboratory Project

The project co-ordinator is Colin van Toeran, and there are two technicians/ laboratory assistants who have been trained to conduct and assist with the practical work. A bakkie is used to transport the physical science equipment from school to school. The bakkie was sponsored by the Kwa-Zulu Natal Department of Education and the Midlands Technical College. The equipment (STA kits) used was purchased from Edutrade.

As per a timetable, practicals are conducted during school hours at a time negotiated between the Mobile Physical Science Lab team and the school in question. The equipment is brought to the school. The average number of students that attend the practical session is 35. At the beginning of the practical Mr. van Toeran demonstrates the

[5] Eshowe, is in the North Coast of Kwa-Zulu Natal and forms part of the Uthungulu District. Present day Eshowe is a market town, with a 100 km radius catchment area, two shopping centers, a main bus stop serving the hinterland, a major hospital and several schools.

practical and the technicians explain the demonstration to the students in isiZulu. Teachers take over once they become familiar with the practical. During the practical session, students work in groups and are given worksheets which guide them through the practical. In this time, the technicians and teachers move around the classroom assisting students. At the end of the session, the equipment is packed back into the bakkie and taken to a storeroom where it is prepared for the next practical demonstration.

Although still in the early stages, the Mobile Physical Science laboratory services 16 schools, within a radius of approximately 80km. Each school has received three visits since the projects inception. It is proposed that these schools will be visited a total of nine times a year. However, because of demand, there are plans to increase the number of schools in the project from 16 to 28 in 2007, hence the total number of visits per year will decrease to five per school.

The co-ordinator indicates that the following are benefits of the project:

- One set of equipment services 16 schools,
- Every student gets hands-on practical experience,
- Students get the opportunity to improve their group-work skills,
- Deductive skills are improved,
- Teachers are empowered to run their own practical work session.

3.3. Costing of the mobile laboratory

Mobile Biology Lab

Start up costs

Vehicle was sponsored by VW, with an estimated cost for such a vehicle between R150000 and R200000.

Biology Equipment around R50 000

Running expenses

Salaries plus project costs R275 000

(A detailed budget is provided in Appendix 3).

Mobile Physical Science Lab

Start up costs

Bakkie	R90 000
STA Physical Science Kits	R50 000

Running annual expenses

Salaries plus project costs	R200 000

(See Appendix 4 for full budget).

4. COMPUTER SOFTWARE SIMULATIONS

The learning of physical science involves both conceptual and mathematical abstractions. To assist students to comprehend the abstract principles of physics, teachers integrate practical work or physical 'demonstrations' into classroom teaching as a way to bring visual appeal to the abstract subject matter and mathematical formulae. Feedback from students reaffirms the notion that practical demonstrations are a very popular and helpful component of many science courses (McKenzie, 2006). However, there are difficult concepts of physical science do not lend themselves easily to demonstration by physical means. Through the progression of time and technology many of these previously problematic concepts may now be represented visually through computer simulations (McKenzie, 2006).

Computer simulations typically allow the student, whatever the subject matter, to pick the initial conditions, hit a 'start' button and observes what happens. During such observations, the student is able to manipulate the objects in the simulation and view its outcome. Hence there is little space for sitting back and absorbing the visuals. Although at times such simulations are often criticized as being instructive, they could offer a critical interactive component to any physical science curriculum. This can enable students to apply themselves and to assume an active role thus engaging their minds as well.

As noted by (McKenzie, 2006) benefits of such computer simulations include the fact that they make the unobservable observable. McKenzie (2006) notes that many phenomena may exist outside the range of human senses. To combat these limitations, through simulations in curriculum areas such as Kinetic theory, students are able to see the world as it would look if human senses were able to extend beyond their limitations. In addition, a computer simulation offers the learner an opportunity to generate mental constructions of the subject at hand, to sharpen these mental images as nature itself does. Thus, in a classroom setting, computer simulations could provide an invaluable tool to the creation of such an environment for the benefit of the teacher and learner.

The use of computer simulations has been lauded by teachers who have used them. One high school science teacher[6], indicated that these software simulations allow her students to 'feel like real scientists' which generates 'healthy competition between groups and classes' (Horszowski, 2004). In addition computer simulations impacts positively on female enrolment in science. This causal effect has been demonstrated by numerous case studies (Horszowski, 2004). This may be attributed to the fact that nowadays both boys and girl are equally familiar with computers and technology. As seen such exercises achieve to elicit the much desired 'hands on' and 'minds on' approach to the teaching of science.

Examples of Computer Simulations

Crocodile Physics (Crocodile Clips - Software Express, 2004)

Crocodile Physics is a computer simulation software programme much like a well stocked physical science laboratory that allows you to experiment on any physical science subject matter. Within the software there are masses, trolleys, lenses and electronic components to assemble and experiment and take measurements with. In addition the software allows you to learn about forces, swing pendulums, change gravity and manipulate the angle of ramps. The optical tools in the software, for example, enable a learner to split light into its colours with a prism and see how fibre optics transmits. The software comes with fully prepared worksheets designed to assist with the interactive sessions.

Crocodile Chemistry (Crocodile Clips - Software Express, 2004)

Crocodile Chemistry is a computer simulation software programme designed to function as a simulated chemistry laboratory where you can model experiments and reactions

[6] Adele Botha, in Irene, Gauteng, South Africa.

safely and easily. The software allows you to drag chemicals, equipment and glassware from the toolbars from the side of the screen and combine them as you wish. The instructor or learner may choose whatever quantities and concentrations are needed, reactions are modelled as soon as the chemicals are mixed. Graphs maybe plotted to analyse data from the experiment and mechanisms can be viewed using 3D animations.

The designers of the Computer simulations indicate the following benefits of Computer Simulated Software:

- Set up a lesson in seconds with the aid of a lesson kit. The lessons in the kits are designed around the science curriculum and thus make it much easier to set up simulations.
- Simulations are suitable for presentation in front of a class using a whiteboard.
- Change settings quickly and easily. Unlike other computer simulation software, the software is not a series of limited animations, but is a full and flexible simulator hence allowing for changes made by the learner or instructor.
- Simulation of real life examples. For example, in *Crocodile Physics*, the mass or elasticity of the ball may be changed. In *Crocodile Chemistry*, the exact concentrations of a solution could be set or you could choose between using fine or coarse powder.
- Graph data in real time. In *Crocodile Physics*, with the aid of the graph tool it is possible to plot any quantity on either axis, for example voltage against current, as well as against time. In *Crocodile Chemistry*, with the graph tool, you may plot quantity on any axis, for example pH against volume.
- Let students experiment freely. Students may experiment using the simulator hence giving them a safe and easy to use virtual laboratory.

