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INTRODUCTION OF RADMASTE MICROCHEMISTRY IN DISADVANTAGED SCHOOLS IN GAUTENG: A CASE STUDY

VOLUME 1

Lebala Miriam Kolobe

A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science.

Johannesburg, January 1998.

DECLARATION

I declare that apart from the assistance acknowledged, this research report is my own unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

L.K.Kolobe

Lebala Miriam Kolobe

On this 9th day of JUNE, 1998.

ABSTRACT

A case study was conducted in two regions (Duduza and Soshanguve) in the Gauteng province to establish how the RADMASTE Centre of the university of the Witwatersrand introduced RADMASTE microchemistry to science teachers in three schools in these regions, and how the teachers subsequently introduced it to their pupils. The content knowledge, skills and attitudes achieved by the pupils through the introduction of the RADMASTE microchemistry approach was qualitatively investigated using interviewing, observations, and questionnaires modes.

Three standard 10 (Grade 12) teachers were monitored starting from the introduction workshops until the introduction of the RADMASTE microchemistry to their pupils. The pupils too were monitored in terms of their performance with the RADMASTE microchemistry after they were introduced to the small-scale chemistry.

The results of this study indicate a low attendance of the workshops by the teachers, as well as content difficulties on the part of the teachers as well as the pupils. These also indicate teachers who neither copied nor adjusted their normal teaching practices with introduction of the kit and allied materials. Almost all participants were seen to have difficulties with the kit on their maiden encounter, but everyone said they liked the RADMASTE microchemistry approach.

Suggestions are made in the last chapter on ways of introducing the RADMASTE microchemistry kit and allied materials in the schools.

DEDICATION

In memory of my late mother

`Ma-Lebala Kolobe

1944 - 1976.

ACKNOWLEDGEMENTS

I wish to thank my supervisors Dr. K.C. Naik and Ms M. Brand for their constructive criticism and support throughout this project.

I also wish to thank all my friends and family for their support, especially my loving father and mother: Lefuo and `Ma-Morero Kolobe. Sincere acknowledgements go to my colleagues as well for their assistance in the word processing of this research report.

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ALPHABETICAL LIST OF ACRONYMS

D.E.T.:- Department of Education and Training (Department for black education under previous government).

F.R.D:- Foundation for Research and Development

IDT:- Independent Development Trust

NGO:- Non-Governmental Organisation.

RADMASTE Centre:- Research and Development in Mathematics, Science and Technology Education Centre.

S.E.P:- Science Education Project

SGT:- Self-Governing Territories (under previous government included certain areas).

SYSTEM:- Students and Youth into Science, Technology, Engineering and Mathematics.

T.E.D:- Transvaal Education Department (former provincial education department under previous government).

T.S.P:- Thousand Schools Project

1

INTRODUCTION

1.1 INTRODUCTION

Most science teachers and science educators throughout the world agree on the necessity and value of practical science for effective science teaching and learning. However, there is still debate within science education circles regarding the way practical work is implemented in schools (Clackson & Gee, 1992; Hodson, 1990; Woolnough, 1991). In South Africa, teachers are encouraged by the education departments to do practical work whenever they can (e.g. the former Transvaal Education Department Syllabus (T.E.D.) 1986, see Appendix 7.1). Although this is the case generally, very little practical work, either individually, or in groups or as teacher demonstrations, is done in secondary schools (Naik, 1995). The reasons (with short discussion) given for the lack of practical work are listed below.

(a) Lack of equipment and apparatus

In South Africa, most secondary schools, especially the former Department of Education and Training (D.E.T.) schools, do not have sufficient apparatus and other resource materials with which to teach practical work. On the other hand, the department of education expects the pupils to perform individual experiments as a requirement for the completion of the final matriculation examination. In those schools that have a few sets of apparatus available, some teachers do demonstrations for the pupils and the pupils do not perform experiments either on an individual basis, or in groups.

(b) Large class size

Science teachers in secondary schools, especially the historically black schools and those schools falling under the former Self-Governing Territories (SGT) have a teacher-pupil ratio of about one teacher to sixty pupils. Because there are so many pupils in the class, the distribution of chemicals and apparatus becomes difficult and costly as more

chemicals and sets of apparatus are needed for individual or group practical work. It would also be less safe to have individual pupils having their own chemicals and glass apparatus. The amount of waste or other hazardous chemicals produced from large classes could be unmanageable. If the large class is divided into smaller groups, then it might be difficult to manage these groups, since there may be too many groups for one person to manage.

(c) **Timetable constraints**

This problem is faced by most teachers in most schools. The time allotted for the lessons (which is around 30 minutes a lesson in most cases) does not allow for the inclusion of practical activities in the lessons as these need more time to be completed.

(d) **Lengthy syllabi**

Science is a practical subject. It is therefore appropriate that pupils perform the experiments as part of their learning. Because it takes more time for pupils to perform practical activities, this means that an even longer time is needed for the pupils to perform all the required activities included in the syllabus. Most teachers thus opt for teacher demonstrations and do not give the pupils the chance to perform the activities as this could delay the completion of the syllabus, especially at the matriculation level.

(e) **Dearth of qualified teachers**

Adding to the fact that many secondary schools are underresourced, most science and mathematics teachers in South Africa are not suitably qualified for what they teach. The science teachers have neither the expertise nor the confidence to do practical work. Some of these teachers did not do any practical work when they trained as teachers. This situation limits the extent to which the teachers can use minimally available resources or improvise to perform practical work (Naik, 1995).

To address the lack of practical work in secondary schools in South Africa, various initiatives have been implemented. Some Non-Governmental Organisations (NGOs) like the Science Education Project (S.E.P.) have developed low cost practical science packages (consisting of

kits and resource materials) for secondary schools, and have implemented these, mainly in some black (disadvantaged) schools.

The terms that will be used in this research report which have specific meanings and might not be commonly known are explained below.

1.2 DEFINITIONS OF TERMS

(a) *Small-scale chemistry* refers to the practical exercises in chemistry which are done either in the laboratory or in the classroom on a small-scale. These practical exercises use small quantities of materials and also use small-scale equipment which costs less than the conventional laboratory apparatus. Because small quantities of chemicals are used, there is a large reduction in chemical waste which consequently reduces waste disposal problems. Since most of the items used in small-scale chemistry are made of plastic, safety hazards are also reduced. Many of these experiments can be done in a much shorter time than the conventional experiments, particularly when fine motor skills have been developed. The type of small-scale chemistry approach used in this study is called RADMASTE microchemistry. This is discussed further in section (e).

(b) *Disadvantaged schools* are those schools that do not have laboratories, adequate equipment or apparatus, or enough chemicals to do practical exercises. Most of these schools also have a shortage of qualified teachers. These schools and teachers are found in different regions in South Africa -both in the urban and the rural areas. Previously, most of these schools were underresourced under the apartheid structures, being under the control of the Department of Education and Training (former D.E.T.) or schools in the former Self-Governing Territories (SGT).

(c) *Gauteng* is the former PWV province, which covers Pretoria, Witwatersrand and the Vaal triangle (Vereeniging and Vanderbijlpark). This province is mainly urban although it has some rural areas.

(d) *RADMASTE Centre,* short for the Research and Development in Mathematics, Science

and Technology Education Centre, is a Non-Governmental Organisation (NGO) based at the University of the Witwatersrand, Johannesburg. The RADMASTE Centre engages in research and development projects in mathematics, science and technology education. The mission of the RADMASTE Centre is to enhance the quality, relevance and accessibility of mathematics, science and technology education in South Africa.

(e) *RADMASTE microchemistry kit* contains the basic equipment needed to do selected small-scale practical exercises. This kit is accompanied by worksheets (which give experimental instructions and some questions), a teacher's manual which guides the person and provides lesson preparation hints, and a box of chemicals required to perform the selected experiments. In the teacher's manual, there is specific information on what observations are expected during the exercises. Items of the kit can be found in Appendix 7.3.

(f) *Thousand Schools Project (T.S.P.)* is partly a government and partly an independent body. It is sponsored by a government-sponsored body called the Independent Development Trust (IDT). The aim of TSP is to select one thousand schools in all the nine provinces in South Africa and upgrade the quality of the teachers and the teaching materials that they have. Different NGOs using different approaches, tender their services to the schools. Teachers and head teachers in these schools are the persons who decide on an NGO that they will work with, depending on what the needs of the school are. Once the desired NGO has been chosen, the NGO introduces its teaching packages to science teachers in those schools. A coordinator is employed by T.S.P. to liaise between NGOs and the schools involved.

1.3 AIMS OF THE RESEARCH

The main purpose of the study is to investigate the introduction of the RADMASTE microchemistry kit and allied materials in three disadvantaged schools in the Gauteng province. The study will attempt to answer the following questions:

1. How are the RADMASTE microchemistry kit and allied materials introduced to teachers?

2. How do teachers introduce the RADMASTE microchemistry kit and allied materials in their schools?
3. What are the content knowledge, skills and attitudes competencies associated with the RADMASTE microchemistry approach?

1.4 RESEARCH DESIGN.

The research was in the form of a Case study. The schools involved were chosen and were clustered by the Thousand Schools Project (TSP). For this research, the clusters involved were Duduza, which is situated to the East of Johannesburg and Soshanguve, which is located to the North of Johannesburg. Both places are in the Gauteng province (see Appendix 7.2).

These areas were chosen because they were within relatively easy reach of the university (90 km and 120 km - Duduza and Soshanguve, respectively). It is also because their workshop dates suited the researcher. For a school (already falling under T.S.P.) to take part in the research, a standard 10 (i.e grade 12) physical science teacher of that school had to attend an orientation workshop and two follow-up workshops. Two teachers attended the orientation workshop in Duduza and one teacher attended in Soshanguve. The research looked at two schools in Duduza and one school in Soshanguve following the criteria stated above. Thus, there were three teachers involved in the study. Because each teacher had one standard 10 physical science class, there were three standard 10 classes involved in the study.

The sample was therefore not representative. However it is believed that investigation of the process of introduction of small-scale chemistry by these teachers, in disadvantaged schools, will be illuminative. It is stated in Cohen and Manion (1994) that the purpose of observing individuals deeply in Case studies is to try and establish generalisations about the wider population to which that unit belongs. It was with this view in mind that this study was conducted.

Table 1.1 shows the sequence of events with description of the event in parentheses, the researcher followed to collect data plus the methods of data collection that were used. The third column represents the participants of each event plus the role played by the researcher in the

event. The role is indicated in parentheses.

The original plan was to have the teachers attend the orientation workshop, introduce microchemistry to their pupils and then attend the second and third workshops to report on what had happened and solicit their opinions. However, the teachers could not introduce microchemistry to their pupils before they attended the second workshop due to school examination and holiday periods that followed the orientation workshop. The proposed plan was therefore not firmly adhered to. The plan followed appears on Table 1.2 in the form of a table of events.

TABLE 1.1

RADMASTE EVENTS AND METHODS OF DATA COLLECTION

EVENT	INSTRUMENTS	PARTICIPANTS
orientation workshop (introduction to microchemistry)	field notes, teacher questionnaires	RADMASTE facilitator, teachers & researcher (observer)
first school visit (interview on perceptions and plan to introduce microchemistry to pupils)	interview protocol	Teachers & researcher (interviewer)
second workshop (report-back from schools, opinions and concerns)	field notes	RADMASTE facilitator, teachers & researcher (observer)
second school visit (teachers introduce microchemistry to pupils)	interview protocol, pupil evaluation forms, pupil workbooks, field notes, teacher evaluation forms	Teachers, pupils & researcher (observer, & interviewer)
third workshop (report-back from schools, opinions and concerns)	field notes	RADMASTE facilitator, teachers & researcher (observer)
RADMASTE management interviews (based on plan & target population plus their success)	interview protocol	RADMASTE director, facilitator & researcher (interviewer)

In the paragraphs that follow a report of the procedures that the researcher used to answer these three questions is given.

Q1: How is the RADMASTE microchemistry kit and allied materials introduced to teachers?

The teachers first encountered the RADMASTE microchemistry kit and allied materials in the orientation workshop. The researcher observed and recorded the events of the orientation workshops as the RADMASTE microchemistry kit and allied materials were introduced to the teachers. The researcher then followed the teachers to their respective schools to find out their perceptions (through interviews) on the way the RADMASTE microchemistry kit and allied materials were introduced to them. The RADMASTE Centre management was later interviewed regarding the introduction of the RADMASTE microchemistry kit and allied materials to teachers and then to the pupils in the schools.

Q2: How do teachers introduce the RADMASTE microchemistry kit and allied materials in their schools?

After the RADMASTE microchemistry kit and allied materials were introduced to the teachers, the teachers then had to introduce it to their pupils in their schools. The interviews conducted in the schools with the teachers involved finding out the plans made by the teachers to introduce the RADMASTE microchemistry kit and allied materials to their pupils. The teachers were then observed in their schools when they introduced their pupils to the RADMASTE microchemistry kit and allied materials and field notes were taken.

Q3: What are the content knowledge, skills and attitudes competencies associated with the RADMASTE microchemistry approach?

To answer this question, first the worksheet used in the orientation workshop was analysed in terms of content knowledge, skills and attitudes stipulated by the syllabus. The pupils were then observed as they performed the experimental exercise that their teacher performed at the orientation workshop and field notes were taken. The pupils

were interviewed after completing the experiment to find out their attitudes towards the RADMASTE microchemistry approach and materials and to find out if they understood what was happening during the experiment. The pupils also completed a questionnaire in which they were asked about their attitudes and content attainment when using the RADMASTE microchemistry approach. During the experiment, the pupils were asked to record their results in workbooks. This allowed the researcher to see from a document analysis whether the pupils were able to make expected observations and whether they understood the experimental exercise. The RADMASTE Centre management was interviewed on how they thought the RADMASTE microchemistry kit and allied materials should be introduced to the teachers and what they have achieved from their approach. The response was compared to what actually happened and what the teachers and pupils claimed to have achieved from this approach.

SUMMARY

The procedures are reflected in Table 1.2 on the next page. The table shows the different research methods followed and the events in which these methods were used. A key is given for the abbreviations of the events used in this table. A 'yes' is used to indicate the questions answered by each research method.

KEY:

Numbers:1-3:Research questions

O.W.S : Orientation W/Shop

F.S.V : First School Visit

R.I : RADMASTE Centre Interviews

S.S.V : Second School Visit

S.W.S : Second W/Shop

T.W.S : Third W/Shop

TABLE 1.2

RESEARCH METHODS FOLLOWED AND CORRESPONDING RESEARCH QUESTIONS

RESEARCH METHODS AND EVENTS	RESEARCH QUESTIONS 1	2	3
OBSERVATIONS ORIENTATION WORKSHOP (OWS)	yes		
SECOND WORKSHOP (SWS)	yes		
SECOND SCHOOL VISIT (SSV)		yes	yes
THIRD WORKSHOP (TWS)	yes		yes
INTERVIEW PROTOCOL TEACHERS (F.S.V.)	yes	yes	
PUPILS (S.S.V.)		yes	yes
RADMASTE (R.I.)	yes	yes	yes
QUESTIONNAIRE TEACHERS (O.W.S.)		yes	
PUPILS (S.S.V.)			yes
PUPIL WORKBOOKS (S.S.V.)			yes

SUMMARY

Table 1.2 above shows the research questions and methods used to answer the three research questions. As the table shows, each question has been addressed at more than one event. Also, each method has been used to investigate more than one question. As pointed out in Cohen and Manion (1994), exclusive reliance on one method may bias or distort the researcher's picture

of the reality that is being investigated. Due to this weakness in using a single method, more than one method was used to answer each research question.

1.5 DATA ANALYSIS

To analyse the data obtained from the research methods, different methods of analysis were followed. Field notes from the three workshops were analysed in terms of the way microchemistry was introduced to the teachers and teachers' opinions and concerns regarding the RADMASTE microchemistry approach. Teacher interview transcripts were analysed for teachers' opinions about the orientation workshop and plans to introduce RADMASTE microchemistry in the schools. Pupil evaluation forms, and pupil workbooks were also analysed for the concerned parties' perceptions about the RADMASTE microchemistry approach. The experimental worksheet was analysed in terms of the content knowledge, skills and attitudes stipulated in the physical science syllabus.

1.5.1 Orientation workshop

From the orientation workshops, the researcher obtained field notes plus teacher evaluation forms. The field notes from the workshops were analysed in terms of the number of teachers present at the workshop, the aims of the workshop and the role played by the RADMASTE facilitator while the teachers did the experiment to achieve the goals of the workshop. The experimental worksheet developed by the RADMASTE Centre and used in the orientation workshop was collected and analysed for content knowledge, skills and attitudes in comparison to those prescribed in the mentioned syllabus.

1.5.2 First school visit

From this visit, the data obtained were interview recordings and transcripts. Some examples are included as Appendices and they are described in the chapter of results. From these teacher interview transcripts, teacher perceptions on the workshop, teacher intentions to link the theory of the acid-base titration experiment to the practical exercise performed and the relation of that practice to the school's normal practical work practices were analysed. The link between the way the RADMASTE microchemistry kit with allied materials was introduced to teachers and the way teachers intended to introduce it to their pupils was analysed from the interview

transcripts.

1.5.3 Second workshop

The teachers had not done any experiments with their pupils yet (as stated in the research design, section 1.4). The teachers, however, posed some questions to which possible answers were given and regarding their concerns suggestions were made. Field notes to this workshop were analysed for possible solutions and suggestions made to the teachers' questions and concerns.

1.5.4 Second school visit

The researcher recorded what happened while the teachers were introducing the RADMASTE microchemistry kit and allied materials to their pupils. Data obtained from these visits were:

(a) field notes on teacher and pupils performing the acid-base titration experiment;
(b) pupil interview transcripts;
(c) pupil workbooks; and
(d) pupil evaluation forms which were completed after the RADMASTE microchemistry experiments had been performed.

Analysis of the pupil interview transcripts gave some insights into the following:

(a) whether or not pupils understood the experiment in terms of making expected observations and making sense of the observations;
(b) pupils' attitudes towards the RADMASTE microchemistry kit and allied materials;
(c) the clarity of the worksheet; and
(d) the difficulty experienced in using the microchemistry apparatus.

The field notes from the schools were analysed in terms of whether the pupils were able to cope with manipulating the microchemistry kit apparatus. The role played by the teacher in relation to the way the RADMASTE Centre facilitator introduced the RADMASTE microchemistry kit to the teachers was also analysed.

The pupils' responses to the worksheets were collected and investigated for the expected results

of the experiment and whether the pupils were able to understand the experiment.

1.5.5 Third workshop

At this point, the teachers had already had the chance to introduce RADMASTE microchemistry to their pupils and the pupils had performed the experiment on acid-base titration. The teachers then reported what happened at their schools and these were recorded as field notes. These were analysed for problems that teachers faced or any other issues related to the RADMASTE small-scale chemistry approach.

1.5.6 The RADMASTE Centre visit

The interview transcripts from the RADMASTE Centre management regarding the RADMASTE Centre microchemistry approach were analysed for their intended plans of implementation in the RADMASTE Centre microchemistry approach. The analysis also looked at RADMASTE Centre's achievements with the target group (i.e. teachers and pupils) at that point.

2

LITERATURE SURVEY

2.1 INTRODUCTION

The literature on practical work in general is reviewed with specific attention being paid to small-scale chemistry practical work. The status quo of practical work in Southern Africa, and especially in the Republic of South Africa (RSA), is described and analysed. Learners' conceptions of acids and bases and the rationale for the research methods is then reviewed.

Aspects of practical work discussed include its history (in UK and Israel), problems facing its implementation and its status in Botswana, Lesotho, Swaziland, Zimbabwe and the Republic of South Africa.

Literature on the implementation of small-scale chemistry as an alternative to conventional or other forms of practical work is also reviewed. The views of some science educators about introducing practical work in schools are discussed. The researcher then considers the advantages of using many research methods, like interviews and observations, to answer the research questions. The limitations of some of these methods are also considered.

2.2 ISSUES AROUND PRACTICAL WORK

2.2.1 History of practical work in general

Practical science, according to Woolnough (1991), means doing practical experiments or practical exercises with scientific apparatus, usually in the science laboratory. This is the context in which the word 'practical work' is used in this research report.

The history of practical work described here is that of the United Kingdom since the styles of practical work in RSA followed the British model. Also, there is very little literature available, describing the history of practical work in RSA.

About three hundred years ago, science pupils were taught theory without any practical exercises. Clackson & Gee (1992) state that John Locke of England proposed that children should be given something practical to do during the course of their education.

Practical work, which was mainly in the form of teacher demonstrations then, depended on items that were sold at that time. Makers and suppliers of scientific apparatus, who were conscious of this, targeted their goods at the educational market in the 1830's, in England. This implied that trade influenced teaching and consequently, educational pace was affected. But at that time, there were still no formal courses for laboratory instruction. Some textbooks however, gave instructions for practical work to be performed in the home kitchen. This was done because there was belief that people could learn better when doing things for themselves rather than passively observing experiments being performed (Clackson & Gee, 1992).

Still in the 1830s, many science educators were talking about the need for formal laboratory instruction for different science orientated disciplines like mechanics, medicine and pharmacy. In 1835, David Reid built a laboratory at school level which catered for pupils to work individually. In 1837, Joseph Griffin took the work further by launching cheap and easily manageable apparatus for schools. Griffin also guided untrained science teachers to organize and manage laboratories in their schools. However, practical work was not done formally in most schools because of lack of support from the state (Clackson & Gee, 1992). The Great Exhibition in 1851, where instrument makers displayed simple equipment triggered government funding in science. This exhibition was, however, not found to be adequate for education, but it managed to put demonstrative science in elementary schools in place. It also invited opinions from leading scientists about practical science to be implemented in schools.

In 1854, the Department of Science and Art emerged. The government then diverted funds from elementary schools to secondary science schools through this department. The department also introduced science examinations, the success of which won the teacher a bonus. This led to the publication of 'cram' texts for those candidates who sat for the examinations, because teachers received bonuses based on results only. Many students did not actually perform these experiments, and were taught these in theory only (Clackson & Gee, 1992).

Because the practical examination papers were still of a poor quality, the department introduced regulations for experiments to be performed 'before the pupils' eyes' in 1870. Although people in science education agreed with the idea, they were worried about the cost. The Department of Science and Art offered a grant for this work to be done. It also introduced regulations that schools should build laboratories and specified the equipment that these laboratories should have. This made way to the beginning of individual practical work in chemistry, in particular, at school level (Clackson & Gee, 1992).

The following paragraphs describe the rationale given for introducing certain styles of practical work and the criticisms levelled at the various styles respectively. By 1890, science teaching in the United Kingdoms (UK) and the United States of America (USA) was mainly instructional (Woolnough, 1991). The teachers performed demonstrations before the pupils to confirm theory (Lock, 1988; Woolnough, 1991). This was because it was believed that when the practices of early scientists were repeated, the students would have better understanding (Lock, 1988). But some scientists thought that this method did not lead to good understanding of underlying theory and also, the children were not given the chance to perform practical activity for themselves (Woolnough, 1991).

Towards the end of the 19th century, in Britain, Armstrong advocated the introduction of heurism since his belief was that investigation was central to practical work and if the inquiry was genuine, the discovery would lead to understanding of theory (Lock, 1988). A heurism driven syllabus was approved by the Oxford and Cambridge Examination Boards in 1896, but some science educators found this method to be too challenging for average and below average pupils and time consuming as well (Lock, 1988). To expect that they make intelligent observations and draw reasonable conclusions from ordinary experiments was found to be unrealistic and, therefore, useless (Lock, 1988). The guided discovery (heurism) was, however, not popular because there was disagreement on the efficiency of individual practical work. Individual practical work was being criticised as a waste of time in both Britain and the USA. It was thought that teacher demonstrations would be more economical and effective. The effectiveness of individual practical work as opposed to teacher demonstrations was, however, not investigated (Clackson & Wright, 1992). This method of individual practical work subsided

in the USA, but it continued for some time in Britain though not to the same extent as before (Lock, 1988).

Guided discovery which was advocated by the major American science courses namely, Biological Science Curriculum Study (BSCS), Physical Science Curriculum Study (PSCS) and Chem Study became prominent from the late 1950s in the USA (Lock, 1988; Woolnough, 1991). Guided discovery was criticised for attempting to combine the discovery of predetermined theory and self discovery. These two purposes, it was claimed, were not compatible (Woolnough, 1991).

From the 1960s to the 1980s, practical work became biased towards learning the techniques (or skills or processes) of science (Lock, 1988; Woolnough, 1991). This approach was advocated by the American Association of Advancement of Science (AAAS) and Oxfordshire Certificate of Educational Achievement (OCEA) (Woolnough, 1991). This practice of learning the processes was criticised for asserting that such skills or process skills existed on their own without the underlying theory.

The Schools Council 5-13 project, Nuffield A-level physics, and the Assessment of Performance Unit (APU) advocated instrumental objectives approach and investigational practical work (Woolnough, 1991). According to Chisman (1992), in Britain, the concern was that although Nuffield approaches made science more interesting, the focus was still on the content. He advocated that the needs of students and the society in which they live be considered. Yager in his contribution to Woolnough's (1991) 'Practical Science' criticized the investigational practical work in that the laboratories were used for verification activities and not for real investigations. According to him Science, Technology and Society (STS) approach was the one that focused completely on practical work. He advocated this approach by arguing that in this case (i.e. STS approach), each stage was practical and personal, and the individual students were therefore personally involved (Woolnough, 1991).

As history has shown, the aims and the methods of practical science have changed over the last one hundred years and more. Science educators and teachers have still not provided a rationale

and style for practical work that is agreed on by most or all science educators (Woolnough, 1991; Hodson, 1996).

2.2.2 Aims of practical work

In 1976 and 1979, Lynch and Naik respectively both carried out independent studies where they asked teachers in South Africa to rank the aims of practical work in order of importance. They adopted the lists of aims of practical work used by Kerr and Thompson in 1963 and 1975, respectively. The six most important aims were found to be the following:-

(1) To make science phenomena more real through actual experience.

(2) To encourage accurate observation and careful recording.

(3) To elucidate the theoretical work in order to aid comprehension.

(4) To give training in problem-solving.

(5) To promote scientific method of thought.

(6) To arouse and maintain interest.

This rank order was the same as the one ranked by the teachers in the UK from different studies (qouted in Naik, 1995).

Hodson (1996) describes the major purposes of practical work being to:

(i) learn science, which means acquiring and developing concepts and theoretical knowledge;

(ii) learn about science, which implies understanding the nature and methods of science; and

(iii) do science, where one engages in developing expertise in scientific inquiry and problem solving.

He also believed that all the three purposes were closely related and that they could be developed at the same time.

2.2.3 Some problems encountered in implementing practical work

Learners, teachers, educators and scientists all agree that practical work is essential when teaching or learning science. The rankings of aims of practical work have, however, changed according to the rationale given for doing practical work e.g. to confirm theory or to learn the

skills and processes of science. Lynch (1994a) writes that the major problems of implementing practical work are associated with the curriculum and facilities available to the teachers involved.

An investigation carried out with some student teachers revealed that they believe that experiments are essential to science teaching. These future teachers tend to assume that science must be:

(i) taught in the laboratory; and

(ii) taught via experiments.

With these assumptions, practical work is used by many teachers to try and achieve every goal of science education (Hodson, 1996). In this case practical work is being used to fulfill too many aims. But Hodson (1996) also argues that in some instances, it is under-utilised, meaning that its potential is not fully exploited. Duggan & Gott (1996), mention that practical work is abused because the aims of practical work listed in the syllabi are often so confusing that they leave the teacher without a clear rationale for doing practical work. The laboratory is taken by some teachers as a place for creation and recreation of scientific knowledge and methods, which lead some teachers to assume that any form of practical work fulfils the principles of heurism (Nott, 1996).

Some researchers have found that practical work does little to improve the learning of concepts (Duggan & Gott, 1996; Lynch, 1994a). Hodson (1996) argues that it is only an investigative approach type of practical work that can develop the three kinds of learning:

(i) conceptual understanding;

(ii) procedural knowledge; and

(iii) investigative experience.

Some South African schools do not have the opportunity to practise any form of practical work. This position is brought about by different problems. The general problems are:

(i) shortage of funds;

(ii) lack of personal and environmental safety;

(iii) inappropriate teacher competency;

(iv) syllabus constraints; and

(v) lack of apparatus, and lack of services-like water, electricity, and equipment.

In the light of the foregoing literature survey on practical work, it is shown that the people involved with science education and teaching all agree that practical work is essential. However, there has not been any one style of practical work that is universally agreed upon. There is also no agreement as to which approach between individual practical work and teacher demonstration, is more fruitful. The curriculum and the facilities available to many teachers in the schools do not allow the teachers to do what is expected of them. Some teachers do not know what style of practical work to employ and also, they do not know the reasons for doing practical work themselves.

2.3 PRACTICAL WORK IN SOME SOUTHERN AFRICAN COUNTRIES (Botswana, Lesotho, Swaziland and Zimbabwe).

Although the countries are listed here alphabetically by name, the sequence followed is chronological.

Zimbabwe

Before independence in 1980, Zimbabwe developed a low-cost science programme called ZimSci. The programme consisted of written materials and a science kit for the performance of experiments. The kit used mainly cans and other household items in place of conventional apparatus. Although this science programme ended up being accessible to thousands of Zimbabweans in secondary schools, it was originally meant for distance education for secondary school leavers. Due to a high turnover of untrained teachers, the programme could not be productively sustained since these teachers were incapable of handling it (Kahn & Rollnick, 1993).

Botswana

Botswana imported and adapted the ZimSci kit in 1984. The adaptation concerned the addition of glassware and the inclusion of various chemicals to the ZimSci kit. This was called the BotSci kit and was available in secondary schools. Although this BotSci kit had glassware, it

was still a low-cost package which allowed science teaching to occur without the need for special laboratory facilities (Kahn & Rollnick, 1993). Since all secondary schools had been turned into government schools and basic education was compulsory for all, all schools had the same equipment (i.e. science kits and chemicals). The type of science teaching and practical work prescribed by the curriculum developers was thus uniform (Kahn & Rollnick, 1993; Nganunu, 1992).

Swaziland

In Swaziland, the schools that had scientific equipment were exceptions rather than the rule and therefore practical work at secondary level was not performed on regular basis. The teachers were, however, expected to improvise and also to use the environment in general wherever they could for practical work. Swaziland experienced a shortage of qualified science teachers and teaching resources for a long time. However, it had overseas in-service support for teachers and teacher training in place (Kahn & Rollnick, 1993). This showed that the government took an initiative to help un/underqualified science teachers so that even though the schools may not have had enough resources, the teachers could gain the experience, confidence and expertise to perform practical activities for their pupils.

Lesotho

Practical work was not compulsory in the schools. There was a great shortage of practical equipment in many schools (Kahn & Rollnick, 1993). Anecdotal evidence suggested that practical work depended on the teachers' enthusiasm for demonstrations. In the rural areas, there was a very low number of laboratories in schools and hardly any practical work was done. There was a severe shortage of practical work equipment and trained science teachers. The country was dependent on expatriate teachers and foreign teacher support services for their science education (Kahn & Rollnick, 1993).

The situations in Lesotho and Swaziland were similar in that the resources available in the different schools differed greatly. Those schools where students paid high fees (which are mostly private schools) could afford more resources and competent teachers than those schools where pupils paid lower fees (these were mostly government and church schools) and these

were attended by people from poor economic sector.

It is not known what changes have occurred in these countries recently.

2.4 PRACTICAL WORK IN SOUTH AFRICA

2.4.1 Laboratory situation in RSA

The quality of education in the RSA differed according to its 'races' and regions (Hall & Hofmeyr, 1995). Before the 1994 elections, the departments of education were divided according to 'race', and the independent territories also had their own departments of education. More money, per pupil, was spent on the 'white' education than other (i.e. 'Indians', 'coloureds' and 'blacks') 'race' groups for the last four decades (Lynch, 1994a). Different schools had differing access to facilities, apparatus, equipment and maintenance of laboratories for practical work (Lynch, 1994a).

What follows in the following paragraphs looks at the situation of laboratories in the different former education departments. A well equipped laboratory according to Lynch (1994a) was one that had:

(i) a sufficient supply of equipment and glass; and

(ii) adequate provision of services to perform practical work on individual or small groups (i.e. of 3 to 5 pupils) bases.

A sufficient number of laboratories per school was taken as 1 laboratory per 200 pupils.

The former 'white' schools were relatively privileged over other schools in terms of laboratories, services and resources. They also had well-trained teachers and smaller class sizes of 20-30 pupils (Lynch, 1994a; Bradley & Vermaak, 1996). Practical work (i.e. teacher demonstrations or individual/groups) in these schools was, however, not fully exploited since it was not compulsory.

The private schools had better financial resources and no bureaucratic hindrances like many of the other schools. So practical work was better organised than in the state educational authorities.

In the 'Indian' schools, falling under the former House of Delegates (HOD), practical work was compulsory. The supply of apparatus and chemicals for prescribed experiments was better maintained. However, about one half the teachers surveyed in these schools claimed to find it difficult to perform teacher demonstration due to insufficient facilities in the schools. However, many teachers in these schools, therefore, preferred teacher demonstration over pupil hands-on practical work, as the latter would require more time and addition- esources.

In the 'coloured' schools (former House of Representatives, HOR), there was a fair supply of apparatus and chemicals, like in the former 'Indian' schools. The facilities were regularly maintained, although practical work was not compulsory. The style of practical work followed here was mostly teacher demonstrations and very little was done to encourage individual or group practical work.

Former 'black' schools (i.e. falling under former Department of Education and Training, D.E.T.), especially in the rural areas, had the poorest provision of services, equipment and material resources. The situation was brought about by the tense political environment of the 1950s. Some schools had no laboratories at all. In those schools that had laboratories they were not functional due to lack of required apparatus or equipment; lack of maintenance and the exclusion of some facilities (such as gas, w:.:r and electricity) in the construction of the laboratories. Practical work was, therefore, neglected in many schools due to the above situation, coupled with overcrowded syllabi. Added to this was a problem of large numbers of pupils in classes, with teacher/pupil ratio ranging from 1:30 to 1:60. There was also a substantial shortage of qualified and competent teachers. In these schools, facilities were limited even for formal demonstrations. The department however, set practical questions in the examination papers to encourage teachers to perform practical work (Naik, 1995). Although this was the case, practical work was generally not done in the schools. Only the enthusiastic teachers performed practical work while the other teachers did not participate at all (Lynch, 1994a; Bradley & Vermaak, 1996). The situation in these schools was similar to that in the former SGT. Due to the situation in former 'black' schools being far worse than the others, these are referred to as the disadvantaged schools in this research report. In many of these schools the Science Education Project (S.E.P.) kits were found and were taken as conventional

practical work equipment. Many teachers were found to recommend them and in most cases used them for teacher demonstrations although they were designed for pupil group work (Lynch, 1994b).

In general, very little practical work was done in schools in RSA, although the majority of science teachers claimed that it was important in science teaching (Naik, 1995). Bradley & Vermaak (1996), however, write that practical work is given more value than it deserves. Some teachers in schools that have equipped laboratories have been found to avoid practical work.

The table below shows the findings from an FRD feasibility study of the laboratory situation in five clusters in RSA. Namely, Port Elizabeth/ East London/ Ciskei; Natal/ Kwazulu; East Rand; Western Transvaal and Lebowa. These are labelled cluster 1-5 respectively. A sample (i.e. not all schools in a region) of schools in each cluster was surveyed for this study and many of these schools were D.E.T. schools and those in the independent territories.

KEY:

PE, EL & Cis: Port Elizabeth, East London and Ciskei
Natal KZ: Natal and Kwazulu
E.Rand: East Rand
W.Tvl: Western Transvaal

TABLE 2.1
LABORATORY SITUATIONS IN 5 REGIONS IN SOUTH AFRICA (FRD FEASIBILITY STUDY)

REGION	PE,EL & Cis	Natal KZ	E.Rand	W.Tvl	Lebowa
Cluster No.	1	2	3	4	5
Number of schools	7	6	5	8	6
Number of Pupils	6500	5100	7850	7535	6100
Context	both	both	urban	both	rural
LABORATORY					
Formal labs provided	19	4	9 of 21	24	7
Services	2g 4w 4e	1g 3w 3e	4g 5w 5e	3g 8w 8e	3g 4w 4e
General Apparatus	4	1	2	4	4
Chemicals	7c 5b 2a	6c 4b 1a	5c 5b 1a	8c 7b 5a	6c 4b 0a
Alternate to labs eg kits	6S	5S	2o 4S	0	7S
Storage	6R	4R	5R	8R	7
Maintenance	0	1	1	0	0
Ordering	3S 1O	-	2S	1S 1O	0

Taking the East Rand cluster as an example, where this study was conducted, it is labelled cluster 3. In this cluster, 5 schools, all of which were urban, were visited and there was a total of 7850 pupils in these schools. The schools had 21 laboratories in all, but only 9 of them functioned (i.e. were used when doing practical activities). Only 4 laboratories had gas while 5 had water and 5 had electricity. Two laboratories only had general apparatus for physical science experiments. Five laboratories had adequate chemicals, 5 had rough balances, and only 1 had an accurate balance. Four laboratories used S.E.P. kits as an alternative to practical work and teachers in 2 laboratories improvised by using other means. Only 5 laboratories had proper store rooms. One school had maintenance strategies in place, and only 2 schools had used the ordering procedure to order equipment or chemicals in the year prior to the survey. In the light of this data these schools are, therefore, considered to be disadvantaged.