Costing of Computer Simulated Software

In a Southern African setting, for such a system to be effective it is assumed that there is access to computers and the necessary infrastructure such as electricity to support such an initiative whereas in reality it might not be so. Teachers should be computer literate to operate such computer simulations. One teacher indicated she uses the computer simulations as part of the teaching and treats it as a demonstration lesson. Thus she needs a computer, data projector and the computer software.

Computer Simulated Software

Crocodile Physics and Crocodile Chemistry[7]

Concurrent user licence (5 computers)	R3000
School Site Licence for School (< 600 students)	R8625
Annual Upgrade (<600 students)	R2025

Hardware

Computer	R8000
Data Projector	R7000

5. FUN SCIENCE

There are initiatives at public spaces, like science centres, to make science attractive and fun and is a mechanism to get kids turned on to science. These initiatives are presented here as a mechanism to be used to encourage practical work.

5.1. Science Centres

Around the world, an established network of interactive science centres has proven that these facilities encourage and strengthen the culture of science. According to Limson (2001) these science discovery centres will complement conventional teaching and learning methods as well as create interest and enthusiasm in science and technology, especially among young people.

Science Centre, in addition to being a public good space to increase science interest and awareness, has also incorporated a dimension of their work to target schools and school students. Many science centres have explicit programmes that link with the school curriculum and extend the school curriculum.

Science Centres, in keeping with the aims of promoting public understanding, appreciation and awareness of science and technology, especially among educators and students through an exciting and interactive learning environment, offer activities like:

[7] As per Software Express Inc costing, 2004. US Dollars converted to ZA Rands at the conversion rate of 1$: ZAR 7.50

- Organised educational tours to students, educators and the general public
- Provides guidance to schools of science projects as well as advice to interested organizations on managing science centres and building hands-on models
- Running science projects and workshops during school vacations
- Exciting physics and chemistry demonstrations and lectures
- Outreach programmes to ensure the enhancement of public understanding by taking science and technology to different communities through travelling exhibitions and displays, demo-lectures, science shows and workshops.

SAASTA and the Network of Science Centres, provides an umbrella body for these institutions. Appendix 4 provides the list and map of the spatial location of each science centre in South Africa. Although the location and audience may differ between each of these interactive science centers, the core function of each organization remains steadfast, that is the promotion of the understanding of science - and this can be exploited to improve the learning activities of students.

5.2. Experilab Science Shows

The Experilab Explosive Science Presentations/ Shows were started approximately 10 years ago. Over the years the shows have developed into a popular event with schools, universities and other institutions. Two years ago, Experilab expanded its horizons in Australia where the centre is pursuing the same interests and concepts. To date the show has been viewed by over 200 000 people with an average about 65 shows being done annually. The shows are not actively marketed but the interest in the shows are shared and passed on by word of mouth. Science shows are also conducted during school vacations. The duration of each show ranges from 45 to 90 minutes. The emphasis of the science shows is on exciting and fun demonstrations whilst the scientific information is not neglected, but is shared with the audience. The typical contents of a show are provided in Appendix 6.

Other than a science show, Experilab also conducts workshops titled 'Exciting Chemistry' for Grades 8-12. In addition, during National Science Week, Experilab goes on tour in the Free State. Furthermore, Experilab also conducts on average around 15 shows during Expo week for the Gauteng Department of Education. The Experilab team have also done shows sponsored by SAASTA.

Some schools have a stand-in booking and the Experilab team returns to them on a yearly basis Shows are also held at Open Days (schools and universities), shopping malls, holiday resorts, corporate functions and at science fairs. Responses and feedback from both clients and the general public affirm the positive and encouraging effect that these science shows have had on the perception and attitude towards science.

Owner of Experilab and one of the presenters of the science shows Mr Francois Germishuizen commented on the concept of the educational science shows by saying that "a science show can really spark the interest of a budding scientist whilst also creating increased awareness amongst the general. Another result is that many teachers become interested to use demonstrations in their science classes after seeing a show". Mr Germishuizen adds that "science is one subject where the use of demonstrations can really bring things alive and often this can be achieved at a small cost and effort. I believe that science shows can truly alter perceptions of people in a very positive way and that edutainment (educational entertainment) should play an increasing role in our society".

Cost of Experilab Science Shows

Due to the fact that each show is unique and different demonstrations are performed, the cost for each show will therefore differ accordingly. However, the approximate cost per show is below R400. A basic show ranges from R200 to R300 and a more sophisticated show ranges from R300 to R400.

The standard cost of a science show to a client is R2100[8]. Usually a client, for example a school, will charge a minimal entrance fee (R5-R10) to recover the cost or they have the option of allowing a student to purchase an Experilab Super Science Kit for R20 (normal retail price) as the entrance fee (minimum 500 students per show) hence there is no cost

[8] This will involve cost for an assistant which is R400 for a one and half hour show and R300 for one hour or less. In terms of travelling costs, the first 100kms are included in the show costs. Shows conducted in Pretoria and Johannesburg has no additional costs.

for the show. The cost for the public is R12. Shows take place at the Experilab's Science Auditorium

6. CONCLUDING COMMENTS

In this discussion above, we have provided a description and cost of the physical science resources. We will provide further analysis in the next chapter, on recommendations.

CHAPTER FIVE
FINDINGS and RECOMMENDATIONS

1. INTRODUCTION

The aims of this research was to highlight international best practice in terms of laboratory equipment and systems to support secondary school education from the perspective of entry into and optimal performance in tertiary level science and engineering courses, and to provide a detailed survey of the generic items of equipment and systems available in the market together with an indication of their cost.

In our scope we indicated that the literature review about international best practice will span the practices in both the developed and developing worlds. As this was a limited budget project, we decided to limit the scope of this research proposal to examine the grade 10 Physical Sciences curriculum (implemented in 2006) and identify the resources needed for the effective teaching of the subject. We will use the KwaZuluNatal province to illustrate the intervention recommendations.

2. CONTEXT FOR DEVELOPING RECOMMENDATIONS

The debates about the best practices of resources for the effective teaching of science must be located within the realities of South African society. South African children experience different conditions of schooling. There are the well resourced suburban schools located within safe and affluent neighbourhoods to schools which are in deeply, poverty embedded, rural areas with inadequate school buildings and infrastructure and low quality teaching inside. These contrasts show up, especially, in science education classrooms, because science, is both a subject demanding high levels of analytical reasoning, and is resource dependent. The cost to a nation of implementing science education improvement programmes is substantial, but less than the cost of not producing a scientifically literate society and workforce. We acknowledge that this is a high cost investment and it will not be possible to ensure a high quality science education for every school and every child immediately. However the argument presented in this report is to look for points to leverage the system in the short term and recognize that it will take a long time to achieve an equitable, quality science education for all.

Using **KwaZuluNatal** as the example to illustrate the issues for education, science teaching and practical work, let us examine the province in terms of the number of schools, poverty levels and the spatial distribution of schools.

There are 27 000 public schools in the country. In KZN there are 6000 schools (5614 public schools and 174 independent schools). Of these there are 3818 primary schools, 1470 secondary and 326 combined schools. We know from the School Register of Needs Audit, that one quarter of KwaZuluNatal, secondary schools indicated that they have laboratories. Of the 113 schools designated as Dinaledi schools, about half the schools indicated that they do not have a physical science laboratory.

Performance in the key areas of mathematics and science is poor by international, regional and national assessment standards. The results for KwaZuluNatal mirror the national results. The grade 12 national mathematics performance is unsatisfactory and in particular, there is the concern about the small number of learners passing with higher grade mathematics. (see chapter 1)

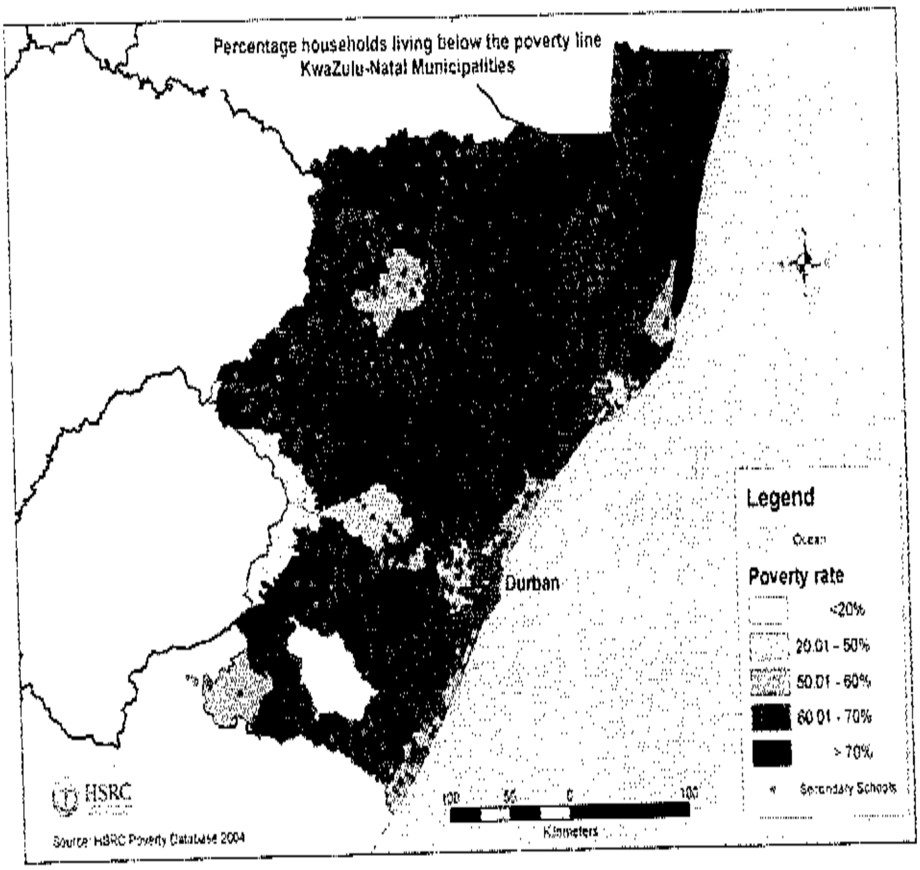
In 2006 there are 220 000 grade 10 learners in KwaZuluNatal province. Examining the subject choices made by the grade 10 learners, 55% of students enrolled for mathematics and 45% enrolled for mathematical literacy. Less than one third of students (at 29%) enrolled for Physical science. We know these numbers (and percentages) will decrease as students progress to grade 12. There are major challenges in ensuring that we have higher numbers of students with high quality passes in mathematics and science leaving the schooling system. These students will enter tertiary institutions following mathematics and science careers and form the scientific and technical workforce allowing South Africa to become a competitive nation. It is within this context that we will present the recommendations.

Another contextual factor that will inform the recommendations is the socio-economic conditions in which schools are located and the spatial distribution of schools. The picture below (Map 1: generated from the HSRC Poverty Database 2004) indicates that a vast majority of the population are living below the poverty line. The poverty line in households has been determined according to the household size[9]. The dots on the Map I

9

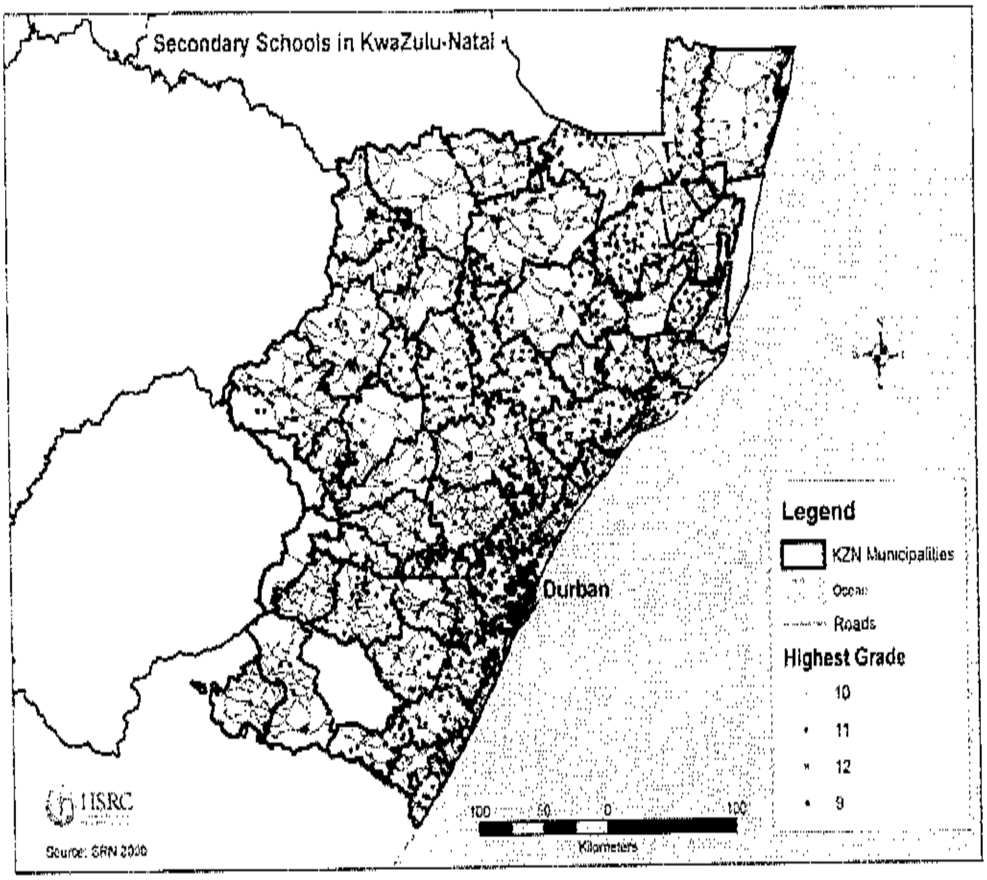
indicate where the secondary schools are located relative to the poverty conditions of the area. Map 2 indicates where secondary schools are located relative the main cities and road networks (giving an indication of access).