The cost of education in the well-equipped schools was very different from the cost of education in the former D.E.T. schools and those schools falling under the former self-governing territories (Kahn & Pollnick, 1993). There was however, a hope to have basic free education including science education for the first ten years of schooling. In which case many children would have the opportunity to learn science.

The Lynch (1994a-c) reports are the latest available references about the school laboratory situation in RSA. Anecdotal evidence suggests that the situation has not changed much from the one described by Lynch in 1994.

2.4.2 Current physical science teachers' qualifications

According to Lynch (1994a), very small numbers of student teachers enrolled in science subjects specialisation. Also, many teacher educators in these colleges of education did not have the academic qualifications and the teaching experience to motivate the student teachers (Hofmeyr, Salmon, Shaw, Mbulawa, De Wee, Cook and Letuka (1995)). The majority of physical science teachers were trained at colleges within the 'black' education system and they used the D.E.T. teacher training syllabus (Lynch, 1994a). The facilities in these colleges were lacking. The small number of inadequately trained teachers coupled with qualified and competent teachers leaving teaching for better salaries and less stressful jobs led to a lot of

vacancies in secondary schools. These were sometimes filled by teachers trained in other subjects or by those with any science degree but without teaching certificates (Lynch, 1994a; Hall & Hofmeyr, 1994).

One definition of a qualified science teacher is one who has a standard 10 certificate and three years of professional training (M+3), (Hall & Hofmeyr, 1995). Another definition requires a four years' teaching diploma specialising in science subjects; or a university degree with majors in science subjects and higher education diploma (Lynch, 1994a). Hall & Hofmeyr (1994) say that the statistics of 1994 report that 53% of African secondary teachers were un/under-qualified to teach general science at a level up to grade 9. They also report that another 27% of African teachers taught physical science (i.e. at a level up to grade 10-12) without the appropriate qualifications. They found that more un/under-qualified teachers were in the teaching system for a longer period than the qualified teachers.

According to Lynch (1994a), a teacher competent in practical work should also be competent in science teaching. And he defines competent teachers as those who are able to:

(i) do practicals themselves;

(ii) use the practicals; and

(iii) manage the scientific facilities.

These teachers will be able to shape science learning. In the disadvantaged schools, there were very few qualified and competent teachers. This then implies that practical work could not be done adequately in the disadvantaged schools.

The SYSTEM (acronym for Student and Youth into Science, Technology, Engineering and Mathematics) programme is a National Ministry of Education initiative. It is intended to give selected students a second chance to write the senior secondary school leaving certificate in science, mathematics, English and technology. SYSTEM is also intended to improve science teachers' qualifications; train more science teachers; and also to train some arts teachers to be science teachers (Education Department ANC, 1994). This is an initiative to alleviate the problem of the dearth of qualified science teachers able to perform and manage practical work.

2.4.3 In-service teacher training for teachers in the disadvantaged schools

As stated in the previous section, the majority of teachers were trained through the D.E.T. system which itself was failing to produce suitably competent and qualified teachers. It was believed that these teachers would then upgrade themselves professionally through the in-service teacher training programmes. Studies made on the pre- and in-service programmes revealed that there is no articulation between the two. It was suggested that this could be caused by the fact that they were run by different organisations. The majority of teachers did attend various in-service programmes, more especially so for the un/under-qualified teachers. Even the qualified teachers improved their qualifications to four or five years' professional training after matric. However, this was often not science focussed (Hall & Hofmeyr, 1995).

Teachers attended in-service courses because they experienced difficulties when pursuing skills, concepts, cognitive abilities, understanding, etc, when they get to the schools. They also attend in-service courses because it is believed the skills and knowledge acquired in the pre-service courses are limited. The teacher trainers, however, believe that most of the skills developed through practice, experience and advice from peers in the schools. However, some people did not believe these pre- and in-service courses could offer the learners enough opportunities to gain skills and competencies in practical work in particular (Lynch, 1994a).

2.5 SMALL-SCALE CHEMISTRY (MICROCHEMISTRY) EXPERIMENTS IN SECONDARY SCHOOLS AND TERTIARY INSTITUTIONS

According to a (1996) Brochure from Somerset Educational (i.e. the kit producing company), microchemistry was developed in Princeton University and other international institutions. In the brochure, it is stated that the first individual kit was produced in 1993 and since then it has been undergoing research and development. It is, however, not mentioned which institution produced it initially and where the kit was used first. Forms of microchemistry are also found in international educational systems.

The researcher identified the reasons that different institutions gave for opting for a small-scale approach rather than using the conventional scale. Butcher (1985), opted for small-scale experiments in instructional laboratories of educational institutions because initially they had

a problem of the air quality in the laboratories. They proposed two options: 1) that of increasing the amount of hood space and ventilation per student, and 2) completely eliminating some materials from use. The former would be too expensive and the latter would not enhance educational objectives. They opted for modifying experimental techniques used by students in order to minimize laboratory emissions. Therefore, experiments were carried out on a smaller scale. This proved to be beneficial in a number of ways. Those that are relevant to this research work are listed below.

(i) Increased laboratory safety with almost complete elimination of fire explosions.

(ii) Lowered capital investment.

(iii) Lowered energy use, since instead of a burner or an electric heater, a micro burner was used.

(iv) Lowered material costs as less material was used.

Sonnenberger and Ferroni (1989) converted some high school experiments into microscale due to cost problems listed by Butcher (1985). This approach solved their problems regarding cost, and chemistry experiments could still be done.

According to Chloupek-McGough (1989), the microscale approach was adopted in an attempt to solve the problem of waste disposal in the USA. Waste disposal was found to be expensive and also there seemed to be no place willing to accept it. In secondary schools in RSA, not much work has been done on the impact of waste from school laboratories.

A microscale approach was also adopted at Deakin University initially to save money, chemicals and to increase safety of the laboratory. The lecturers at this university then found microscale to be challenging and associated with current research. They also viewed it as a process of providing students with answers to their own questions relating to theory and practical work (Mocellin & Russell, 1996). According to the these authors, the idea of reducing amounts and sizes of materials used for chemistry experiments had existed since the 1950s. They however, mention that small-scale chemistry has taken a long time to be widely used because some teachers who have taught for a long time, tend to be reluctant to change.

Gruvberg & Schultz (1996) discovered that the chemistry experiments performed by their pupils had very little connection with everyday life. Coupled with this the experiments themselves involved a lot of preparatory work, items to use and many steps to consider. They converted these conventional experiments to small scale experiments with the aim of drawing the students' attention to chemistry. They managed to capture students' attention and also found that the students appreciated it for:

(i) saving time and preserving environment;

(ii) facilitating understanding; and

(iii) giving students the opportunity to perform experiments that they could not perform on the conventional scale.

Points (i) and (iii) are included in the advantages listed by Butcher, for using microchemistry. From a survey conducted with students involved with microchemistry, the students had the following comments to make about it:

(i) the concepts behind the experiments are easier to find; and

(ii) it is safer to work with.

Teenagers enjoyed microchemistry more than adults.

The authors also list the following institutions that have adopted microchemistry:

(i) National Microchemistry Centre in North Andover; and

(ii) Colorado State University.

A study by Bradley & Vermaak (1996), conducted in RSA revealed that the pupils found microchemistry interesting, supporting understanding of concepts and safe to work with. The second and third points are similar to two of the three points listed by Gruvberg & Schultze (1996). Some pupils however, did not like the size of the apparatus used in an early version of the RADMASTE microchemistry kit (Bradley and Vermaak, 1996). Bradley & Vermaak (1996) also found that former T.E.D. pupils were more positive towards microscale approach than former D.E.T. pupils. They argue that D.E.T. and T.E.D. pupils have different attitudes towards practical work because they have studied in different environments.

In the light of these findings, the researcher decided to investigate the implementation of small-

scale chemistry in some disadvantaged, former D.E.T. schools.

2.6 REVIEW OF PUPILS' UNDERSTANDING OF SOME CONCEPTS OF ACIDS AND BASES.

Literature on how pupils understand some concepts of acids, bases and neutralisation was reviewed. The teachers and the pupils, involved in this research, were observed performing an acid-base titration experiment using RADMASTE microchemistry equipment. Pupils' understanding of these concepts from the literature was used when analysing the outcomes of some parts of this research.

In a study conducted by Cros, Chastrell & Fayol (1988), students were found to define an acid as a substance which releases H^+ ions and they were also found to leave out that it has pH less than 7. The majority of these students were also found to say that a base releases OH^- although the students were taught to avoid that explanation. Students were also found to understand acids better than bases. Cros et. al. (1988) believed that it happened because in many instances, teachers pay more attention to acids than bases.

Botton (1995), in his research found a group of students using the terms 'strong' and 'concentrated' acids interchangeably, as if they meant the same thing. They, however, understood the process of neutralisation. On the other hand, the study conducted by Schmidt (1995) with senior high school students revealed that acid-base pairs were only applicable where neutralisation reactions occurred. It is not explained that neutralisation in these cases does not imply that a neutral solution, which is neither basic nor acidic (which is the literal meaning of neutral), is formed. This was proof that students sometimes could not predict the outcomes of an acid-base reaction. They often understood that any acid-base reaction resulted in a neutral solution (Schmidt (1991); Schmidt (1995)). This is attributed to the Arrhenius definition that neutralisation is when hydrogen ions reacted with hydroxide ions forming water molecules. It also used the same theory that acids release H^+ ions and bases release OH^- ions, Schmidt (1991). Schmidt (1995), therefore, appreciated why students experienced difficulties where acid-base reactions are concerned.

Two senior high school students involved in a study conducted in Canada were found to have the following misconceptions:

(i) a gas is produced during the neutralisation of one acid by a base;

(ii) more hydrogen gas is displaced from a strong acid because the strong acid contains more hydrogen bonds than the weak acid;

(iii) acids taste bitter and peppery;

(iv) all substances with sharp and strong smells are acids;

(v) all acids are strong and powerful;

(vi) acidic substances are not to be ingested;

(vii) acids contain hydroxide ions;

(viii) all acids are poisonous;

(ix) fruits are basic; and

(x) substances that burn are acids.

This study also showed that it was difficult to remove some misconceptions which the students bring to class, Ross & Munby (1991).

2.7 THEORETICALLY IDEAL MODEL FOR INTRODUCING PRACTICAL WORK.

Brian Woolnough (1991), in his book entitled 'Practical Science' argues that practical activities in school science consist of three things. These are investigation, exercise and experience. The sequence followed is the one followed by Woolnough himself. He however, does not state that the three stages should follow each other in a particular order. Each of these categories are described according to Woolnough in the following paragraphs.

Investigation

He writes that each scientific activity must have a practical investigation behind it. The investigation involves planning, performing, interpreting and communicating which is coupled with continual modifications obtained from feed-back.

Exercise

Woolnough says that exercise is necessary if one needs to develop certain skills or to become familiar with some apparatus. He, however, believes that the practical exercise should be incorporated to a specific scientific activity so that the skill is not developed out of context.

Experience

Experience means that the learner gains the feel for the phenomena under investigation. The experience gained then forms the basis for understanding and subsequently acting after forming the links.

Woolnough then compares his theory to Hodgkin's (one of the authors in his book) model. According to Hodgkin, in order for personal growth to take place, the learner needs to have commitment and challenge. The teacher should provide a supportive and stimulating environment for the learner. Hodgkin also describes three types of activities that the learner needs to do, to enjoy a wide range of experience. These are: playing, practising, and exploring. Hodgkin says that the learner plays to gain interest and familiarity, practices to gain competence and confidence and explores to meet challenges. Woolnough argues that playing (i.e. according to Hodgkin) compares to his experience, practice to his exercise and exploring to his investigation. It is also argued in this book (Woolnough, 1991) that practical science gives the learner the opportunity to develop all three activities together. This happens best when interest, enjoyment, commitment, perseverance, self-confidence and challenge are maintained throughout the practical activity.

The roles of a learner and the teacher stipulated by Woolnough for an ideal learning situation are described. While the learner plays, the teacher should create the space for that and when learners practise (i.e. the skills), the teacher should sustain a dialogue or feed-back that can help the learner to modify practices continuously. And finally, when learners explore new avenues, the teacher should stimulate learners by providing them with the fun and the challenges of science.

Woolnough also writes that it is important for the teacher to consider the preconceptions,

skills, expertise and attitudes which are gained from years of experience, that the learner brings into this science lesson. The teacher should also consider the skills and ways of solving problems that have been taught or learnt by the learner. The teacher should bear in mind that the learner's insight and knowledge grows in the learning institution through discussions, exposition and consolidation which are available from tackling scientific problems.

What is deduced from Woolnough and Hodgkin is that the most important thing for learning (and in this case introduction of the RADMASTE kit) to occur is the enthusiasm and commitment from the learner (both teachers and pupils) which are cultivated by the supportive and stimulating environment provided by the teacher (facilitator or teachers). The learner should first play so as to cultivate interest and to become familiar with the materials used or the styles followed. There should be challenges that the learner is faced with. The latter needs to have confidence, and the skills (gained from previous practice or exercise) required to tackle the new problem.

2.8 RATIONALE FOR THE RESEARCH METHODS FOLLOWED IN THE STUDY

2.8.1 Case Study

The purpose of a case study is mainly to understand a phenomenon. It involves subject's feelings, beliefs, ideas, thoughts and actions about situations and events being narrated. The events and situations are studied better through observations and interviews. In case studies, research strategies are flexible and the researcher has a choice of methods since the study does not require that a methodology be decided in advance. More than one method of data collection can be employed. For a case study, the researcher focuses on one phenomenon which will be described, analysed and understood in depth. The validity of a case study rests on the study's strength in describing or evaluating it. This is so because the study will have a lot of data supporting any given argument. A case study is, however, not reproducible since the research conditions purposely are not controlled (Rossman & Marshall, 1989).

2.8.2 Multimethod approach

More than one method was used to answer each of the three research questions in this study. It is the aim of the study to give a clearer picture of what is happening in the schools and the

workshops where microchemistry is introduced. Cohen and Manion (1994) argue that if one method is used in a research, it can affect the findings of that research. They write that in some instances, the respondent is either suspicious or wary, or aware of what the researcher wants. They, therefore, respond in a way that they believe will please the researcher (Cohen & Manion, (1994); Marshall & Rossman, (1989)). Many methods should, therefore, be used to show that the outcomes are not a result of the one method used. When the methods contrast with each other, then this means that the outcomes become more reliable. If multiple sources of data are employed, then this enhances the study's chances of being generalisable. Qualitative research is otherwise not generalisable since it becomes highly focused (Marshall and Rossman, 1989).

The methods used in this research include, observations of classrooms and workshops; teachers' and pupils', and RADMASTE staff's interviews; analysis of teacher and pupil evaluation forms and of pupil workbooks. Data obtained from these different methods, therefore, becomes abundant and it becomes another problem for the researcher to select important findings from unimportant ones (McMillan & Schumacher, 1993).

2.8.3 Interviewing

Interviewing can be used to achieve the following:

(i) for gathering information (e.g knowledge, values, attitudes);

(ii) for clearer explanations and understanding; and

(iii) to support other methods for validation of the method or to understand the respondent's behaviour better (Cohen & Manion, 1994).

An interview is a good method of data collection when the researcher wants the respondent to reflect on past events. It also allows the researcher to have detailed discussion with the respondent and therefore the researcher might have better understanding (McMillan & Schumacher, 1993). Interviews tend to be biased if the interviewer is not thought of as a 'neutral medium through which information is exchanged'. That is if the interviewer is somehow associated with the purpose of the interview.

2.8.4 Observations

Observations rely on the researcher who observes and not on the subjects concerned. If observations are made without the researcher's or observer's bias and judgements are made subsequently, they are more reliable.

Advantages of observations are the following:

There is no self-response bias; response set; and limitations to recalled information alone. For observation, behaviour can be recorded as it occurs and the settings are not artificial, they are as they occur. Although this is the case, complex behaviour is difficult to record. However, it is important for the researcher to define the aspects that will be observed. When continuous observation is used, description of the subject's behaviour is described chronologically (Schumacher & McMillan, 1993).

2.8.5 Questionnaires

Questionnaires can be used in research because they are: economical; have standard questions; can ensure anonymity and the questions used can be written for the specific purpose intended. Questionnaires can be used to gather information if there are no other, more reliable and valid techniques that can be used (Schumacher & McMillan, 1993). Questionnaires, however, have the limitation that they are not interactive and one has to rely solely on the clarity of the questions to the respondent.

SUMMARY

Many science teachers and educators agree that practical work is essential for the science orientated subjects. The styles of practical work have, however, changed from theory alone, to laboratory instruction in the form of teacher demonstrations, to guided discovery, to processes, investigation and to Science, Technology and Society. The aims of practical work have been ranked in the same order by different teachers in the UK and in South Africa.

Many teachers seem to lack the rationale and competence to perform effective practical work in the schools. Existing literature, however, shows that practical work often does little to improve conceptual understanding. On the other hand, many schools suffer bureaucratic, financial, curriculum and safety problems that hinder them from implementing individual

practical work. Some institutions implemented a small-scale (microchemistry) approach to solve this problem. Such schools (i.e. disadvantaged), in RSA are those investigated in this study. Introduction of RADMASTE microchemistry (a small-scale chemistry approach) was compared to Woolnough's model of introducing practical work. Woolnough suggests that learners should practice and then use the experience gained in this practise to tackle more investigations.

The literature also revealed that within the topic 'acids and bases', pupils generally:

(i) confuse 'strong' and 'concentrated' substances;

(ii) assume that any acid-base reaction result in a neutral substance, and, therefore, cannot, predict the outcomes of an acid-base reaction; and

(iii) have their understanding of acid-base reactions based on the Arrhenius definitions of acids and bases.

Case study is good when one wants to describe, analyse and understand a phenomena in depth. It involves a variety of methods and it is flexible although it cannot be reproduced. Interviews, observations, questionnaires and workbook analyses were, therefore, employed in this study to enable one to answer the questions in a more comprehensible way.

3

METHODOLOGY

3.1 INTRODUCTION

The RADMASTE Centre started its project of introducing small-scale chemistry (referred to as microchemistry) in secondary schools in May 1994. These secondary schools were some of the schools selected from the Thousand Schools Project (T.S.P.). T.S.P. placed the schools in clusters depending on their locations. The researcher was involved with the Duduza and Soshanguve clusters. Both these clusters were located in the Gauteng Province, were relatively easy to access and the timing of the workshops suited the researcher.

RADMASTE microchemistry was introduced to physical science teachers through three workshops in each cluster. These consisted of one orientation workshop and then two follow-up workshops. These workshops were about six weeks apart. The six weeks spacing of the workshops allowed for changes, if the initial dates did not suit some of the participants.