MAP 1: GIS PLOT OF SECONDARY SCHOOLS AND PLACES OF POVERTY



Household size	1	2	3	4	5	6	7	8
Poverty Line income	R587	R773	R1028	R1290	R1541	R1806	R2054	R2503

MAP 2: SCHOOL LOCATION RELATIVE TO THE ROAD NETWORK



3. FINDINGS AND RECOMMENDATIONS FOR INTERVENTIONS

Findings

1. South Africa's social and economic development is dependent on an educated citizenry and a skilled workforce. Enhanced innovation is the engine of economic growth and wealth creation, and this enhanced innovation is dependent on a high quality SET human resources. However, there is a low supply of suitably qualified mathematics and science students from the school system to enter the national science system. The trends, gleaned from the participation in the matriculation examinations is that about one third of students sitting for the matriculation examination enrol for physical science – of these one third (50 000) take the subject on the higher grade and two thirds (100 000) on the standard grade. To improve the national system of innovation we need to look at ways of improving the schooling system as the school is the pipeline to the competitive sector.

2. There have been many initiatives (by government, NGOs, private sector and individuals) to improve mathematics and science teaching in the country. Many of these initiatives have looked at teacher development. There has been minimal research and engagements about practical work and ways to provision schools with resources and equipment to conduct practical work for science teaching. This study, commissioned by NACI, is timely to stimulate debate about resources for science teaching and ways to resource schools.

3. Secondary schools have different levels of resources for the teaching of physical sciences. Conventional laboratories are expensive and with the levels of shortages in the country it is not possible to provide every school with a fully resourced laboratory in the short term. The international debates point to the importance of practical activities in science rather than only practical work (laboratory based).

4. South Africa, and many other developing countries, have been innovative and developed high quality equipment, packaged in a the form of a kit, for the teaching

of sciences. The usage of the kits is not dependant on electricity, gas or running water hence making them suitable for diverse environments. In addition there are other less expensive ways to illustrate a concept.

5. In reviewing the resources and equipment, for the effective teaching of the physical sciences, our main evaluation criteria is that the resources must lead to concept development, illustrates abstract concepts and have minimal 'noise and distraction' in the learning process.

6. We cannot separate provisioning of schools with science resources and equipment and from teacher development. For effective practical work and physical science investigations the teacher must be well qualified in the subject knowledge, be able to manage practical work in a reasonably sized class, be able manage equipment, ensure that there are mechanisms for the replenishment and maintenance of the resources.

7. Of the 5513 secondary schools nationwide, one third (1869 schools) have a laboratory. There are a large number of schools without a laboratory and it would be safe to say that most schools without the laboratory are schools that were designated for African students in the apartheid state and is located in areas where the poorest groups of the population live. To improve the state of all schools in the country with a laboratory, will require a massive investment from the state.

8. Since 1976, the non-government sector (NGOs) had developed kits of science equipment to provide the resources for the teaching of the sciences. Some schools had been provided this equipment (either by private sector investment or by some provincial government departments).

9. In South Africa there is a shortage of skilled science teachers and therefore any provisioning intervention must include a mechanism for teacher development.

Teachers need support on how to use these resources and how to manage practical work in the classroom. Any science provisioning initiative must include a plan for maintenance of equipment and replenishment of chemicals.

10. As indicated earlier, there is little research on this topic in South Africa. Suggested future research areas are: (i) more research on the impact of doing practical work on learning outcomes, attitudes and motivation of students; (ii) how teachers use practical work in their teaching, (iii) The SRN 2006 will provide information of infrastructure that exists (e.g. number of laboratories etc). This data should be mined to provide a more detailed picture for science teaching, (iv) We need more information about the usage patterns of resources in schools.

Recommendations

1. A science provisioning initiative must include government, NGOs, private sector and individuals (especially retired teachers). Presently, government capital expenditure budgets are directed to building schools, classrooms and capitalization of the FET colleges. With the many demands on the budget, the provision of resources for the teaching of the sciences is lower on the agenda of government. However, the private sector in South Africa has been involved and committed to education, especially science education and this could be an opportunity to harness their committment.

2. Retired teachers are looking for ways to use their science skills to plough back into the community in the proximity. The science provisioning initiative could provide an opportunity to bring back those skills to education.

3. A science provisioning initiative must build on and add value to existing initiatives. For example. link the intervention to Dinaledi schools, or locate the intervention in a node of development.

4. When considering private sector involvement in schools, before an intervention begins, schools must be operating at a certain threshold level and they must meet a minimal set of conditions. This will ensure that there is a partnership involving the school.

5. As indicated earlier, there is little research on this topic in South Africa. Suggested future research areas are: (i) more research on the impact of doing practical work on learning outcomes, attitudes and motivation of students; (ii) how teachers use practical work in their teaching, (iii) The SRN 2006 will provide information of infrastructure that exists (e.g. number of laboratories etc). This data should be mined to provide a more detailed picture for science teaching, (iv) We need more information about the usage patterns of resources in schools.

4. SCENARIOS FOR PROVISIONING OF RESOURCES FOR PHYSICAL SCIENCE

Scenario 1: *Providing laboratories to schools who do not have laboratories*

The perceptions of most schools are that a laboratory is the answer to effective science teaching. This, however, remains an idealistic and expensive solution. **If we consider that the approximate cost of the construction and provisioning of a laboratory is R1 million:**

- If every school in KwaZuluNatal is to have a laboratory, it means an additional 1175 laboratories needs to be built. This would cost the province R1175 million.
- If KZN Dinaledi initiative is supported, 61 laboratories need to be provided. This would cost R61 million.
- If every secondary school in the country is to have laboratory, it means an additional 3500 physical science laboratories have to be built. The cost will be R3500 million.
- If every Dinaledi school is targeted for support, 180 laboratories need to be provided. This would cost R180 million

The building of school laboratories is the responsibility of the Department of Public Works. If such an initiative is embarked upon the roll out of the initiative would be longer term. One could expect the building of 100 laboratories a year. It would be best to target the schools which have a record of good performance – that is there is stable governance and a culture of teaching and learning. It would then make sense to start this initiative with in the Dinaledi schools in the first two years and using the same criteria of schools demonstrating sustained good performance of selecting those schools the building of laboratories.