The researcher attended these three workshops (i.e. orientation and two follow-ups) in both Duduza and Soshanguve. The researcher also visited the individual teachers at their schools to find out their impressions on the orientation workshop and their intended plans of introducing the RADMASTE Centre small-scale chemistry to their pupils. The information was obtained using recorded interviews. The teachers then attended a second workshop where they were asked to report on their impressions regarding the RADMASTE microchemistry approach since the orientation workshop. The researcher visited the teachers at their schools in order to observe them introduce 'RADMASTE microchemistry' to their pupils. The teachers and the RADMASTE Centre facilitator met again at a final workshop to discuss problems associated with the RADMASTE Centre materials.

The details of the workshops and schools' visits are discussed in the following paragraphs.

3.2 ORIENTATION WORKSHOP

This workshop was arranged by the T.S.P. coordinator to include the teachers and the RADMASTE Centre staff. The orientation workshop in Duduza was held at the Duduza Resource Centre, while in Soshanguve it was held at the only school that was involved in the orientation workshop. The researcher attended both orientation workshops and took field notes.

The RADMASTE Centre facilitator told the teachers what microchemistry was and where the whole idea came from. The parties involved in the production of the materials were mentioned. He told them the advantages of microchemistry and the experimental topics that could be done using the RADMASTE microchemistry kit. He then told the teachers that the aim of the workshop was to show them how to perform experiments using the RADMASTE microchemistry kit and let them become confident using it. The talk was facilitated with the help of overhead transparencies (Appendix 7.3). The idea was that they would then be able to show their pupils how to perform experiments using the RADMASTE microchemistry materials.

The RADMASTE Centre facilitator chose Experiment B2 (Appendix 7.4) from the RADMASTE Centre worksheet for the teachers to perform. The teachers, both in Duduza and Soshanguve, performed Experiment B2 and they used the RADMASTE microchemistry kit and allied materials. The focus question for this experiment was; 'What volumes of sodium hydroxide solution are required to titrate equal volumes of two different acids of the same concentration?'. (The apparatus and chemicals that the teachers needed for this experiment were set out by the RADMASTE Centre facilitator.) The arrangement was such that on each table there was one worksheet, one paper cup of water, two sets of kits and one box of chemicals. Before the teachers could start on the experiment, the facilitator showed the teachers the components of the RADMASTE microchemistry kit, with their respective names and their uses. The facilitator watched the teachers as they performed the experiment and at strategic phases held some discussions with the teachers when he thought they needed explanation. The teachers were then asked to answer the questions on the worksheets. These were then discussed by all the workshop participants in a plenary session.

When the experiment was completed, the RADMASTE Centre facilitator gave out forms, (Appendix 7.5) which were for evaluation as well as planning, for the teachers to fill in. The questions on the evaluation form were then discussed by all the workshop participants so that the participants could hear different opinions, and give feed-back to the facilitator.

When this task was completed, each teacher was then issued with 40 RADMASTE microchemistry kits, 20 worksheets, 1 box of chemicals and 1 teachers' manual. The teachers then signed receipt of the equipment.

The researcher took teachers' contact telephone numbers so that they could be contacted for further school visits by the researcher.

3.3 FIRST SCHOOL VISIT

The researcher visited the individual schools on the days agreed on by the teacher and the researcher, to interview them. For interviews, the researcher used an interview protocol (Appendix 7.6). These interviews were transcribed and analysed for teachers' views and implementation plans (Appendix 7.7). The teachers were asked to indicate their impressions on the orientation workshop regarding the following issues:

(i) difficulties they experienced when working with the microchemistry kits;

(ii) their attitudes towards the RADMASTE microchemistry kits; and

(iii) the chemistry content that they had learnt from the workshop.

The teachers were then asked to explain the type of practical work they had in their schools before they were introduced to 'RADMASTE microchemistry' and how they intended to introduce RADMASTE microchemistry to their pupils. The teachers and the researcher then agreed on a date that the teacher would be introducing microchemistry to their pupils.

3.4 SECOND WORKSHOP

Although this workshop was arranged as a follow-up workshop to the orientation workshop, any teachers that were unable to attend the orientation workshop, but belonged to that particular cluster, could still attend the follow-up workshop. Such teachers were not followed to their schools by the researcher as they had not attended the orientation workshop and,

therefore, could not be interviewed on the orientation workshop. Field notes were recorded in these workshops as data. The teachers were then given a different experiment to perform on that day. No further equipment was issued to the teachers.

The second workshop was arranged to give the teachers the opportunity to report on their impressions when introducing the RADMASTE microchemistry to their pupils. It was expected that by this time the teachers would have introduced the RADMASTE microchemistry kit and allied materials to their pupils. However, this never took place in Duduza or Soshanguve. The orientation workshops were held in May for both centres. From the teachers' perspective: the physics component was not yet completed; and this was the time when the mid-year examination papers had to be set, checked, typed or word processed and printed. When the examinations were over, school holidays started. In effect, there was virtually no time for introducing RADMASTE microchemistry to pupils (as planned) between the first and second workshops. In practice, one teacher (T2) from School 2 had tried the approach (with another experiment), while two other teachers (T1 and T3) had not. Thus, only a few issues or concerns regarding the experiment on acid-base titrations could be reported in the second workshop.

3.5 SECOND SCHOOL VISIT

This visit was arranged by the teacher and the researcher based on what the teacher intended to do when introducing the RADMASTE microchemistry materials. This information was gathered from the interview that the researcher had with the teachers. In all the three cases, the teachers wanted to teach an introduction to the theory of acids and bases before the pupils could perform the experiment on the titration of monoprotic and diprotic acids. The researcher attended these classes as an observer and took notes on what the teacher taught and/or demonstrated.

The introductory lessons and the actual performing of the experiments did not take place in a day. It took several lessons, over a few days, for the theory to be taught and a lesson period was set aside for performing the experiment. As the pupils performed the experiment (experiment B2), they noted the results they obtained from the experiment on record sheets and

the researcher collected these record sheets to see whether the pupils obtained the expected observations (Appendix 7.8). When the pupils had done the experiment, they were then asked to fill in evaluation forms where they evaluated the experiments they had performed up to that point (Appendix 7.11). The teachers were then asked to select two pupils from their classes, one of high outstanding ability and the other one, a low ability pupil. These two pupils were to be interviewed on the following aspects:

(i) attitude towards the RADMASTE microchemistry kits and allied materials;

(ii) clarity of the worksheets; and,

(iii) understanding regarding the theme of the experiment.

The first pupil came in and after being interviewed went out and the second pupil came in not having time to communicate with the pupil that was interviewed before him. This prevented consultation amongst pupils. These pupils were interviewed by the researcher using an interview protocol (Appendix 7.9). The transcriptions of these interviews were made (Appendix 7.10).

3.6 THIRD WORKSHOP

After the teachers had done two sets of experiments in the orientation and the second workshops, and held discussions with the RADMASTE facilitator on their problems and concerns, they were called for a third workshop. This workshop was arranged to let the teachers try more experiments available on the worksheets so that they would gain confidence in using the RADMASTE microchemistry materials, and also to raise and discuss any problems and concerns that they had or anticipated regarding the RADMASTE microchemistry approach. The RADMASTE facilitator tried to answer the questions and also made suggestions to alleviate the teachers' concerns. The researcher made field notes.

3.7 RADMASTE CENTRE INTERVIEWS

One of the RADMASTE Centre directors and the facilitator were both interviewed on the RADMASTE microchemistry approach. In particular, they were interviewed using an interview protocol (Appendix 7.12) to find out the reasons for the RADMASTE microchemistry approach and beliefs about the achievements of this approach. These interviews were then transcribed (Appendix 7.13).

4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter the document, used by teachers in the orientation workshop and used by pupils, when introduced to RADMASTE microchemistry, is described and analysed based on the content knowledge, skills and attitudes stipulated in the physical science syllabus. This is done so that the reader knows the nature of the experiment performed. Description of the series of events the researcher attended to collect data follows. The sequence followed is more or less the same as that of the series of events.

In the orientation workshops, the field notes and teacher evaluation forms that were completed comprise the data. The outcomes of these workshops are discussed. The researcher visited the teachers at their schools (first school visit) and interviewed them, and so the teachers' perceptions of the RADMASTE microchemistry approach are discussed. During the second workshops, field notes were recorded and these are also discussed. In the second school visits (which happened for a period of more than one day), the teachers introduced RADMASTE microchemistry to their pupils. During these visits, the researcher took field notes, collected pupils' record sheets plus pupils' evaluation forms, and interviewed the pupils. The information obtained from these visits is discussed in detail in this chapter in section 4.6. The outcomes of the final (third) workshops are also discussed. The outcomes of the interview with one of the RADMASTE directors, and with the microchemistry project leader follows.

In some cases there are comments written in square brackets. These are the researcher's comments and are used to clarify observations or highlight anomalies or discrepancies. Sometimes the comment is to draw the reader's attention to matters which a straightforward reporting of field notes might not make obvious.

Comparisons and analyses of the results obtained will be discussed in chapter 5.

4.2 DOCUMENT ANALYSIS

This analysis of the RADMASTE worksheet is done in relation to the relevant parts of the school physical science syllabus and it focuses on the content knowledge, skills and attitudes (Appendix 7.1) .

Section 1.1.1 of the 'aims' (which precedes the specific content of the syllabus) states that physical science teaching should 'provide pupils with the necessary subject knowledge'. The experiment that was performed for this research was based on acid-base titrations of hydrochloric and sulphuric acids (of same concentration) with a base also of known, similar concentration. According to section 2.7.2 standard 8 (for grade 10) of the same syllabus, the subject content that the pupils should learn includes neutralising an acid with a base. The specific practical activity listed in the syllabus is neutralisation of hydrochloric acid with sodium hydroxide. With the (grade 10) material, it is stated that the pupils should learn and carry out a simple acid-base titration. The worksheet that the pupils used for the practical exercise provided the necessary help on the subject knowledge that is specified by the syllabus. Students were performing titrations of these two strong acids with the base, sodium hydroxide solution. So the worksheet covered the content requirements of the grade 10 syllabus.

Section 4.5 of the grade 12 syllabus deals with acids and bases. It specifies that the pupils should learn about nearly complete and partial dissociations of acids in solution. It also deals with this dissociation of acids to give H^+ ions and bases to give OH^- ions in aqueous solution. The syllabus also states that the pupils should learn about proton (or hydrogen) transfer, donation and acceptance. It includes the use of indicators to determine acidic and basic substances. In the experiment performed, the worksheets dealt with the dissociation of hydrochloric and sulphuric acids to give H^+ ions and that of sodium hydroxide solution to give OH^- ions. An indicator, methyl orange, is used to determine the acidic, basic and neutral states of the different solutions. The pupils needed to understand the dissociation concept if they are to make sense of the pH concept. Definition and calculation of pH using H^+ and OH^- ions are also part of the syllabus. pH calculations are dealt with in certain of the RADMASTE worksheets, although not the particular ones investigated in this research.

The next general aim of the syllabus states that the pupils should also develop the necessary skills, techniques and methods of science. In the practical exercise, the pupils handled different items. They needed to develop the necessary manipulative skills in order to perform that experiment and the subsequent ones. This aim of the syllabus is addressed in the RADMASTE instructional materials as well.

The syllabus states that pupils should be introduced to 'scientific explanation of phenomena'. It also states that pupils should learn to use scientific language. The questions in the worksheet require the pupils to give explanations to certain phenomena that they observed. While doing this, they would need to use scientific language. In this way, the materials do address this aim of the syllabus.

In Section 1.2 (also 'Remarks') it is stated that teachers need to simplify and summarise for pupils. This is up to individual teachers as to how they do it. In the RADMASTE approach, teachers are encouraged to do that. This was made explicit in the orientation workshop.

There is a section (1.5) within the Introduction of the syllabus, which emphasises that pupils should be exposed to continuous hands-on practical work which should be evaluated and marks allocated. It is also emphasised that the teachers should ensure the safety of the pupils during the practical activities. The RADMASTE materials include guides which give the teachers information on the safety measures that they should follow. Teachers could, if they wish, use the worksheets and other means for evaluating their pupils' practical performance. So the materials can be used to address the aspect of practical work assessment.

Another aim states: 'to develop in pupils desirable scientific attitudes, such as interest in natural phenomena, desire for knowledge, critical thinking, etc.'. This aim is indirectly developed since the kit is something that the pupils saw for the first time and which they were allowed to handle, as opposed to watching demonstrations or handling conventional apparatus. The worksheets they used were also written (according to their teachers) in a different style to what they were used to. This could also trigger some interest, curiosity and critical thinking.

There is no specific mention about the affective domain with respect to science learning. This means that the syllabus aims do not include mention of helping students to like or enjoy their studies of science. However, psychological research suggests that students who enjoy what they do progress further than others of similar intellectual capacity who do not enjoy what they do.

4.3 ORIENTATION WORKSHOPS OUTCOMES

[The leader of the microchemistry project at RADMASTE Centre took the role of a facilitator during the workshops. He is thus referred to as the facilitator.]

4.3.1 Orientation workshop in Duduza

This workshop was held on the 23rd of May, 1995 at the Duduza Resource Centre. Four teachers were present at the workshop. Three of these teachers were males and one teacher a female. Two of the males and the one female were from the same school (School 1) and the other male teacher was from another school (School 2). Other participants in the workshop were the RADMASTE Centre facilitator who ran the workshop, and the researcher who acted as an observer, and took field notes. The workshop can be divided into four major events. These were:

(a) introduction to RADMASTE microchemistry;

(b) experimental exercise for the teachers;

(c) discussion and guidance for school use; and

(d) distribution of microchemistry equipment.

The details of the introductory remarks made by the facilitator can be found in Appendix 7.14. The introduction, consisted of the following:

(i) mention of advantages of microchemistry (i.e. small-scale chemistry) over conventional scale practical work in terms of cost and safety;

(ii) RADMASTE Centre and Somerset Educational's (i.e. materials producing company) partnership in producing the then existing worksheets and apparatus found in the kit;

(iii) the workshop was designed to allow the teachers some practice on microchemistry experiments in order to be able to introduce it to their pupils; and

(iv) demonstration and identification of names of items found in the kit together with allied materials using an overhead projector (OHP).

The facilitator arranged the RADMASTE materials so that the teachers worked in pairs. Detailed description of the experimental exercise for teachers, the role played by the facilitator and the discussions held in the workshop are given in Appendix 7.15. Below is a brief description of the experimental exercise.

The following happened:

(i) the facilitator helped the teachers, individually, to identify the items found in the kit;

(ii) T1 worked alone throughout the experiment and obtained reasonable (i.e. experimentally determined) results;

(iii) T2 could not understand why they obtained different volumes for the three titrations and he discussed this with the facilitator and consequently claimed to understand;

(iv) one teacher taught mathematics, but attended a science teachers' workshop;

(v) teachers said microchemistry experiments would be much easier than using the conventional method, both for them and for their pupils; and

(vi) the teachers completed a questionnaire about teachers' plans for the introduction of RADMASTE microchemistry in the schools, this was discussed and the facilitator gave advice.

4.3.2 Orientation workshop in Soshanguve

A similar workshop was held in Soshanguve for one science teacher and one biology teacher. Introduction in Soshanguve was the same as that held in Duduza. The arrangement was such that the teachers worked individually. The main features of the workshop are given below while the detailed description is given in Appendix 7.16.

(i) several teachers from other disciplines intended to attend the workshop, but were not allowed to do so and other science teachers chose not to attend;

(ii) teachers from another school who were invited did not arrive at the school;

(iii) during the experimental exercise, the biology teacher was asked to repeat the experiment several times but T3 (i.e. the physical science teacher) obtained reasonable

results;

(iv) the experiment could not be completed since the facilitator ran out of time;

(v) the teachers were observed to have difficulty using the propettes and the facilitator helped them practise; and

(vi) during discussion, the facilitator and the teachers agreed that the pupils could work in groups (although RADMASTE microchemistry was planned for individual or pairs and not for groups).

Generally, the workshop was run for one science teacher who managed to obtain reasonable results and the biology teacher was found to be incompetent by the facilitator.

TABLE 4.1

SUMMARY TABLE OF SIMILARITIES BETWEEN ORIENTATION WORKSHOP IN DUDUZA AND SOSHANGUVE

EVENT	DUDUZA	SOSHANGUVE
INTRODUCTION	-2 physical science teachers present -a mathematics teacher attended -used OHT for presentation -told teachers advantages of microchemistry -worksheets described -names and uses of items found in the kit described -aims of workshop described	-1 physical science teacher present -a biology teacher attended -used OHT for presentation -names and uses of items found in the kit described
TEACHER EXPERIMENT	-teachers worked in pairs (although one left midway) -teachers familiarised with kit items and chemicals -experimental hints given to teachers -T1 managed experiment -T2 had several conceptual difficulties and did not handle the kit himself	-teachers worked individually -facilitator discussed focus question and experimental requirements -biology teacher performed experiment wrongly -T3 managed to perform the experiment correctly
DISCUSSION	-experiment discussed -implementation questionnaires completed and discussed	-experiment discussed -implementation questionnaires completed and discussed
DISTRIBUTION	-equipment issued to physical science teachers	-equipment issued to physical science teacher

4.4 TEACHERS' REFLECTIONS AND IMPLEMENTATION PLANS

The researcher arranged the dates of visit with the teachers over the telephone. The purpose of this first visit to the schools was for the researcher to interview the teachers on their opinions regarding the orientation workshop and plans to introduce RADMASTE microchemistry to their pupils. The researcher used an interview protocol (Appendix 7.6) to interview the three teachers, and subsequently transcribed the interviews (e.g. Appendices 7.7.1, 7.7.2 and 7.7.3).

Below is a short description of the three teachers' (T1, T2 and T3 respectively) perceptions about the orientation workshop. Detailed descriptions can be found in Appendix 7.17.

T1:

(i) used microscopic and macroscopic terms interchangeably;

(ii) incorrectly said that the experiment was based on determining the effect of concentration; and

(iii) had problems when handling some items found in the kit.

T2:

(i) did not mention the difficulty regarding the chemistry content which the researcher observed in the workshop;

(ii) avoided discussing the basis of the experiment the teachers performed in the orientation workshop; and

(iii) had inconsistent plans of introducing RADMASTE microchemistry (e.g. in terms of preparatory lessons, distribution of equipment and pupil guidance through the experiment).

T3:

(i) avoided discussing the content of the experiment; and

(ii) wanted pupils to work in groups of 10 and later changed to planning to have them work in pairs.

SUMMARY TABLE

The table on the next page is a summary of the three teachers' impressions about the orientation workshop, their previous practical work and the way they planned to introduce RADMASTE microchemistry to their pupils.

The titles used in the table are described below:

EXPERIMENT refers to teachers' reflections and impressions on the experimental exercise performed at the orientation workshop. It also refers to the teachers' impressions about RADMASTE microchemistry.

PRACTICAL WORK refers to the type of practical work that the teachers had prior to being introduced to RADMASTE microchemistry.

INTRODUCTORY PLANS refers to how the teachers plan to introduce RADMASTE microchemistry to their pupils.