Scenario 2: *Providing Science Kits to schools without laboratories*

Science kits are an economic and effective way for science teaching. As shown in the Costing and Provisioning chapter (chapter 4), **a school could be provided with a teacher demonstration table, the FET Physical Science Kit for teacher demonstration and say 6 sets of Electricity kits for group work for around R20 000.** This set of equipment would be used by the grade 10, 11 and 12 classes.

Private sector companies could select a set of schools in close proximity their business or where they draw their workforce from or within a node of development to provide the kits of equipment. In providing the kits it would be important to also include a budget provision for the school to train the teachers on how to use the kits, maintain the kits and replenish stocks of chemicals. In providing resources it is also important to have a set of pre-conditions that a school should meet before resources are committed to a school. This will ensure a greater chance of success in the utilisation of the resources.

If 3500 schools at present do not have a laboratory and the expectation is that in the next 5 years at least 500 more schools will have a laboratory. then there are still 3000 schools seemingly without resources. These schools should be targeted for the provision of kits.

The roll – out for the next 5 years is 700 schools a year. The initial cost of provision is 700 x R20 000 – i.e. R14 million for the first year and an inflation linked increase for each of the subsequent five years.

There must be an additional budget to provide support to teachers to be trained on this usage of kits.

The school provisioning budget must then include a ring-fenced amount for teacher development and subsequent replenishment of stocks etc.

Scenario 3: *Providing Science Kits to Dinaledi Schools without laboratories*

The Dinaledi schools are receiving additional physical and human resources to improve participation and performance in mathematics and science among previously disadvantaged learners. **Sixty one (61) schools in KwaZuluNatal have indicated that they do not have laboratories.** Private sector could target to provide kits of equipment in these schools and thus further enhance the conditions for teaching and learning.

Scenario 4: *Providing schools with science computer simulation resources*

Computer simulations work best in an environment where there is a qualified science teacher (i.e. one having the requisite science knowledge) who could engage the students in discussions and learning. **This will involve an investment of R20 000 per school (hardware and software).** We would recommend that in following this route, teachers have to demonstrate their track record in teaching and this package be provided as an incentive.

Scenario 5: *Supporting individuals who have started local initiatives to introduce students to practical work.*

Individuals, (e.g. ex-teachers, retired subject advisors) who are interested to work with a group of schools (teachers and students) to demonstrate practical work, like in the Mobile Biology Lab should be supported. If private sector chooses to support this kind of initiative they should go into partnership with provincial departments of education.

Individuals should be encouraged to submit a business plan, which would indicate that they would provide assistance to teachers and students by bringing in the equipment to conduct practical work. They should service between 15 to 20 schools (say 400 – 600 learners), in especially areas far from big cities. In these business plans they should indicate that they would employ local matriculants as laboratory assistants. **The initial layout costs (for the vehicle and equipment) is between R150 000 to R200 000 and the running costs are R200 000 - R300 000 a year.**

5. POLICY MESSAGES FOR THE IMPROVED RESOURCING FOR PHYSICAL SCIENCES

Message 1

There is a silence in the discourses about educational performance about the learning of the physical sciences concepts. Science knowledge is cumulative and the learning of science concepts requires an experience base of the phenomena. In the national discussion and debates we need to shift from the broad statements about a quality education to direct statements about science knowledge and how learning can be facilitated. The *recommendation* is that the Minister, in his speeches introduces the ideas and examples of the experiences of school sciences and how this moves from the experience base to analytical knowledge base.

Message 2

We must improve participation and performance in the whole schooling system. School science is the responsibility of the Ministry of Education and the delivery of school science is responsibility of the provincial departments of education. Any initiative for the provision of resources for schools must involve a co-ordinated approach and relationship between the Department of Science and Technology and the National and Provincial Departments of Education and the Department of Public Works. It is *recommended* that the Minister of Science and Technology and Minister of Education sign a MoU for a joint project around the resourcing of schools for the teaching of the sciences.

Message 3

The learning of physical sciences requires students to experience the phenomena. This can be achieved through an experience in a laboratory or through using kits of equipment which have been packaged in a way to make certain concepts available. Most schools are either not resourced or under-resourced with science equipment. The provincial Department of Education is responsible for resourcing of schools.

Recommendation is that the Minister of Science and Technology, with the Minister of Education, initiates a meeting with provincial officials responsible for the delivery of school science, to discuss the plan for resourcing the schools. The plan for resourcing of schools must be accompanied with a plan for professional development of teachers, support for teachers doing practical work, maintenance of the equipment and setting up a system of accountability regarding the delivery of a quality education.

<u>Message 4</u>

There are different ways in which students could experience science – through science conducted in laboratories or using kits of equipment of accessing resources from around. The kits of equipment that are being developed in South Africa are both pedagogically and financially accessible and it is recommended that government departments consider these for the provision of experiences for learners.

Recommendation is that state departments look to placing kits of equipment on the list of requisitions from the state.

<u>Message 5</u>

There are massive backlogs in school resources. The provision of resources will have to be phased in. It is recommended that a strategic plan be developed for how the resources will be provided – i.e. is it Dinaledi schools first or schools linked to other initiatives? We do not recommend starting new initiatives for the driving of the resourcing for schools but rather this initiative is linked to present initiatives.

<u>Message 6</u>

One could construct a part of the resourcing initiative to involve the usage of retied skills. Like the DST has a programme to deploy the skills of unemployed graduates through an internship programme, it could build a register of retired and retrenched science teachers, especially those based in areas away from the main centres that could provide support to science teachers. They could be encouraged to be involved in a project like the Mobile

Laboratory project. Such an initiative will require strong collaboration with the provincial ministry of education.

Message 7

The resourcing initiative could be used to stimulate private sector involvement. One could provide to potential funders a 'neat package' consisting of what resources and training they could provide to a school. The recommendation is that the Minister of Science and Technology stimulates such a discussion and 'sells' such a package to private sector.

6. PLAN OF ACTION FOR THE SCIENCE PROVISIONING INITIATIVE

2. *Laboratory provisioning plan* given the vast backlogs (3500 schools need laboratories) and the other school capital demands, plan should target to build 100 new laboratories a year. This will cost an additional R100 million a year (and in following years the cost are inflation linked). Given the cost, a decision has to be taken about which schools are first to be targeted. It would make sense to target the Dinaledi schools, where the school has shown a good record of passes and where there is assurance of a qualified teacher. This would probably be where there would be a higher return on the investment.

   The laboratory provisioning plan will involve negotiations between the Department of Science and Technology, Department of Education, Department of Public Works with Treasury.

2. *Science Kit provisioning*

Laboratory provisioning will take a long time. Therefore there must be a *science kit provisioning strategy*, where kits of equipment are provided to schools. This initiative will involve the Department of Science and Technology, the national and provincial Department of Education and Treasury and it is an initiative that could involve a partnership between government and private sector.

The plan would be to provision 500 schools a year and given that there are 3500 schools to be provisioned, the roll-out will take 7 years.

The kit package that could be offered to schools will be a teacher demonstration table, the FET Physical Science Kit for teacher demonstration and six sets of Electricity kits for group work. This set of equipment would be used by the grade 10, 11 and 12 classes. The present cost of this kit is R20 000. In addition to the provision of the kits of equipment the strategy will include a plan for teachers to be trained on how to use of the kits of equipment and how to manage practical work in a classroom. The strategy will also include a 5 year plan for maintenance of the kits and the replenishment of chemicals and this component will involve an extra R5 000 per school.

The cost of the kit provisioning strategy is:

	Cost of Kits	**Teacher support + kit maintenance**	**Total**
Year 1	R14 million	R3.5 million	R17.5 million
Year 2	R16 million	R7million	R21 million
Year 3	R18 million	R 9 million	R 27 million
Year 3	R21 million	R12 million	R33 million
Year 4	R24 million	R16 million	R40 million
Year 5	R29 million	R20 million	R49 million

Schools would be selected by the provincial department of education on the basis of the readiness of the school to deliver a quality education.

Private sector companies could be encouraged to participate in the science kit provisioning strategy by sending them the names of schools in close proximity their business or where they draw their workforce from or within a node of development to 'adopt' that school and provide the kits of equipment.

3. *Supporting retired science professionals to start local initiatives to introduce students to practical work*

The Department of Science and Technology should spearhead an initiative to attract retired science professionals to set up a Mobile Laboratory to service between 15 to 20 schools (400-600 learners)..

The retired science professionals would be invited to a business plan, which would indicate the schools in a cluster that they would support by bringing in the equipment to conduct practical work. Initiatives proposed in areas away from big cities should be prioritised. The business plans would indicate the names of the schools in a cluster that would be supported, the plan for school visits and the plan to employ a local matriculant as a laboratory assistant.

The initial layout costs (for the vehicle and equipment) is between R150000 to R200000 and the running costs are R200 000 - R300 000 a year. The Department of Science and Technology should set aside R10 million a year to co-ordinate and support this initiative. This is again an initiative that private sector could be interested in supporting. There would then be a partnership between private and the provincial departments of education.

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Appendix 1: STA Physical Science Kit Grade 10-12 (FET Phase)

The table below notes the item contents of the kit with:

- **Item numbers 1-111**: Physical Science - Equipment and apparatus
- **Items numbers 112-175**: Chemistry – Dry Chemicals and apparatus
- **Item numbers 176-194**: Chemistry - Liquid Chemicals and apparatus
- **Item numbers 195-198**: Manuals for Grade 10-12 Science

Physics					
No	**Item Description**	**Qty**	**No**	**Item Description**	**Qty**
1	Ripple Tank	1	2	Ammeter- Triple Scale	1
3	Voltmeter Triple Scale	1	4	Boyle's Law Apparatus-250 KPA	1
5	Filter Paper	1	6	Balance Kit-Double Beam	1
7	Glass Burette-25ml	1	8	Bicycle Pump	1
9	Optics Kit	1	10	Dynamics Track (Separate)	1
11	Beakers-250ml	2	12	Boiling Flask-250ml	1
13	Large Burner	1	14	Glass Conical Flasks-250ml	2
15	Glass Jet-150mm	1	16	Glass Rod-150mm	1
17	Glass Tubes-60mm	4	18	Evaporating Basins	2
19	Plastic Pipette	1	20	Glass Tubes	4
21	Plastic Trough	1	22	Gas Jars	6
23	Measuring Cylinder-100ml	1	24	Gas Cover Slips	6
25	Wash Bottle-250ml	1	26	Thermometers	2
27	Pair Safety Glasses	1	28	Funnel	1
29	Medicine Droppers	2	30	Pipe Clay Tray	1
31	Thistle Funnel	1	32	Stainless Steel Spatula	1
33	Syringe-50ml	1	34	Plastic Spoons	2
35	Deflagrating Spoons	2	36	Plastic Delivery Tubes	4
37	Large Wooden Spatulas	2	38	Delivery Tubes with S/S Elbows	2
39	Rubber Delivery Tube	1	40	Retort Clamp	1
41	Retort Ring	1	42	Retort Stand	1
43	24mm Solid Stopper	2	44	24mm One Hole Stopper	2
45	24mm Two Hole Stopper	1	46	30mm Two Hole Stopper	1
47	24mm Test Tube Brush	1	48	24mm Test Tube Rack	1
49	Test Tube with Dowel Handle	6	50	Boss Head	1
51	Circuit Board	1	52	Cell Holders/Battery Tray	2
53	Cell Pins	2	54	Cell Dividers	2
55	Pair Carbon Rods	1	56	Connectors	6
57	Rectangular Coil	1	58	Electroscope	1
59	Leads-300mm,Black Croc Clips	3	60	Leads-300mm, Red Croc Clips	3
61	Joules Calorimeter(1.2/2.2/3.3 Ω)	3	62	Resistance Board-Short	1
63	Resistors Mounted (10/15/22 Ω)	3	64	Switch	1
65	Pair Chrome Magnet	1	66	Leads-1m Red/Black-Croc	2
67	Leads-1mRed/Black-Croc-Banana	1	68	Perspex Strips 260x30x3mm	2
69	Polythene Strips 260x30x3mm	2	70	Pivot Pin Stands	2
71	Flannel Cloth	1	72	Magnet Support	1
73	Roll Copper Wire	1	74	Brass Rod-90 Deg Bend	1
75	Bulb Holders and Bulbs	3	76	Split Platform	1

77	Plotting Compasses	2	78	Compass Stands	2
79	Iron Core Electromagnet	1	80	'U' Shaped Electromagnet	1
81	White Screen	1	82	Dynamics Trolley-Plain	1
83	Dynamics Trolley-Plunger	1	84	Ticker Timer DC	1
85	Weight-500gm	1	86	Metal Mass Pieces-10gm s/steel	20
87	Boyle's Law Valve	1	88	Reel Cotton	1
89	Carbon Discs	20	90	Force Board Pulleys	2
91	Hooks	3	92	Line Level	1
93	Pendulum Bob	1	94	Pendulum Bob Support	1
95	Ticker Timer Tape	1	96	Newton Spring Balances	3
97	Set of 4 Ripple Tank Legs (Pkt 4)	1	98	Roller Bar	1
99	Convex Perspex Shape	1	100	Concave Perspex Shape	1
101	Rectangular Perspex Shape	1	102	Ripple Tank Light	1
103	Ripple Tank Light Holder	1	104	Curved Wave Barrier	1
105	Straight Wave Barriers	3	106	Rippler Bar and Motor	1
107	Prestik	1	108	Slinky Spring	1
109	Tuning Fork	1	110	Rippler Bar Springs	2
111	Rippler Bar Slides				