TABLE 4.2

SUMMARY OF TEACHER RECOLLECTIONS OF ORIENTATION WORKSHOP, OF 'USUAL' AND PROPOSED PRACTICAL WORK.

ITEM	T1	T2	T3
EXPERIMENT CONCEPTUAL INTERPRETATION	-incorrect interpretation of experiment	-vague interpretation of experiment	-vague interpretation of experiment
APPARATUS HANDLING	-had difficulty handling apparatus	no difficulty handling apparatus	-had difficulty handling apparatus
WORKSHEET & CONTENT	-no problems with worksheet -no new concepts learnt -no difficulty with content	-no problems with worksheet -some new concepts learnt -no difficulty with content	-no problems with worksheet -some new concepts learnt -no difficulty with content
PREVIOUS PRACTICAL WORK	-1 set apparatus between two large groups	-pupils worked in groups of 6	-no practical work
INTRODUCTION PLANS	-give introductory lesson -familiarization with kit -pupils to work individually -pupils expected to understand experiment	-introductory lesson given to selected 8 and later changed -familiarization with kit already done 2 plans given: a) 8 pupils selected to perform experiment; b) whole class to work individually -pupils expected to understand experiment	-no introductory lesson mentioned -familiarization with kit 2 plans: a) pupils work in groups of 10; b) pupils work in pairs -pupils expected to understand experiment

4.5 SECOND WORKSHOP OUTCOMES

4.5.1 Duduza second workshop

The second workshop was held at the Duduza Resource Centre. Present at the workshop were T1 and T2 who attended the orientation workshop and two other persons whom the researcher had not met before.

One of these two other persons was a teacher from School 1 and apparently T1 had asked her to represent him at the workshop as he thought he would be late for the workshop. So, when T1 arrived, this teacher left. The other person called himself a Community Worker. He said his task was to see that the Duduza Resource Centre was being utilized by the Duduza community, and he also gave his unequivocal support in this respect. He said he could facilitate communication between teachers and people involved in education.

The RADMASTE facilitator had brought someone else (who had just been employed by RADMASTE Centre for the same microchemistry project) with him to assist him in running the workshop. This person was introduced to the teachers.

The workshop was planned to progress through three major steps. These were:

(a) report-back by the teachers on their experiences in the schools plus any issues that the teachers wanted to raise regarding microchemistry with possible solutions and hints from the facilitator;

(b) teacher exposure to more microchemistry experiments; and
discussion of the experiment just performed.

Details of these events follow the same sequence as the list of events above viz., (a) and (b). The description of the above-mentioned events is in Appendix 7.13.

The following points can be highlighted about the workshop:

(i) T1 had not introduced RADMASTE microchemistry to his pupils because the orientation workshop was succeeded by examination periods where he had to perform

some administrative tasks and did not have adequate time to introduce it;

(ii) T2 had introduced RADMASTE microchemistry using an experiment entitled 'Rates of Chemical Reactions' and the exercise took much longer than he had expected, also, the pupils did not understand the chemistry content involved in the experiment;

(iii) the facilitator advised the teachers to use the worksheets for guidance rather than something that should be strictly adhered to; and

(iv) the teachers performed another experiment using the RADMASTE microchemistry kit and subsequently discussed the chemistry content.

4.5.2 Soshanguve second workshop

A similar workshop to the one held in Duduza was held in Soshanguve. Two teachers were present for the workshop. These were T3 and another teacher from a second school (T4) who had not attended the orientation workshop. This workshop was held at School 3 where the orientation workshop was held.

This workshop is described in detail in Appendix 7.19.

In short:

(i) the facilitator gave another introduction as he did in the orientation workshop;

(ii) T3 had still not introduced RADMASTE microchemistry to his pupils as the schools closed immediately after the orientation workshop; and

(iii) another RADMASTE microchemistry experiment was performed and then discussed.

The two follow-up workshops were held for two teachers each. In both workshops the teachers could not introduce RADMASTE microchemistry in the time that passed between the orientation and the second workshops.

TABLE 4.3

SUMMARY TABLE OF THE SECOND WORKSHOPS (SWS) IN DUDUZA AND SOSHANGUVE

EVENT	DUDUZA	SOSHANGUVE
OVERVIEW	-T1, T2, assistant facilitator and community worker present -latest kit developments	-T3, T4 and assistant facilitator present -latest kit developments -introduction repeated for T4
REPORT-BACK	-T1 had not introduced the kit -T2 introduced the kit and lessons had taken a long time -some hints given to teachers	-T3 had not introduced the kit -no hints
EXPERIMENTAL EXERCISE	-results predicted and discussed -teachers worked with facilitators	-facilitator demonstrated some steps -teachers worked individually
DISCUSSION	-experiment discussed	-experiment discussed

4.6 RADMASTE MICROCHEMISTRY INTRODUCTION IN SCHOOLS

[The teachers were only able to introduce RADMASTE microchemistry to their pupils after the second workshop, except for T2, who claimed to have done so after the orientation workshop. This section deals with how the teachers prepared the pupils for the acid-base titration experiment that was performed using the RADMASTE microchemistry kits and allied materials]

4.6.1 Setting the scene in the schools

The way the teachers prepared their pupils for the RADMASTE microchemistry experiments is described below. In all three schools, the teachers gave introductory lessons based on some of the concepts related to acids and bases, viz., dissociation (of acids and bases) and neutralisation. The lessons given by the three teachers are described in detail in Appendix

7.20. The main points of the lessons in the three schools are highlighted below.

S1

Day One:

(i) the lesson took place on the first day of the second school term;

(ii) the pupils were told that they would be taught about acids and bases and then perform an experiment using the two substances;

(iii) T1 demonstrated dilution of strong (sulphuric) and weak (acetic) acids, without taking any accurate measurements;

(iv) T1 listed the names and formulae of some acids (with incorrect formula for benzoic acid);

(v) T1 also listed the dissociated forms of the above acids (ignoring the aqueous media) and also mentioned how this dissociation leads to weak and strong acids;

(vi) he mentioned that there was a difference between concentration and strength of an acid, although he did not discuss the clear distinction and he also gave incorrect units for concentration;

(vii) the distinction between volume and concentration was made with the use of problems from one textbook;

(viii) the effect of acids (acetic acid was used) on litmus paper was demonstrated but did not show expected colours (probably due to the acid being too weak) and function of indicators was also mentioned;

(ix) he said that the strengths of acids can be determined from the hydronium ions that the acids form when they dissociate;

(x) pupils were given more problems to solve and T1 later solved them on the board; and

(xi) many pupils did not take any notes during the lesson but only scribbled something after T1 told them the lesson was part of the syllabus.

Day two:

(i) T1 demonstrated titration of hydrochloric acid with sodium hydroxide (both of which were prepared without accurate measurements);

(ii) different colours of the indicator bromothymol blue (in different pH media) were

identified;

S2:

(i) T2 promised to give the researcher notes for his first lesson as he had to start without the researcher, but in the end these notes were not made available;

(ii) incorrect information concerning the researcher's presence in the class was given to the pupils;

(iii) reactions of acids with different substances were listed, one of which was incorrect and ionisation of these acids were also discussed;

(iv) equilibrium concept relating to acids was also discussed, much of which seemed confusing to the pupils; and

(v) the lesson, which T2 had said was incomplete, was never completed.

S3:

(i) formulae of several mineral acids and equations of dissociation (leaving out aqueous media) were listed on the board. Pupils were asked to do the same for other acids and they managed;

(ii) pupils could not complete the equation between sodium hydroxide and hydrochloric acid; and

(iii) the concept of neutralisation was illustrated using an analogy of boys of same strength, fighting and saying that no one would win. [One must take cognisance of the fact that an analogy can sometimes be misleading and misconceptions can arise.]

TABLE 4.4

SUMMARY TABLE OF MAIN POINTS OF INTRODUCTORY LESSONS IN THE THREE SCHOOLS

EVENT	S1	S2	S3
INTRODUCTORY LESSON	-lesson conducted in a laboratory	-lesson conducted in a laboratory	-lesson conducted in a classroom
	-5 to 7 pupils per bench	-4 to 6 pupils per bench	-2 pupils per bench
	-told about microchemistry	-microchemistry introduced without researcher	-description of microchemistry
	-demonstration of conventional titration	-no demonstration	-no demonstration
	-researcher correctly introduced	-incorrect introduction of researcher	-researcher not introduced
	-names and formulae of some acids (erroneous)	-none mentioned introduction made before	-names and formulae of some common acids listed on the board
	-dissociation of some acids to form ions -difference between strength and concentration	-substances containing acids or bases (erroneous) -strong and weak acids plus their dissociation (erroneous)	-dissociation of these acids (some parts erroneous)
	-properties of acids and of indicators some indicators mentioned	-properties of acids (some parts erroneous)	-no revision of acid properties
	-no analogy used to describe neutralisation	-concept of neutralization with analogy involving hot and cold water	-concept of neutralisation with analogy involving people fighting

4.6.2 Hands-on in the schools

This section deals with the pupils performing experiments using the RADMASTE kits and allied materials. The way the pupils were introduced to the RADMASTE microchemistry kits and allied materials differed in the three schools. These three events are briefly described below, looking at each school individually.

S1:

(i) pupils were each given a kit and each pair was given one worksheet;

(ii) pupils worked in pairs and followed worksheet instructions on their own;

(iii) use of the comboplate, propettes, mixing rods and chemicals were described but not demonstrated;

(iv) T1 distributed the chemicals and ran out of some of the chemicals. The pupils were asked to share the chemicals;

(v) a summary of the experimental procedure was given by T1; and

(vi) pupils were observed to have difficulty using the propettes and following instructions from the worksheets.

S2:

(i) T2 distributed the kits and worksheets. Groups of four or five pupils sat at each table and each group was given one kit and one worksheet;

(ii) chemicals were collected from the front bench by pupils using propettes:

(iii) an experiment on determining indicator colours for different pH values for three different indicators was performed by the pupils prior to acid-base titration;

(iv) T2 guided the pupils through the first few steps of the instructions;

(v) indicator colour range for one of the indicators gave different results from those given in the RADMASTE teachers' manual;

(vi) for the acid-base titration experiment, pupils worked in similar groups to those described in point (i) above;

(vii) pupils, however, obtained volumes which were two to three times more than experimentally determined values and this was attributed to incorrectly prepared chemicals; and

(viii) T2 promised to prepare new 'correct' solutions. He later informed the researcher that they worked, but the researcher did not observe this.

S3:

(i) T3 distributed one kit and one worksheet to each pair of pupils;

(ii) the pupils worked in pairs to perform an experiment on equilibrium and they followed instructions from the worksheet. The experiment was discussed by the whole class

afterwards; and

(iii) the acid-base titration experiment was, however, performed in three groups of, on average, ten pupils and they still followed the instructions on their own.

TABLE 4.5

SUMMARY TABLE OF DIFFERENCES AND SIMILARITIES IN THE INTRODUCTION OF RADMASTE MICROCHEMISTRY IN THE THREE SCHOOLS

S1	S2	S3
-names and uses of apparatus discussed -some problems with handling apparatus	-teacher claimed names and uses had been discussed -no problems with handling	-names and uses of apparatus discussed -no problems with handling
-individual kits distributed -worksheets shared per pair -pupils worked in pairs	-kits and worksheets shared per group of 4 pupils on average -pupils worked in these groups	-1 kit and worksheet shared per group of 10 pupils on average -pupils worked in these groups
-some problems with worksheet	-some problems with worksheet	-some problems with worksheet
-experiment worked	-experiment did not work	-experiment worked

4.6.3 Pupils' experimental results

This section deals with the results the pupils obtained from the acid-base titration experiment they performed. After the pupils performed the experiment and obtained results, they had to answer the questions which followed. The pupils' results and responses to the questions which followed are discussed in this section. This data was obtained from the pupils' workbooks that were collected after the pupils perform the experiment.

N.B. The questions as they appeared in the worksheet are written in the normal font. Inside the square brackets are elaborations to the situations and/or the researcher's comments. The pupils' responses for the three schools are grouped and inserted in tables.

The pupils in S1 worked in pairs and so the results in S1 are reported per pair. The results for S2 are reported per individual pupil and for S3 per group of ten pupils on average. So 1 for S1 represents 1 pair, 1 pupil in S2 and 1 group in S3.

Observations:

Obs.1: Note the colour of the solution in well A [1].

The pupils' responses from the three schools are combined in the table below.

[In this section, the pupils were adding one drop of methyl orange indicator to five drops of water. The resulting colour should be **orange or yellowish**. The table below has categorised the colours obtained or recorded from this procedure and the next column has the number of pairs which obtained that colour.]

TABLE 4.6

PUPILS' RESPONSES TO OBSERVATION 1 OF THE EXPERIMENT

COLOUR	S1(pairs)	S2(individuals)	S3(groups)
*Orange or Yellow	6	0	2
Pink & Red	0.00	0	1
No response	5	ALL	0

Obs.2: Note the colour of the solution in well A[2].

[In this case the pupils were observing the colour of the solution after adding one drop of methyl orange indicator to five drops of acid A. Acid A was 0.1 mol dm^{-3} hydrochloric acid. The colour of this should be **pink or reddish**. The colours were grouped and the number of pupils (i.e. using the same criteria as one used in Observation 1 above) that gave this response recorded next to the particular colour].

TABLE 4.7

PUPILS' RESPONSES TO OBSERVATION 2 OF THE EXPERIMENT

COLOUR	S1(pairs)	S2(individuals)	S3(groups)
Red & Pink	6	0	3
No response	5	ALL	0

FOR TABLE 4.8

[The pupils were then asked to add a 0.1 mol dm^{-3} sodium hydroxide base to the hydrochloric acid (referred to as acid A in the worksheet) and indicator solution until the colour of this solution was the same as that of water with indicator (i.e. until the solution was neutral). Five drops of a 0.1 mol dm^{-3} hydrochloric acid would be neutralised by the same volume of a 0.1 mol dm^{-3} sodium hydroxide (i.e. five drops). This titration was performed three times. The second set of titrations was that of 0.1 mol dm^{-3} sulphuric acid (five drops of this) with 0.1 mol dm^{-3} sodium hydroxide. A volume of sulphuric acid (five drops in this case) would be neutralised by sodium hydroxide of twice that volume (i.e. ten drops).

The table below shows the two sets of titrations (i.e. with acids A and then acid B), each titration being performed three times for the three schools (i.e. three trials). Values below 4 drops for the titration of acid A were too low and **4 to 6 drops** were acceptable. Values of 7 drops and above were taken to be too high. The average values are given in the same range as the titrations above it. The correct answer is marked by an asterix (*) and written in bold].

TABLE 4.8

GROUPED PUPILS' RESULTS FOR TITRATION OF ACID A

TITRATION	DROPS	S1(pairs)	S2(individuals	S3(groups)
1ST	Below 4	2	0	2
	*4 - 6	5	0	1
	7 and above	5	16	0
2ND	Below 4	1	0	0
	*4 - 6	5	0	3
	7 and above	6	16	0
3RD	Below 4	0	0	0
	*4 - 6	5	0	3
	7 and above	6	16	0
AVERAGE	Below 4	1	-none calculated	0
	*4 - 6	7		3
	7 and above	3		0

The table above shows that 70% of the pupils in S1 and 100% in S3 obtained expected results and in that sense showed they were, therefore, able to understand the instructions of the worksheet. All pupils in S2 could not obtain expected results and did not calculate average drops for the titrations performed. [This probably happened because the concentrations of the solutions were incorrect and also because the pupils did not understand that they were expected to calculate average values.]

The table below shows the titration of the second acid (sulphuric acid) in all three schools. The experimentally determined volume of this titration was **10 drops** of sodium hydroxide. Volumes from 7 drops downwards were regarded as too low. Those between 8 and 12 drops, inclusive, were regarded as acceptable. [The range of acceptable drops is larger here because more volume was required and there were more chances of error.] Those values above 12 were too high. The same criteria are used to report the average values.

TABLE 4.9

GROUPED PUPILS' RESULTS FOR TITRATION OF ACID B

TITRATION	DROPS	S1(pairs)	S2(individuals)	S3(groups)
1ST	Below 8	2	0	2
	*8 - 12	6	0	1
	13 and above	2	15	0
2ND	Below 8	3	0	0
	*8 - 12	5	0	3
	13 and above	1	16	0
3RD	Below 8	2	0	0
	*8 - 12	7	0	3
	13 and above	2	16	0
AVERAGE	Below 8	0	-none calculated	1
	*8 - 12	9		2
	13 and above	1		0

The table shows similar results to those shown in Table 4.9, but a better percentage (i.e. 90% as compared to 67%) in S1 obtained experimentally reasonable results. A lower percentage in S3 (i.e. 67% as compared to 100%) obtained experimentally determined results with acid B. S2 pupils had a similar error to that incurred with acid A.

QUESTIONS:

Q1: What is the answer to the focus question 1? [The focus question was as follows: **What volumes of sodium hydroxide solution are required to titrate equal volumes of two different acids of the same concentration?** (see worksheet Appendix 7.4 , page 1). The correct answer was that for hydrochloric acid it is **5 and for sulphuric acid it is 10 drops.** These volumes are obtained by calculating the average volume from the three titrations of each acid. The values written in parenthesis represent the number of pupils (or pairs or groups, depending on the school) who obtained that value if they are more than one].

TABLE 4.10

PUPILS' RESPONSES TO QUESTION 1 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
*-different volumes (8)	-no response (16)	-6
-3.7		-7
-9.3		-pink changed to orange

[Nobody answered the focus question correctly. Those that wrote that the volumes were different are correct but they do not give the actual volumes required. Perhaps the questions was not specific enough since a large percentage (i.e. 80% in S1) of the pupils gave this response.]

Q2: What is the volume ratio of NaOH/acid A? Hint: see Table 1. [The correct ratio is **5 drops NaOH/5 drops acid A = 1**. Values below 0.8 were too low, 0.8 to 1.2 acceptable and values above 1.2 were too high.]

TABLE 4.11

PUPILS' RESPONSES TO QUESTION 2 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
Below 0.8 (2)	- no response (16)	-5 and 5.7
*0.8 - 1.2 (4)		-12
Above 1.2 (5)		-ratios not the same

[The ratios in S1 were mostly calculated correctly with few errors. S3 pupils seem to have misinterpreted the question. The answers suggest that the questions were either too advanced or too ambiguous for the pupils.]

Q3: What is the volume ratio of NaOH/acid B?

Hint: see Table 2. [**The correct ratio is 10 drops NaOH/5 drops H_2SO_4 = 2**

The volume ratios below 1.6 were too low, 1.6 to 2.4 acceptable and above 2.4 was too high.]

TABLE 4.12

PUPILS' RESPONSES TO QUESTION 3 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
- Below 1.6 (2) ***-1.6 - 2.4 (5)** -above 2.4 (4)	-no response (16)	-5(NaOH) & 10(acid B) -no response (2)

[The one group that responded in S3 gave acceptable volumes but did not express them as ratios.]