Chemistry

Dry Chemicals

No	Item Description	Qty	No	Item Description	Qty
112	Aluminium Grit	1	113	Aluminium Sulphate (sml)	1
114	Ammonium Carbonate (sml)	1	115	Ammonium Chloride (sml)	1
116	Ammonium Thiocyanate (sml)	1	117	Calcium Carbonate (sml)	1
118	Calcium Chloride (med)	1	119	Calcium Hydroxide (sml)	1
120	Cobalt Chloride (sml)	1	121	Copper Chloride	1
122	Copper Granules (sml)	1	123	Copper Oxide	1
123	Copper Nitrate	1	125	Copper Sulphate (sml)	1
126	Iodine Crystals (sml) 50gm	1	127	Iron III Chloride (Ferric)	1
128	Iron II Sulphate (sml)	1	129	Iron III Nitrate (sml)	1
130	Iron Filings (sml)	1	131	Iron Sulphide (sml)	1
132	Lead Nitrate (sml)	1	133	Magnesium Carbonate	1
134	Manganese Dioxide (sml)	1	135	Manganese Sulphate (sml)	1
136	Magnesium Nitrate (sml)	1	137	Magnesium Sulphate (sml)	1
138	Magnesium Oxide	1	139	Mercury (sml)	1
140	Mercury II Chloride (sml)	1	141	Napthalene	1
142	Oxalic Acid (sml)	1	143	Potassium Bromide (sml)	1
144	Potassium Chloride (sml)	1	145	Potassium Chromate (sml)	1
146	Potassium Dichromate (sml)	1	147	Potassium Hydroxide	1
148	Potassium Iodide (sml)	1	149	Potassium Iodate	1
150	Potassium Nitrate (sml)	2	151	Potassium Permanganate (sml)	1
152	Potassium Thiocyanate (sml)	1	153	Sodium Bisulphate (sml)	1
154	Sodium Carbonate	1	155	Sodium Chloride	1
156	Sodium Hydroxide (med)	1	157	Sodium Nitrate	
158	Sodium Nitrite (sml)	1	159	Sodium Oxalate (sml)	1
160	Sodium Sulphate (sml)	1	161	Sodium Thiosulphate (sml)	1
162	Starch Powder	1	163	Sulphur Powder (sml)	1
164	Zinc Granules (sml)	1	165	Zinc Sulphate (sml)	1

166	Sodium Sulphite (sml)	1	167	Pair Copper Strips	1
168	Bk Litmus Paper Red	1	169	Bk Litmus Paper Blue	1
170	12g Magnesium Ribbon	3	171	Steel Wool	1
172	Pair Zinc Strips	1	173	Pair Rubber Gloves	1
174	Box – Ref 16	3	175	Wooden Box & Check List	1
Liquid Chemicals					
No	**Item Description**	**Qty**	**No**	**Item Description**	**Qty**
176	100ml Diethyl Ether	1	177	500ml Acetic Acid	1
178	500ml Ammonium Hydroxide	1	179	100ml Bromothymol Blue Solution	1
180	100ml Calcium Chloride Solution (sub for Barium Chloride)	1	181	500ml Chlorine Water	1
182	100ml BromineWater	1	183	500ml Ethanol	1
184	100ml Formic Acid	1	185	500ml Hydrochloric Acid	1
186	500ml Methanol	1	187	500ml Methylated Spirits	1
188	500ml Nitric Acid	1	189	100ml Silver Nitrate Solution	1
190	100ml Universal Indicator	1	191	500ml Xylene	1
192	500ml Sulphuric Acid	1	193	White Tile	1
194	100ml Litmus Solution	1			1
Manuals					
No	**Item Description**	**Qty**	**No**	**Item Description**	**Qty**
195	Grade 10 Science	1	196	Grade 11 Science	1
197	Grade 12 Science	1	198	Chemical Safety Data	1

APPENDIX 2: Radmaste/ Somerset Educational Microscience Equipment (Kit and Teacher Resource Kit) and Printed Resources (Worksheets and Teacher Guides)

PHYSICS		
EQUIPMENT		
No	**Item Description**	**Cost**
1	RADMASTE Microelectricity and Magnetism Kit	R 154.00
2	RADMASTE Microelectricity Teacher Resource Guide (Includes 4 Multimeters)	R 704.00
3	Physics: Forces, Motion and Dynamics Kit and Manual (Teacher Demo)	R 2420.00
4	Physics: Waves, Light, Sound and Optics Kit and Manual (Teacher Demo)	R 1870.00
PRINTED RESOURCES		
No	**Item Description**	**Cost**
5	RADMASTE FET Microelectricity Worksheets (Gr 10-12)	R 275.00
6	RADMASTE FET Microelectricity Teacher Guide (Gr 10-12)	R 330.00
CHEMISTRY		
EQUIPMENT		
No	**Item Description**	**Cost**
7	RADMASTE Basic Microchemistry Kit	R 88.00
8	RADMASTE Advanced Microchemistry Kit	R 132.00
9	RADMASTE Chemistry Microburette Kit	R 25.30
10	RADMASTE Organic Microchemistry Kit	R 132.00
11	Combo Still Distillation Apparatus	R 308.00
12	RADMASTE Advanced Microchemistry Teacher Resource Kit	R 3000.00
	CHEMICALS	
No	**Item Description**	**Cost**
13	RADMASTE Organics Microchemicals Kit	R 550.00
14	Combo Still Chemicals Kit	R 550.00
	PRINTED RESOURCES	
No	**Item Description**	**Cost**
15	RADMASTE FET Microchemistry Worksheets (Gr 10-12)	R 275.00
16	RADMASTE FET Microchemistry Teacher Guide (Gr 10-12)	R 330.00
17	RADMASTE Organic Chemistry Microscience Experiments (Manual)	R 60.00
18	RADMASTE Microelectrochemistry Experiments (Manual)	R 42.00
19	MicroChem Safety Manual	R 55.00