Q4: Compare your answers to Questions 2 and 3 above and then explain these results. [The pupils were expected to state that the volume ratio in Question 3 was twice the volume ratio in Question 2.]

TABLE 4.13

PUPILS' RESPONSES TO QUESTION 4 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
- different (10) - acid B stronger than A	- no response (16)	- volumes not equal -B more concentrated than A ***-volumes in B twice volumes of A**

[Responses for S1 and some in S3 do mention that the volumes are different, but do not explain it any further. The common explanation is that acid B is stronger than acid A, which is not the case. Only one group in S3 mentioned that volumes of B are twice those of A, but gave no explanation.]

Extension questions:

Q5: Are the volumes of base, you used, as se[illegible] in Tables 1 and 2, precise or accurate? (Explain your answer and where applicable state if [illegible]her information is needed to answer this question). Hint: What are the definitions of precision and accuracy. [The pupils had to look

at the volumes they used in both tables. It would depend on how close the pupils' values were and they would tell whether the values were precise or not. For accuracy they needed the exact value to which they would compare their average value and tell whether their results were accurate or not. The question was possibly not clear enough. Possibly the two words were not understood.]

TABLE 4.14

PUPILS' RESPONSES TO QUESTION 5 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
- accurate (2) *- precise (10) - not accurate	-no response (16)	-no response *-precise (2)

Q6: If the average number of drops of base required to titrate 6 drops of acid A was experimentally determined to be 8 and the true value should have been exactly 6, is the experimentally determined result imprecise or inaccurate? [The experimentally determined result is inaccurate since it is not equal to 8. To decide whether it was imprecise or not, one needed a set of values and see how close they are to each other.]

TABLE 4.15

PUPILS' RESPONSES TO QUESTION 6 OF THE EXPERIMENT

S1(pairs)	S2(individuals)	S3(groups)
*- inaccurate (8) - imprecise - accurate - no response	- no response	- volumes equal

SUMMARY

The pupils in S1 and S3 answered most of the questions reasonably well. S1 pupils did better than S3 pupils in terms of answering the questions correctly. The pupils in S2 did not respond to any other question except recording the volumes of sodium hydroxide used to titrate the two acids.

4.6.4 Pupils' responses to evaluation forms

After the pupils performed the experiment on acid-base titration, they were given evaluation forms to complete and then a few (two per school) were interviewed. The evaluation forms were prepared by the RADMASTE Centre facilitator. The researcher collected these evaluation forms and analysed them as well. Copies of the evaluation forms together with pupils' responses, for the three schools, are in Appendix 7.22.

It was at the discretion of the teacher when the evaluation forms were to be given to the pupils. There were therefore different numbers of experiments performed by the pupils. The main findings of each school are described below.

MAIN FINDINGS

S1

Many pupils wrote that many of their experiments were performed through teacher demonstrations, but they believed that practical experience was necessary. Many pupils wrote that microchemistry was safer to use. They also wrote that it developed their confidence and practical skills. They mentioned that the worksheets were clear and understandable. The pupils wrote positive comments relating to the microchemistry chemicals.

S2

The pupils in S2 wrote that they both performed experiments as well as observed teacher demonstrations. [The researcher cannot say what this means, or whether the pupils understood the question.] They, however, agreed that practical exercises were necessary in order for one to understand chemistry. They said that the kits were easy and safe to use, interesting and that it developed their confidence. They also gave positive comments about the worksheets and the

chemicals.

S3

The pupils in S3 all worked with partners to perform RADMASTE microchemistry experiments. Many pupils could not recall the titles of the experiments they performed. Many pupils in this school both performed experiments themselves and the teacher demonstrated the experiments to them. [There may be a misunderstanding of the question, as for the pupils in S2.] Many pupils also found the kits easier and safer to use as well as developing their confidence in chemistry. A higher percentage said the worksheets were understandable, but rather too long. The pupils appreciated the storage of the chemicals as well.

4.6.5 Pupils' interviews

In this section the responses of the pupils to the interview are discussed. The pupils were interviewed using the Pupils' interview protocol (see Appendix 7.9). The interview was based under three sub-headings. These were:

(i) attitude towards RADMASTE microchemistry kits (which were labelled KITS);

(ii) understanding the worksheet instructions (labelled WORKSHEETS); and

(iii) understanding the experimental content [these are the concepts involved in an experiment] (labelled CONTENT).

The analysis of the interview transcripts was, however, carried out under four sub-headings. These were: KITS; WORKSHEETS; CONTENT; and COMMENTS. [Comments referred to any other information that the researcher could comment on.]

In each school, two pupils were interviewed. The pupils were labelled pupils 1 and 2, depending on the order in which they were interviewed. So in each school there was a pupil 1 and a pupil 2. In school 2, three pupils were interviewed therefore there were pupils 1, 2 and 3.

Below are brief descriptions of the pupils' interviews in the three schools. Detailed descriptions are in Appendix 7.23.

SCHOOL 1

P1 (Appendix 7.10.1)

She:

(i) said she liked the kits;

(ii) said she understood and could follow worksheet instructions although one of the questions was ambiguous; and

(iii) could not interpret the chemistry content involved in the experiment.

P2 (Appendix 7.10.2):

(i) said he loved the kits;

(ii) said he understood and could follow worksheet instructions;

(iii) said he had difficulty handling some apparatus; and

(iv) his interpretation of the experiment could not be recorded.

SCHOOL 2

P1 (Appendix 7.10.3):

She said she:

(i) found the kits interesting and she liked them;

(ii) understood and could follow worksheet instructions; and

(iii) understood the experiment when the worksheet was shown to her but subsequently claimed to have been absent when the experiment was performed.

P2 (Appendix 7.10.4):

(i) was a different student from the one selected before;

(ii) said he liked the kits but still felt unfamiliar with handling some apparatus;

(iii) said he understood instructions but could not understand the meanings of the words 'monoprotic and diprotic' acids; and

(iv) although he maintained that he understood worksheet instructions, he could not interpret the experiment and he gave a vague description of parts of the procedure.

P3 (Appendix 7.10.5):

(i) he liked the kits;

(ii) said he understood worksheet instructions; and

(iii) could not interpret nor describe the experiment, instead he mixed up several experiments in one experiment.

SCHOOL 3

P1 (Appendix 7.10.6):

(i) liked the kits and saw them useful in the future;

(ii) said he was able to follow instructions in the worksheet; but

(iii) could not interpret his experimental results, although they obtained reasonable results.

P2 (Appendix 7.10.7):

(i) liked the kits as they made experiments real;

(ii) said he understood worksheet instructions and this was evident in the way he described the experiment; but

(iii) could not interpret his results.

SUMMARY

All pupils interviewed said that they liked the kits for various reasons. Almost all of them also said that they understood the instructions in the worksheet, with only two pupils-one pointing out an ambiguity and another pointing out difficulty understanding some words used. S1 and S2 pupils battled to describe the experimental procedure while S3 pupils had a clearer idea. Five pupils out of the seven interviewed pupils were able to say that the process involved in the experimental procedure was a titration.

T2 changed his pupils around several times and also gave 3 pupils when he was asked for two. He could have been trying to give his best pupils.

TABLE 4.16

SUMMARY TABLE OF SIMILARITIES AND DIFFERENCES IN THE PUPIL INTERVIEWS

ITEM	S1P1	S2P1	S3P1
KITS	-liked the kit	-liked the kit -kits interesting	-liked the kit -preparation for further studies
WORKSHEETS	-instruction clear but ambiguous at some point	-claimed instructions were clear	-instructions clear
CONTENT	-experiment interpretation incoherent -process is titration	-claimed to have been absent during experimental activity	-incorrect interpretation of experiment -process is titration
ITEM	S1P2	S2P2	S3P2
KITS	-loved the kit -had handling difficulty -needs way to label propettes	-liked kits for hands-on opportunity -experienced handling problems	-liked the kit - made things real
WORKSHEET	-clear -needs solutions to experiments performed	-clear but some words misunderstood -could follow instructions and how some steps were done	-clear
CONTENT	-experimental description not recorded -experimental interpretation not recorded -process is titration	-incorrect description of experiment -vague interpretation of experiment -process is titration	-correct description of experiment -incorrect interpretation -process is titration

TABLE 4.16 CONTINUED

ITEM	S2P3
KITS	-liked the kit -useful in calculations
WORKSHEETS	-clear
CONTENT	-ambiguous description of experiment -incorrect interpretation of experiment -could not name process

4.7 THIRD WORKSHOP OUTCOMES

The third workshop was held both in Duduza and Shoshanguve. The facilitator informed the researcher that the workshop was designed to allow the teachers and the facilitator to discuss any problems experienced in the schools regarding the implementation of the RADMASTE microchemistry approach. It was also designed to give the teachers another chance to perform some experiments using the RADMASTE microchemistry equipment and allied materials. The outcomes of these workshops are discussed fully in Appendix 7.24.

Duduza:

(i) both teachers T1 and T2 attended;

(ii) T1 reported that his pupils followed instructions and understood experiments, although they struggled with handling some apparatus and confused chemicals due to unlabelled propettes;

(iii) T2 reported that his pupils took long time performing experiments and did not understand the experiments, he also found some experiments too advanced and some too long;

(iv) the facilitator advised the teachers to adapt the worksheets and not to adhere to every instruction given in the worksheet in them; and

(v) teachers performed another experiment using the RADMASTE microchemistry kits and allied materials.

Soshanguve:

(i) the workshop could not be held on the day that was first agreed on because T4 did not arrive for the workshop, the workshop was then held the following day at S4;

(ii) the facilitator briefed the teachers on an experiment based on the precipitation of sulphur which the teachers later performed individually, but could not obtain experimentally determined results;

(iii) T4 was observed to battle with handling some apparatus and the facilitator helped him practise; and

(iv) T3 had introduced RADMASTE microchemistry to his pupils but was not asked to report on it and T4 had not introduced it.

TABLE 4.17

SUMMARY TABLE OF THE THIRD WORKSHOP (TWS) IN DUDUZA AND SOSHANGUVE

EVENT	DUDUZA	SOSHANGUVE
REPORT-BACK	-worksheet instructions understood by S1 pupils -content not understood by S2 pupils -manipulative skills still to be developed -classes at S2 dragged for too long but improved subsequently -some concepts not in the syllabus	-not done
PRACTICAL EXERCISE	-teachers selected experiment - no predictions made for experiments -teachers worked individually -experiment worked	-experiment selected by facilitator -outcomes predicted -teachers worked individually -experiment did not work
DISCUSSION	-none was held	-experiment discussed assuming 'correct' results

4.8 RADMASTE CENTRE'S PLANS

One of the RADMASTE Centre directors and the Microchemistry Project Leader (referred to as project leader or facilitator) were interviewed. The aim of this interview was to find out from the RADMASTE Centre Director and the Project Leader their reasons for the introduction of the RADMASTE microchemistry equipment in the disadvantaged schools. The interview focused on the following points:

(i) reasons for the introduction of the RADMASTE microchemistry kits and allied materials (which will be referred to as the kit in this research report) in schools by the RADMASTE Centre;

(ii) the aims of practical work that the kit was intended to develop;

(iii) the reasons for the particular approach [i.e. three workshops way] of introducing

RADMASTE microchemistry to the teachers;

(iv) the 'help' facilities available for the teachers when introducing the kit to their pupils in their schools and subsequent support; and

(v) the way the kit was introduced in schools (i.e whether the stake-holders knew how the teachers introduced the kit and if not, the most appropriate way that they hoped the teachers used when introducing the kit to the pupils in the schools).

One interview protocol was used to interview the two people (i.e. the Director and the Project Leader), see Appendix 7.12 (page 2). The above points were used to analyse the transcripts obtained from the two interviews (see Appendices 7.13.1 (pages 1-5) and 7.13.2 (pages 1-5)). [Capital letters are used for the titles used in the interview transcripts.] The headings with their respective abbreviations used in the analyses, are respectively:

(i) reasons for introducing microchemistry = R. M/CHEM;

(ii) aims of practical work to be achieved = AIMS;

(iii) reasons for the teacher introduction approach followed = APPROACH;

(iv) help facilities available for the teachers = HELP

(v) RADMASTE's idea of 'appropriate' introduction of the kit to pupils = S. INTRO.

(vi) the final column was allocated for COMMENTS. This is for the responses that emerged but that could not only be classified under the first five categories and were found to be worth commenting on by the researcher.

For the interview, the researcher prepared and read an overview of the research progress to the two persons. In this summary the interviewees were informed about the purpose of the research, the research questions and the methods used to answer these questions (see Appendix 7.12, page 1). A copy of the research questions was also prepared and handed to the interviewees for reference during the interview (see Appendix 7.12, page 3). A discussion of the two interviews is reported below. Square brackets are used for the researcher's comments.

4.8.1 Project leader's views (Appendix 7.13.1, pages 1-5)

The facilitator said that there were three reasons for the RADMASTE Centre to introduce the kit in secondary schools. These were:

(i) to address the lack of practical work in schools;

(ii) to give the pupils the chance to perform the experiments themselves [he believed they learn better that way]; and

(iii) to find out from the teachers, through feed-back, how appropriate the materials produced by the RADMASTE Centre were for the schools (see Appendix 7.13, page 1, lines 18-22).

[The first two reasons were related to literature of practical work while the third reasons was more commercial and related to the project.]

He said that the aims of practical work that can be fulfilled by the kit are:

(i) manipulatory skills while handling the items found in the kit and also using the scientific process of solving problems;

(ii) attitudes change from perceiving science as a dangerous subject to finding it as '...approachable...' (see Appendix 7.13.1, page 2, lines 49-52). The size of the kit also supports this point since no major accidents can occur while using it (feed-back supporting the change in attitude was received); and

(iii) regarding content aims of practical work, the project leader said that the kit can develop the similar content to the existing syllabus plus helping the pupils understand the experiments they perform and why they performed them (see Appendix 7.13.1, page 2, lines 62-64).

The project leader stated that he believed that one learns better when doing hands-on activities and the workshop design allowed that to happen. He believed that the workshops also gave the teachers a chance to interact with other teachers who also do not know anything about microchemistry, and in that case they do not feel abandoned or isolated. He did not favour the idea of sending the materials to the schools without proper workshops since he believed that this would demotivate the teachers (Appendix 7.13.1, page 3, lines 72-80). The facilitator said that he had tried to think of another possible way to introduce the kit, but he could not come up with an appropriate way. On the other hand, he did not think this approach was the best one. When asked why he did not find the approach the best, he said the teachers took him as a person who knew everything and they were embarrassed when they had conceptual misunderstanding. He said that he rather wanted the teachers to find him approachable and

available to help them. The second problem he mentioned regarding the approach was that they had no pilot studies carried out to find out the most appropriate way to introduce microchemistry.

The facilitator had not seen for himself what happened in the schools when the teachers introduced the kit to their pupils. However, he believed he had a general idea of what happened. He said he obtained the general information from the teachers involved as he asked them in the follow-up workshops. In some cases, situations let teachers tell him of their experiences in their schools (see Appendix 7.13.1, page 3, lines 111-118).He did not elaborate on this.

The project leader was also asked about the classroom help facilities available to the teachers when they introduced the kit. The project leader mentioned that the teachers were told to use the RADMASTE Centre's, 'commercial associates' [understood by the researcher to imply Somerset Educational], and regional TSP's (Thousand Schools Project) telephone numbers and ask for help from any one of these. The project leader, however, said that none of these people have been contacted (see Appendix 7.13.1, page 3, lines 121-130). He added that on top of the help line, the RADMASTE Centre had initially hoped to assist the teachers at their schools. This was not financially possible.

4.8.2 Director's views (Appendix 7.13.2, pages 1-6)

The RADMASTE Centre management said that the kit was introduced in the schools to make hands-on practical work possible for the majority of schools that do not have equipment for individual practical chemistry. It was also developed for those schools that did not have laboratories to perform practical work (see Appendix 7.13.2, page 1, lines 4-15).

The director said that RADMASTE Centre had no particular aims that they considered to be developed by the teachers using the kit. In his opinion there were several aims of practical work that could be developed by the kit. He believed that it all depended on the teachers as to which aims they wanted to address using the kits. He said that the aims also depended on the teachers' capabilities when using the kit. [This shows diversity of viewpoints between the

director and the project leader, which should not be.]

The director also mentioned that there was a certain content knowledge they had expected from the teachers and for those teachers who did not have, some teaching had to be done to upgrade their knowledge or background (Appendix 7.13.2, page 2 lines 38-41). The RADMASTE Centre also had expectations from teachers and these expectations are based on individual teachers' experience and expertise (i.e. they expect more to be done with the kits from more experienced teachers, see Appendix 7.13.2, page 4, lines 110-111). [The researcher does not have any records of how these different expectations are indicated by RADMASTE Centre to the teachers involved.]

The director stated that there were no 'strong' reasons for introducing the kit to the teachers the way they did. All they knew was that it was important that there be contact between the teachers and the materials developers. He believed that only enthusiastic teachers would make use of the materials if there was no interaction involved (see Appendix 7.13.2, page 2, lines 50-52). Although RADMASTE Centre could consider spending considerable time with the teachers, the director believed that RADMASTE Centre did not have the time nor the resources to do that. He, therefore, believed that the approach that RADMASTE Centre used was midway between regular school visits and no interaction at all. The director, however, had no evidence whether that approach was sufficient for the majority of teachers to be able to use the kits. [The two persons have similar perceptions regarding introduction, and that there needs to be interaction.]

The RADMASTE director did not know how the teachers introduced the kit to the pupils in the schools. When asked what he hoped for, the director hoped that in the first session the teacher would give the pupils the kits and tell them the names and uses of the different items found in the kit. He hoped that the teachers would then give the pupils a simple exercise which would allow the pupils to know how to use the items and not expect them to understand the content of any experiment. The teacher could then phase complicated experiments gradually as the pupils became familiar with using the kit. He also expected the teacher to make the pupils responsible for their individual kits. This pupil responsibility for the kit was also going

to reduce the load of the teacher concerned in terms of preparation and storage of practical work materials. The director also believed that if the pupils were to deal with the kit (something new to them) and the worksheet, it was too much to learn at the same time. It would also give a negative impression to the pupils of the whole idea because it was not planned properly (Appendix 7.13.2, page 4, lines 103-105).

According to the director, the teachers could use both RADMASTE Centre and Somerset Educational [which he called the manufacturer] whenever they needed help facilities which teachers, however, never used up to that point (see Appendix 7.13.2, page 4, lines 130-133). The director, however, believed that both the RADMASTE Centre and the manufacturer could not afford regular visits to the schools. He was, however, aware that the help they offered was not enough. According to the RADMASTE director, it would be best if the subject advisors were trained to use the kits and as their task is already to visit the schools, they could assist the teachers with using the kits as well.