Appendix 3: Summary Budget the Running costs for the Mobile Biology Laboratory

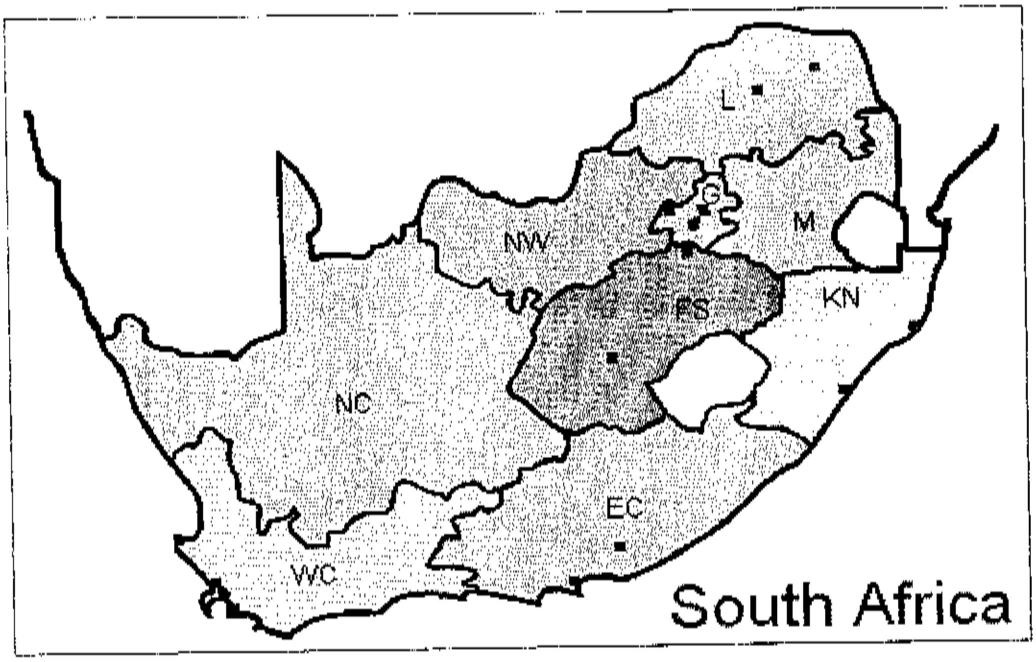
Year	2006	2007	2008	Total R (for 3 years)
Running Expenses:				
Vehicle Maintenance, insurance and licensing	5 000	5 350	5 724	16 000
Petrol	5 000	5 350	5 724	16 000
Consumables (Chemicals and Glassware)	6 000	6 420	6 856	19 300
Printing of worksheets	8 000	8 560	9 159	25 700
Cell phone allowance	4 000	4 000	4 500	12 500
Refreshments for learners	9 000	9 630	10 304	29 000
Salaries:				
1. Co-ordinator	150 000	160 500	170 500	481 000
2. Chief Lab. Ass.	52 500	56 100	60 000	168 600
3. Lab. Assistant	26 000	27 800	30 000	83 800
TOTAL	**265 500**	**283 710**	**302 767**	**851 977**

Appendix 4: **Summary Budget the Running costs for the Mobile Physical Science Laboratory**

Initial Start Up Cost	
Expense	**Cost**
TATA Bakkie	R 90 000
EduTrade Equipment	R 50 000
Salaries (3 people)	R 15 000
Total	**R 155 000**
Annual Expenditure	
Monthly Expenses (R 2000 x 12)	R 24 000
Salaries (R15 000 x 12)	R 180 000
Total	**R 204 000**

APPENDIX 5: Interactive Science Centres in South Africa

The list and map below provides the spatial location of each science centre in South Africa. The province in which each science centre in South Africa is located is noted in the list below and their positions are shown by red dots on the map below.



Source: www.saastec.co.za

The list of interactive science centres include companies producing exhibits for interactive science centres and who are members of SAASTEC.

Boitjhorisong Resource Centre Sasolburg, Free State Province, South Africa

Boyden Observatory - University of the Free State, Bloemfontein, Free State Province, South Africa

Delta Environment Centre, Johannesburg, Gauteng Province, South Africa

Discovery Centre at the Transvaal Museum, Pretoria, Gauteng Province, South Africa

Givani Science Centre, Giyani, Limpopo Province, South Africa

Gold Reef City Exploratory, Johannesburg, Gauteng Province, South Africa

Hartebeesthoek Radio Astronomy Observatory, near Krugersdorp, Gauteng Province, South Africa

Hermanus Magnetic Observatory, Hermanus, Western Cape Province, South Africa

iThemba Laboratory for Accelerator-Based Sciences, Faure, Western Cape Province, South Africa

Johannesburg Planetarium **at the University of the Witwatersrand,** Johannesburg, Gauteng Province, South Africa

MTE Studios, Cape Town, Western Cape Province, South Africa

MTN ScienCentre, Century City, Cape Town, Western Cape Province, South Africa

Old Mutual MTN Sciencentre, Gateway Theatre of Shopping, Umhlanga, Kwazulu-Natal Province, South Africa

Port Elizabeth Museum Complex, Port Elizabeth, Eastern Cape Province, South Africa

Sci-bono **Phase One now open in Newtown,** Johannesburg, Gauteng Province, South Africa

Sci-Enza - **University of Pretoria,** Pretoria, Gauteng Province, South Africa

Scipone Exhibits - Consultants and creators of ethnic educational experiences, Cape Town, Western Cape Province, South Africa

Signatures - **Makers of themed displays,** Cape Town, Western Cape Province, South Africa

Somerset Educational, Garsfontein East, Pretoria, Gauteng Province, South Africa

South African Agency for Science & Technology Advancement - SAASTA, Pretoria, Gauteng, South Africa

South African Astronomical Observatory, educational programmes at Cape Town headquarters and Sutherland observatory.

South African Institute for Aquatic Biodiversity, Grahamstown, Eastern Cape Province, South Africa

South African National Biodiversity Institute, has eight botanical gardens around South Africa.

The Discovery Centre, Cape Town, Western Cape, South Africa

Tsebo Koloing - mobile science centre, University of Pretoria, Technikon Pretoria and Technikon Northern Gauteng, Pretoria, Gauteng Province, South Africa

Ulwazi Partnership, Developing Interactive Science and Cultural Centres

University of Limpopo Science Centre, Polokwane, Limpopo Province, South Africa

Unizul Science Centre - University of Zululand, Richards Bay, Kwazulu-Natal, South Africa

West Coast Fossil Park, Western Cape Province, South Africa

<u>Appendix 6:</u> Experilabs Science Shows

Typical demonstrations include the following:

- Hydrogen balloon explosion, hydrogen rocket
- Sound: Singing rods, resonating pipe etc
- Coffee and Cremora explosion
- Polymers: Instant snow, slime, superabsorbent polymer etc.
- Nassau Clock reaction
- Spontaneous boiling kettle
- Electromagnets
- Magdeburg spheres
- Air Cannon
- Violent exothermic reaction
- Nitro cellulose and gun demonstrations
- Spontaneous chemical reactions
- Static electricity ad Van de Graaff
- Light experiments: plasmas, fluorescence and chemiluminescence
- Spud gun demonstration (outside)
- Pyrotechnic rocket launch (outside)