When asked to comment, the director expressed his surprise at the enthusiasm with which microchemistry was received by different institutions, which was different from other developments which he had seen.

TABLE 4.18 below has subheadings similar to the ones used to analyse the interviews (see Appendices 7.13.1 and 7.13 2). The subheadings are described again below.

(i) reasons for introducing microchemistry = R. M/CHEM;

(ii) aims of practical work to be achieved = AIMS;

(iii) reasons for the teacher introduction approach followed = APPROACH;

(iv) help facilities available for the teachers = HELP

(v) RADMASTE's idea of 'appropriate' introduction of the kit to pupils = S. INTRO.

(vi) the final column was allocated for COMMENTS. This is for the responses that emerged out that could not only be classified under the first five categories but were found to be worth commenting on by the researcher.

TABLE 4.18

SUMMARY TABLE OF SIMILARITIES AND DIFFERENCES BETWEEN THE DIRECTOR'S AND THE PROJECT LEADER'S VIEWS

ITEM	PROJECT LEADER	DIRECTOR
R. M/CHEM.	-address lack of practical work -give pupils hands-on experience -find out appropriateness of materials	-address lack of practical work -give pupils hands-on experience
AIMS	-manipulative -scientific problem-solving -attitudes -content-based	-several but all dependent on individual teacher
APPROACH	-exercise -teacher interaction not best approach but no idea of best one	-contact essential -approach midway -no idea whether approach appropriate or not
HELP	-Somerset and TSP (none used) -RADMASTE's regular visits financially difficult	-RADMASTE and Somerset (none used) -RADMASTE's regular visits financially difficult
APPROPRIATE INTRODUCTION IN SCHOOLS	-does not know, is only told	-does not know -hope practice done (to master manipulative skills) ignoring content and learn content later
COMMENTS	-none	-microchemistry received with enthusiasm

5

DATA ANALYSIS

5.1 INTRODUCTION

Data obtained from the different research methods is analysed and synthesized in order to answer the three research questions already listed in Chapter 1, namely:

(i) How are the RADMASTE microchemistry kit and allied materials introduced to teachers?

(ii) How do the teachers introduce the RADMASTE microchemistry kit and allied materials in their schools? and

(iii) What are the content knowledge, skills and attitudes competencies associated with the RADMASTE microchemistry approach?

The first question is answered in terms of the way the facilitator introduced the RADMASTE microchemistry kit. This is compared with three alternative views on how it should be introduced. The logistics of attendance to the workshops as well as the dates set for the workshops are also included within this section. This is so because these aspects do form part of the introduction of RADMASTE microchemistry kit and allied materials.

The analysis for the second question is based on how the teachers introduced RADMASTE microchemistry with reference to how they had planned to introduce it in the interviews and how the facilitator introduced it in the orientation workshop.

Information for the third question was obtained from the observations made in the workshops, teacher and pupil interviews, classroom observations and pupils' workbook and experimental worksheet analyses. Analysis and synthesis of the question is done first with the teachers and then the pupils. The analysis is based on the content knowledge, skills and attitudes that the RADMASTE Centre microchemistry and allied materials highlight based on the document analysis done in section 4.2. This is done both for the teachers and the pupils.

5.2 HOW ARE THE RADMASTE MICROCHEMISTRY KIT AND ALLIED MATERIALS INTRODUCED TO TEACHERS?

All the workshops were poorly attended, (i.e. conducted with only two teachers while at least six were expected). The dates set for the workshops were such that teachers could not perform experiments with their pupils between the workshops as was intended by the RADMASTE Centre staff. The teachers taught physics in the first part of the year. When they attended the workshops, which were concerned with chemistry, they had not completed the physics component of the syllabus. Some of the teachers attending these workshops were not physical science teachers since the invitations were not given to the right people or the message conveyed was incorrect (i.e. there was a communication problem).

Three ways of introducing practical work with particular reference to small-scale chemistry are described below. One is advocated by Woolnough (1991), the second by one of the RADMASTE Centre directors and the third one is one followed by the researcher in a previous study.

Woolnough (1991) advocates that practical work can be used to develop: exercise (i.e. manipulative skills), experience to solve more problems (problem solving skills); and investigative skills. To learn practical work, he believes that the learners should be given the chance to familiarise themselves with the new equipment through practice. When practising the skills it is recommended that a scientific activity should be used, since otherwise the skill would be developed out of context. It is from such easy exercises that the learner gains the confidence and experience to tackle investigative problems. To best achieve the aims of this approach, the learners should maintain interest, enjoyment, commitment, perseverance and self-confidence. The learner's previous experience should, however, be considered since this affects how a learner learns subsequently.

One of the RADMASTE Centre directors said that the best way that the RADMASTE Centre kits could be introduced to learners is that learners should start by familiarising themselves with the handling of the equipment. He suggested that there should be no content or scientific activity tied to the exercise as this would confuse the learner. It is only after the manipulative

skills have been mastered that scientific activities could be included. He did not comment on whether or not demonstration should occur.

The researcher had previously carried out research where some small-scale experiments were introduced to mathematics and science grade 12 students. In this case, each step of the procedure was demonstrated by the researcher before students attempted the exercise. This was done despite the fact that the students had instructions provided in the worksheets. This was done since the researcher believed that it would help the students understand the instructions and procedures of the exercises better when these were demonstrated to them.

The three methods described above agree that it is important to master the skills before one can engage in serious content-ridden practical exercises.

To introduce the RADMASTE microchemistry kit, the facilitator used an overhead projector to show the components found in the RADMASTE kit. He then asked the teachers to perform the experiment following instructions from the worksheet. He assisted the teachers at strategic points. The facilitator did not demonstrate how to use the apparatus, nor did he give the teachers a chance to practice using the pieces of apparatus required for the acid-base titration experiment. He only did this in the subsequent workshops possibly because he observed teachers still experiencing difficulty with handling the propettes. Woolnough (1991) and the RADMASTE Centre director believe that practice is necessary.

At the end of the workshop, teachers completed questionnaires which probed into their intended implementation of RADMASTE microchemistry in the schools. Discussion and advice on introduction to pupils then took place. Advice and possible pupil behaviour on particular experiments was given. Some of the situations predicted by the facilitator did occur subsequently. For example, the teachers were warned that pupils might think that the volumes of base used to titrate the two acids were different because the two acids had different strengths (rather than because one acid was monoprotic and the other was diprotic) and the worksheet stated that the two acids had same concentration. The pupils in S1 and S3 mentioned this in their interviews. T1 had tried to show the difference in his lessons, but the pupils did not

remember this during the experiment or in the interview. T3 did not mention anything about it in his lessons. This is a common misconception that is possibly difficult to change.

The teachers attended two other follow-up workshops. These workshops were planned to allow the teachers a chance to report on problems encountered when introducing RADMASTE microchemistry to their pupils. No teacher had introduced small-scale chemistry to their pupils by the time they attended the second workshop. This was explained by two teachers as resulting from the fact that the workshop was just before the midterm examinations and no teaching was done at that time. All three also said that they had not yet completed the physics component and so were unable to do the chemistry component. As mentioned earlier, the workshops were not planned to suit the school calender. The RADMASTE Centre staff were possibly unaware of the situation in the schools. In the third workshop, the teachers had managed to introduce RADMASTE microchemistry to their pupils. It was in this workshop that they managed to raise some questions and concerns about classroom practice. The facilitator suggested some solutions to their problems and answered questions. All the three teachers, however, attended all three workshops as scheduled. This indicates that the teachers were committed.

There were no classroom visits made by the RADMASTE Centre to the teachers at their schools once the equipment was given to the schools. There was also no other correspondence between the teachers and the RADMASTE Centre after the three workshops. The RADMASTE Centre facilitator and director added that they had not received any requests and questions from the teachers. Once the three workshops were completed, contact between the teachers and the RADMASTE Centre ended. It is not certain, therefore, whether the teachers did use the RADMASTE microchemistry kits and allied materials or not after the workshops.

5.3 HOW DO THE TEACHERS INTRODUCE RADMASTE MICROCHEMISTRY IN THEIR SCHOOLS?

Introduction of RADMASTE microchemistry in the three schools is described in the paragraphs which follow.

T1 had 32 pupils in grade 12. He reported that before they were introduced to RADMASTE microchemistry, the pupils performed experiments in two big groups which he usually managed. With RADMASTE microchemistry, he planned to give pupils their individual kits and worksheets and let the pupils follow the worksheet instructions on their own. He planned to give the pupils an introductory lesson on the relevant topics and then demonstrate a conventional titration procedure. T1 had also reported that he would introduce RADMASTE microchemistry like the facilitator did in the orientation workshop.

T1 gave the pupils individual kits, but asked pairs of pupils to share the worksheet. He gave the introductory lesson and demonstrated a conventional titration procedure, both of which had errors in terms of content. T1 was possibly not confident with the content himself. He possibly felt obliged to give the lesson as the researcher was present. Or he may have believed that his pupils needed some information to be able to attempt the questions in the worksheet. The pupils ended up working in pairs although T1 wanted them to work individually. T1 also ran short of chemicals. He could have misjudged the volumes of chemicals needed. This is suggested considering the volume he gave each pupil when he distributed the chemicals. He seemed not to remember the help and guidance that they (i.e. teachers) received at the workshops. Although the facilitator used an overhead projector to show the pieces of apparatus found in the kit, T1 did not have or did not use it. The facilitator also showed each teacher the contents of the kit and the names and uses of each apparatus individually. T1 did not do this for his pupils. The facilitator discussed the experiments with the teachers at strategic points but T1 refused to answer the pupils' questions.

In school 2 there were 39 pupils. T2 mentioned that practical work was normally performed in groups of six or less pupils. He said that he often managed the pupils as they performed the experiments. When using RADMASTE microchemistry, (i.e. in the presence of the researcher) T2 was uncertain what he wanted to do. Whether to work with 8 pupils from the class or to work with the whole class. He was uncertain whether to give the pupils an introductory lesson or not before the acid-base titration experiment was performed.

He then claimed that he had introduced RADMASTE microchemistry to the pupils in the researcher's absence. He did not invite the researcher to the introductory lesson as he had promised. He worked with the whole class. He probably wanted to select 8 best pupils to avoid being embarrassed by the other pupils who were less able. He finally did give a lesson which had several content errors and involved many concepts and could have been confusing to the pupils. This may indicate that T2 did not know the content himself. Perhaps he was nervous due to the presence of the researcher. The pupils performed two experiments (one of which was the acid-base titrations) while they were observed by the researcher. Both experiments gave unexpected results due to incorrectly prepared chemicals that the pupils used. The chemicals were prepared by T2. The pupils worked in groups of 4 or 5 pupils. Each group shared one or two worksheets, there was no specific pattern followed regarding the number of worksheets per group of pupils. The teacher guided the pupils through the steps of the experiment although he had said that the pupils would manage on their own. This may indicate that T2 did not really believe his pupils were capable of following the instructions on their own. It also shows that T2 did not use the kits and the worksheets available to him to let the pupils work in pairs or smaller groups. They still worked in groups of less than six pupils and he supervised the exercise, as he claimed he did prior to RADMASTE microchemistry. T2 guided his pupils through the experiment, to a greater extent than the facilitator had done at the workshop. T2, however, did not have an overhead projector to show the components found in the kit. He also did not take time to familiarise the pupils with these items of apparatus, nor did he let the pupils practise handling them. This information was obtained from the interview as the researcher did not attend the introductory lesson.

T3 also gave an introductory lesson that he had planned to give. His lesson had some factual errors although they were fewer than those made by T1 and T2. T3 was more confident than the other two teachers. T3 had a class of 32 pupils and previously no practical work had been performed at that school. T3 had planned that he would introduce RADMASTE microchemistry to his pupils by telling them the names and uses of e h item of apparatus. He planned to let the pupils work in pairs and he said he would not answ r any questions from the pupils until the experiment was completed.

In fact the pupils performed the experiment in three big groups of nine, ten and eleven pupils respectively. He actually did not answer any questions from the pupils. He did that for the two experiments that the pupils had performed. It is not easy to speculate why T3 could have decided to use such big groups with one set of apparatus per group when he had at least 40 kits to work with.

T2 and T3 gave the pupils another experiment to perform before they performed the acid-base titration experiment. This could be considered as practice exercise for the pupils before they could perform the acid-base titration experiment. S1 pupils had more difficulty working with the propettes during the acid-base titration experiment than pupils in S2 and S3.

5.4 WHAT ARE THE CONTENT KNOWLEDGE, SKILLS AND ATTITUDES COMPETENCES ASSOCIATED WITH THE RADMASTE MICROCHEMISTRY KIT AND ALLIED MATERIALS?

Analysis of this question is based on the document analysis on content knowledge, skills and attitudes described in section 4.2.

5.4.1 Teacher content knowledge

When T1 was interviewed about the orientation workshop, he interpreted the content of the experiment they performed incorrectly. He said that they were determining the concentrations of acids while, in fact, they were determining the volumes of base used to titrate two acids which were monoprotic and diprotic respectively. The two acids and the base had the same concentration. It was not easy to tell from the workshop whether he himself understood the content well as he worked alone and was, therefore, quiet in the workshop. His results were, however, acceptable. The worksheets were unambiguous, according to T1. In fact, T1 failed to understand the subject matter of the experiment (i.e. the concepts of neutralisation and acid-base reactions specifically). Perhaps the worksheet instructions were straight-forward, but he probably could not link the experiment to his background knowledge. T1, therefore, did not have the necessary content knowledge prescribed in the syllabus. He could not describe acid-base neutralisation through titration.

T2 had difficulty understanding a number of things from the worksheet. He seemed not to understand why they were repeating a titration more than once. This is deduced from the fact that he expected the volumes to be the same in all three titrations, otherwise, he believed that something was wrong. His comments also suggested that he did not obtain precise results. T2 could have experienced difficulty in understanding: the concept behind the acid-base titration experiment; difference between monoprotic and diprotic molecules of acids; and the difference between precision and accuracy. This is suggested from the discussion he and the facilitator had. However, T2 understood the instructions in the worksheet and could follow them. Perhaps T2 could not make the link between the experiment and his subject knowledge. T2, however, was evasive on direct questions regarding the content of the experiment when he was interviewed. He did not mention his difficulties, as already stated above, during the orientation workshop in the interview. He claimed to have had no difficulty. However, he incorrectly said that the experiment was based on determining the numbers of moles of the two acids, namely, hydrochloric and sulphuric acids. So T2 failed to describe the concepts behind the experiment he performed.

The orientation workshop in Soshanguve was attended by a biology teacher and a physical science teacher. The biology teacher had difficulty coping with the experiment. It is possible that he was intimidated by chemistry that was not his speciality. It is also possible that Tb (i.e. the biology teacher) did not have any clue on what was happening.

T3 obtained expected results in the workshop. When he was interviewed about the workshop, he was able to recall that the experiment was about determining the 'monoprotic and diprotic' acids. He mentioned that the worksheets were clear. T3, however, was asked to repeat the experiment at some point. This shows that there were certain instructions in the worksheet that T3 did not understand. Perhaps the worksheets were reasonably clear but not clear enough for one to understand in the first attempt. In his preparatory lesson, T3 used an analogy for neutralisation that had a potential of causing errors. T3's understanding of neutralisation could have some errors.

From the above information, it can be inferred that none of the three teachers had the correct

content knowledge of the experiment. They were not taught any content at the workshop. It is possible that the facilitator assumed that the content or the background the teachers had was sufficient and the teachers would not have any difficulty in understanding the content. Perhaps the teachers did not think about the theory behind the experiment because they focussed on learning how to handle the new equipment.

5.4.2 Teacher skills

The RADMASTE instructional materials instructions indicated how to handle items of the kit. Using these materials teachers and pupils can develop manipulative skills. T1 confessed that he was still unfamiliar with handling the RADMASTE microchemistry kit apparatus. This implies that he still needed to develop his manipulative skills in order to be able to teach his pupils. Perhaps one needs to practise with RADMASTE microchemistry kit and master handling apparatus. Even though one might be familiar with the conventional practical work, a different form of approach is needed for this kit. So the skills prescribed in the syllabus were being developed.

T2 did not handle the apparatus in the workshop. He was working with another teacher, whom he instructed. When interviewed about the difficulties he experienced in the workshop, T2 claimed that he did not have any difficulty. Perhaps T2 had an oversight of the skills required for one to cope with RADMASTE microchemistry. Unfortunately the researcher did not see him introduce the kit, so cannot say with certainty whether he demonstrated handling the items or not. T2, therefore, did not appear to make an effort to develop the necessary practical skills.

T3 said that he experienced difficulty with handling the propettes, in particular. He also needed to practise his manipulative skills to become familiar with the components in the kit. Specific manipulative skills are, therefore, required for the RADMASTE microchemistry kit. T3 attempted to develop the necessary skills.

Two out of the three teachers accepted that they experienced difficulty in handling the apparatus. All teachers, were, however, positive about the RADMASTE microchemistry being introduced in their schools. They saw a possibility of some of their workload being reduced

and better learning facilities for their pupils. The teachers could have overestimated the clarity of the worksheet. They seemed to forget they themselves experienced difficulty because they said they believed that their pupils could cope with the worksheets.

5.4.3 Teacher attitudes

T1 said he liked the kits for his pupils and believed that they might enjoy working with them. Although he had problems handling some of the items found in the kit, he said he liked the idea of small equipment. He also showed a positive attitude towards the kit by attending all three workshops and participating in them.

T2 had a positive attitude towards the RADMASTE microchemistry kit. T2, however, seemed to have very high expectations of what the RADMASTE microchemistry kit could do. He expected that his preparation time would be reduced so much that he would able to complete the chemistry component of the syllabus in one month. He showed commitment to learning about small-scale chemistry, since he attended all three workshops.

T3 also said he liked the kits and allied materials. He had a positive attitude towards the kits being introduced in schools and the pupils getting the opportunity to handle them

All three teachers were positive about the approach and it is possible that the teachers did not want to disappoint the researcher by saying anything negative about the RADMASTE microchemistry kit and allied materials.

The following paragraphs describe the content, manipulative skills and attitudes of the pupils when using the RADMASTE microchemistry kit and allied materials. This is done for each school individually. This is also done using the content, skills and attitudes that the kit appears to address. These are described in the preceding paragraphs (Refer to section 5.4.3).

5.4.4 School 1 pupil content knowledge, skills and attitudes

When the pupils in S1 were observed performing experiments using the RADMASTE microchemistry kit and allied materials, many pupils had difficulty understanding some

instructions in the worksheet and answering subsequent questions. T1, however, refused to answer the pupils' questions since he said he believed that the worksheets were clear enough for the pupils to follow. However, T1 in the subsequent workshops, admitted that some of the subject knowledge covered in the worksheets was more difficult than the pupils could learn at that stage. T1, therefore, gave two contradictory statements. When two pupils from S1 were interviewed, they gave incorrect responses. This suggests that the pupils did not understand the experiment they performed (i.e. neutralisation and titration). It also suggests that the pupils could not link what they learnt in the preparatory lessons to the experiment they performed since most of the concepts were taught in the preparatory lesson. Although the preparatory lessons had some conceptual errors, the teacher could have failed to give the required background knowledge for the pupils to link it to the practical exercise. The pupils could also have learnt nothing from those lessons. The worksheet instructions could have been unclear to the pupils. Proof of this is given in some paragraphs about the pupils' responses.

The pupils had difficulty manipulating the kit. This implied that they still needed to develop the necessary practical skills.

The pupils, however, were positive about the kits. When observed working with them, they seemed to enjoy what they were doing. They also mentioned in the interviews that they liked the kits.

5.4.5 School 2 pupil content knowledge, skills and attitudes

T2 decided to give the pupils one experiment to perform before they could perform the acid-base titration experiment. This he said he did to prepare the pupils for the acid-base titration experiment since he found the latter experiment too advanced for his pupils. The experiment was based on determining pHs of different substances. The researcher, when observing the pupils, concluded that they still did not understand the experiment. They did not obtain expected results, and they did not respond to the questions in the worksheet. They could have been confused by T2 himself and the way he conducted the sessions plus the chemicals he had prepared for them. During the experiment he read out the instructions to the pupils and also instructed them about what to do. At some points, he summarised the instructions for the pupils

on the board. This suggests that T2 did not believe his pupils would understand the instructions. On the other hand, he had mentioned that the worksheets were clear and that the pupils would manage the experiment on their own, without him guiding them. It is not easy, therefore, to tell whether the pupils understood the instructions in the worksheet or not. When the pupils were interviewed on the experiment performed, none of them could answer the questions based on content of the acid-base titration experiment.

The experiment the pupils in S2 performed before attempting the acid-base titration experiment could have given the pupils some practice in developing manipulative skills. This is suggested because the pupils were observed to have had very little difficulty handling many of the items in the RADMASTE microchemistry kit.

All the pupils who were interviewed said they liked the kits.

5.4.6 School 3 pupil content knowledge, skills and attitudes

In S3 pupils also performed a practice experiment in pairs before the acid-base titration experiment. The pupils, however, performed experiments as three big groups. They performed the experiment with only a few questions being asked of the teacher. This could be because T3 made it clear to them that he would not answer any questions. All three groups, however, obtained expected results. None of the groups answered the subsequent questions correctly. Actually, their answers did not seem to refer to the questions asked. The pupils probably could not make sense of their results. This implies that the questions on the worksheet were not clear enough for the pupils to follow. From the interviews it could be inferred that both pupils had some conceptual errors on acid-base titrations, but they seemed to have better ideas than the pupils in the other two schools.

The practice experiment could have helped them manage handling the RADMASTE microchemistry kit and allied materials. Pupils handling the kit was, unfortunately, not observed by the researcher. Pupils were asked to give each other a chance to perform the experiment. It was not easy to tell whether the pupils coped with handling the apparatus or not. The pupils did practise some handling skills during the first practical exercise. This

suggests that the more opportunities one gets of handling the items in the kit, the better they manage to handle the items at least initially.

Both pupils interviewed had positive attitudes towards the RADMASTE microchemistry kit.

SUMMARY

The outcomes described above suggest that the worksheet instructions for the manipulative aspect could have been reasonably clear. However, pupils did not make sense of what they were doing. This means that pupils did not ultimately reach an understanding of the subject matter intended by the materials developers. It seems the questions asked in the worksheet did not help these students in reaching a full understanding of the material. The kits developed certain manipulative skills that are different from the ones needed for conventional practical work. The RADMASTE microchemistry kit and allied materials interested everyone who was exposed to it (except the biology teacher). Possibly some people did learn part of subject matter although not everything that the experiment could offer.

6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter revisits the following three research questions posed in the introductory chapter:

1. How are the RADMASTE microchemistry kit and allied materials introduced to teachers?

2. How do the teachers introduce the RADMASTE microchemistry kit and allied materials in their schools?

3. What are the content knowledge, skills and attitudes competencies associated with the RADMASTE microchemistry approach?

In this chapter, the research questions above are answered based on the data obtained from this study. Some of the questions overlap and, therefore, the answer to one question also supplement answer to another question. The questions are answered in the same order listed above and these have been followed by recommendations. At the end of each subsection, general recommendations for the case study, resulting from the analysis of the results, are formulated.

6.2 HOW ARE THE RADMASTE MICROCHEMISTRY KIT AND ALLIED MATERIALS INTRODUCED TO TEACHERS?

RADMASTE microchemistry workshops were run for two teachers in the two regions while a minimum of six teachers in each region was expected by RADMASTE Centre. Some of the workshops were run with non-science teachers attending the workshops. This shows that communication between RADMASTE staff and the teachers involved was poor. The science teachers who attended the workshops, however, attended all the scheduled workshops (except

T4). This shows that these teachers were prepared to learn how to use RADMASTE microchemistry equipment and the allied materials. The teachers, however, could not introduce RADMASTE microchemistry between the first and second workshops as this interfered with midyear examinations and vacations.

The RADMASTE Centre facilitator used overhead transparencies to familiarise the teachers with the RADMASTE microchemistry kit. He, however, did not demonstrate to the teachers nor allowed the teachers to handle items of the kit in any way, in order for the teachers to be comfortable with handling the apparatus before performing the experiments. The teachers did experience difficulties with handling some apparatus in the kit as well as understanding the chemistry concepts involved in the experiment. It can be deduced, therefore, that during the introduction of RADMASTE microchemistry, one needs to concentrate on one thing at a time, the skills in handling the equipment on their own and the content, similarly on its own.

It is recommended that the RADMASTE Centre arrange their schedule in co-operation with the school and the teachers involved. This is to guard against the teachers not being able to introduce RADMASTE microchemistry in the RADMASTE allocated time, as well as not attending the workshops, for various reasons.

Communication between the RADMASTE Centre and the teachers involved should be improved to avoid RADMASTE staff incurring expenses for workshops that are sometimes not fully attended nor held at all. RADMASTE Centre should also avoid running workshops if attendance is poor.

6.3 HOW DO THE TEACHERS INTRODUCE THE RADMASTE MICROCHEMISTRY KIT AND ALLIED MATERIALS IN THEIR SCHOOLS?

The teachers did not introduce RADMASTE microchemistry in any of the ways described in section 2.7 of this research report. These were: watch and try method for the procedure (researcher); mastering manipulative skills before introducing the content (director); practising manipulative skills and familiarization with the kit using simple content (Woolnough, 1991);

and helping at strategic points (RADMASTE facilitator). All the three teachers relied on merely mentioning the names and uses of the items without the pupils handling the kit in front of the teachers for encouragement or correction. Their method was deficient in that the pupils were not yet familiar with the names and uses of the items in the kit, nor the instructions in the worksheet. The pupils could not interpret the experiment as well. It can be concluded from this that the way the RADMASTE Centre facilitator introduced the RADMASTE microchemistry kit to the teachers did help the teachers to use supportive teaching methods. They did not emulate him. It can also be concluded from this that the facilitator did not teach the teachers how to introduce RADMASTE microchemistry to their pupils and his method was not copied either. It can be noted that teachers did not have facilities similar to those used by the RADMASTE facilitator.

It can be recommended that when introducing RADMASTE microchemistry, mastering manipulative skills should be one of the major aims. The learners should also be familiar with the different items found in the kit and also how to use them. These can be attained through practice.

There should also be a way which can be used to monitor teachers on how they use the RADMASTE microchemistry kit after the teachers have attended the three workshops. A support system, as well as classroom visits by facilitators could help the teachers.

6.4 WHAT ARE THE CONTENT KNOWLEDGE, SKILLS AND ATTITUDES COMPETENCIES ASSOCIATED WITH THE RADMASTE MICROCHEMISTRY APPROACH?

Content knowledge

Both the teachers and the pupils experienced conceptual difficulties when performing the acid-base titration experiment. Teachers, however, expected the pupils to understand the experiment. The study revealed that two of the teachers and many pupils could not distinguish between concentration and strength of an acid. This is despite the fact that the title specified that the concentrations of the two acids (A and B) were the same. This alternative conception that the two could be used interchangeably were also found in a study by Botton (1995). Many

pupils, however, were aware that the procedure involved in the experiment was a titration. So pupils could not distinguish between dissociation and H^+ concentration (i.e. concepts mentioned in the syllabus the pupils should know).

Teachers defined acids and bases as substances which release H^+ and OH^- ions respectively, as it was found in a study by Cros (1988). The RADMASTE microchemistry kit did not directly deal with the alternative ideas that concentration and strength do not mean the same thing and that bases do not necessarily release OH^-. These alternative conceptions are hard to change since it was mentioned in workshops and in some classrooms and the misconception remained. It can be concluded from this study that the use of the kits and allied materials cannot achieve any content knowledge development without the teachers mastering the content itself. It is also possible that at least two of the three teachers involved in this study were teachers with M+3 qualifications and were, therefore, not suitably qualified to teach physical science at grade 12.

So the kits and allied materials could be used to help the pupils learn neutralisation; acid-base titration; dissociation of acids and bases; and use of indicators to determine acidity and basicity (as prescribed by the syllabus for this particular worksheet). The necessary content knowledge was, however, not learnt by the pupils partly because the teachers did not know parts of it and also because the pupils failed to learn it from the preparatory lessons and the experiment they performed.

It can be recommended that RADMASTE Centre develop the means of determining the teachers' content level before or during the workshops and then upgrade the teachers with content knowledge in order to be able to use the kits to achieve various objectives. Literature has also shown that in-service programmes already exist in South Africa although they may not achieve what they were intended to do. These programmes could be used to upgrade the teachers in a more focussed manner. The RADMASTE Centre could involve the teachers in the development of the materials so as to have their input as well as cooperation.

Skills

All three teachers experienced difficulty when handling the items in the kit for the first time. The same was observed for the pupils. These teachers were observed to handle the items better in subsequent workshops and during school observations. The pupils who performed other experiments before the acid-base titration experiment handled the kit items better than those who were handling the apparatus for the first time. The study shows that practice is necessary for one to master handling the items of the kit. The kit also requires and helps develop certain manipulative skills which are specific to the kit and cannot be transferred from conventional apparatus as the teachers could not have had difficulties in that case.

A recommended way to go about this would be that skills must be mastered before one gets into teaching serious content. A watch and try method as used by the researcher as well as the one recommended by the RADMASTE director could help achieve this.

So the kit and allied materials can help the pupils develop necessary skills, techniques and methods of science. In fact, the pupils learnt to carry out a titration from the exercise and they can learn more from the other experiments.

Attitudes

Both the teachers and the pupils said they loved the kits. It is not easy to say whether these comments were genuine or not. If there is ongoing use, then it would be clear that the comments are true. A method of follow-up is therefore needed. It could be that everyone said they liked the kits simply because they afforded a different approach to what they were used to (i.e. conventional apparatus).

The RADMASTE microchemistry kit can be used and be of value for hands-on practical work in both advantaged and disadvantaged schools. It also has a place in many other countries outside the Republic of South Africa as it has already been introduced there. Literature has shown that practical work is essential although the best way to approach it is still being debated. It can be left to the individual teachers as to how to use practical work in their teaching. The facilities, in this case the kit, should therefore be [illegible] to the teachers. The

RADMASTE Centre, therefore, needs to make a concerted effort for the kits' full potential to be realised as an alternate to the conventional practical work.

There is a place for further research on the introduction of the RADMASTE kits in schools in the place of conventional practical work. They should not, necessarily however, be intended to replace all conventional practical work. Rather it can be used more, not necessarily when there is a crisis. It should be used in schools where conventional practical work is not possible.

The kit and allied materials can provide equipment and apparatus for practical work to take place in both advantaged and disadvantaged schools. They can also provide safe working environments since small amounts of chemicals are used. Once the manipulative skills are mastered time taken to perform microchemistry experiments becomes shorter, the kit and allied materials can be used in short time table slots and lengthy syllabi.

INTRODUCTION OF RADMASTE MICROCHEMISTRY IN DISADVANTAGED SCHOOLS IN GAUTENG: A CASE STUDY

VOLUME 2

Lebala Miriam Kolobe

A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science.

Johannesburg, January 1998.

VOLUME 2

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

DEPARTMENT OF EDUCATION (With Departments of Physics and Chemistry)

HIGHER GRADE TED SYLLABUS FOR PHYSICAL SCIENCE, STDS 8 - 10

INTRODUCTION

1.1 Aims

A few general or broad aims of physical science teaching are the following:

1.1.1 to provide pupils with the necessary subject knowledge and comprehension, i.e. knowledge of the subject as a science and as technology;

1.1.2 to develop in pupils the necessary skills, techniques and methods of science, such as handling of certain apparatus, the techniques of measuring, etc.;

1.1.3 to develop in pupils desirable scientific attitudes, such as interest in natural phenomena, desire for knowledge, critical thinking, etc.;

1.1.4 to introduce pupils to the scientific explanation of phenomena;

1.1.5 to introduce pupils to the use of scientific language and terminology;

1.1.6 to introduce pupils to the applications of science in industry and in everyday life;

1.1.7 to help pupils to obtain perspective in life, for example, to develop a reverence for the Creator and an esteem for the wonders of creation through contact with the subject matter.

It is left to the teacher to specify the objectives for each topic and lesson. This implies that the specific objectives are related to specific subject matter, methods and evaluation.

1.2 Remarks

1.2.1 In teaching the syllabus it will be necessary to make use of simplifications. Simplification, must however, not be such that pupils are left with serious misconceptions. Where conceptual models are used to simplify the explanation of certain phenomena (eg. Rutherford's model of the atom), it must be made clear

that these are <u>models</u> and, as such, are not intended to serve as fully acceptable scientific explanation.

1.2.2 SI units and IUPAC nomenclature must be used throughout.

1.3 Syllabus content

The content of the syllabus is compulsory and the order of subject topics must be adhered to.

1.4 Examining

1.4.1 Separate final examination papers will be set for HG and SG in Stds 8, 9 and 10.

1.4.2 Standards 8 and 9 will be examined internally.

1.4.3 The external examination in standard 10 will be set on the syllabus for standard 10 as well as sections 3.1, 3.2, 3.7 and 3.8 of the syllabus for Standard 9, excluding paragraphs 3.1.4.2, 3.7.3.2, 3.7.4.2, 3.7.4.3 and 3.7.5.2.

1.4.4 The standard 10 examination will not be less than 3 hours in length.

1.4.5 The same number of marks will be allocated to physics and chemistry in the final Std 10 examination.

1.4.6 Not more than one third of the total marks for the Std 10 examination shall be allocated to questions of the multiple choice type.

1.4.7 It will not be required of candidates to memorize numerical constants or the whole of the Periodic Table. In the examination an approved Periodic Table and information sheets will be provided where needed. No formulas which are statements of definition of laws will, however, be supplied.

1.5 Remarks

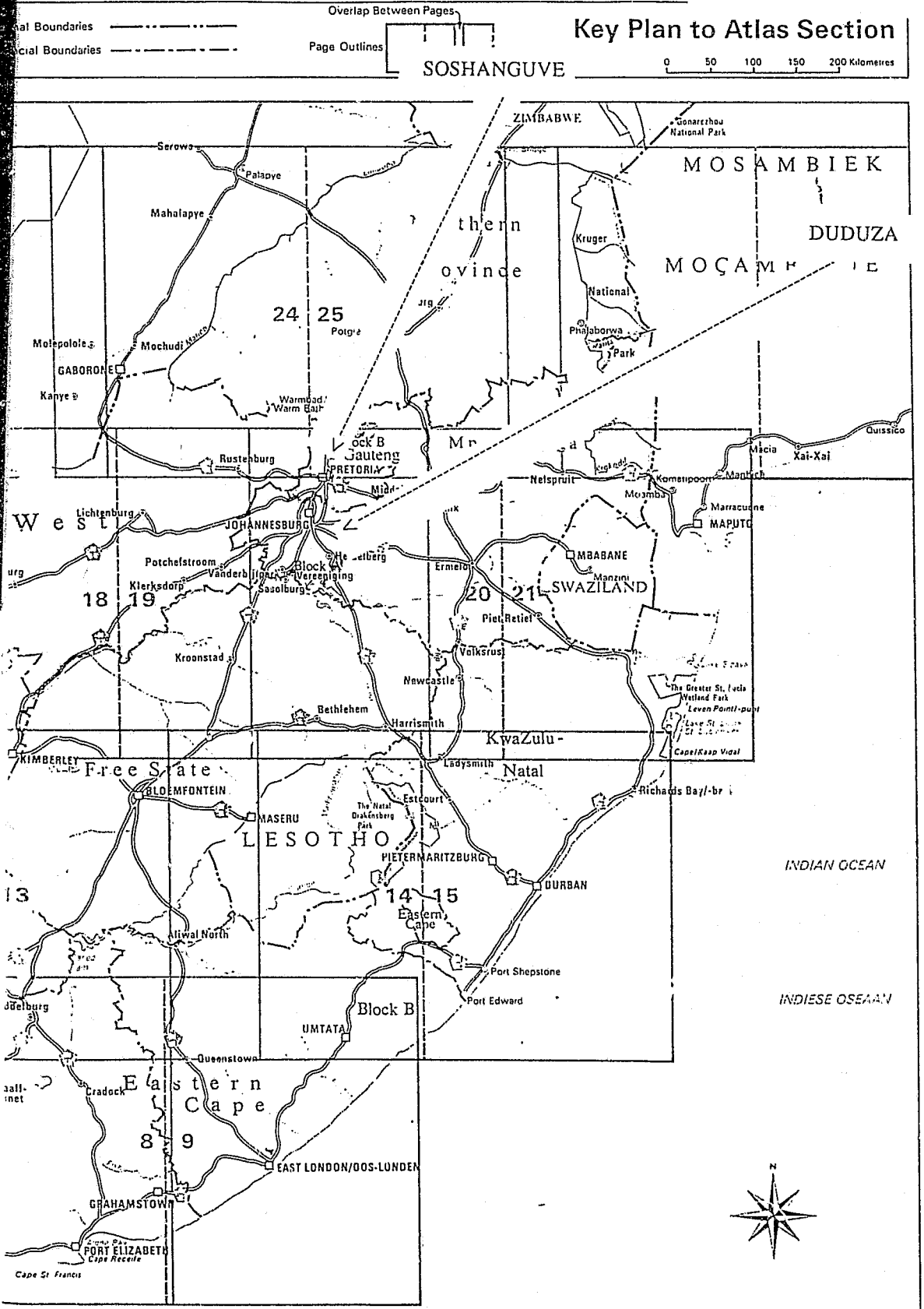
1.5.1 Practical work is an integral part of the teaching of the subject and ample opportunities must be created for pupils to do experiments themselves.

Practical work by pupils should be continuously evaluated and the marks allocated should be incorporated in the pupil's year mark.

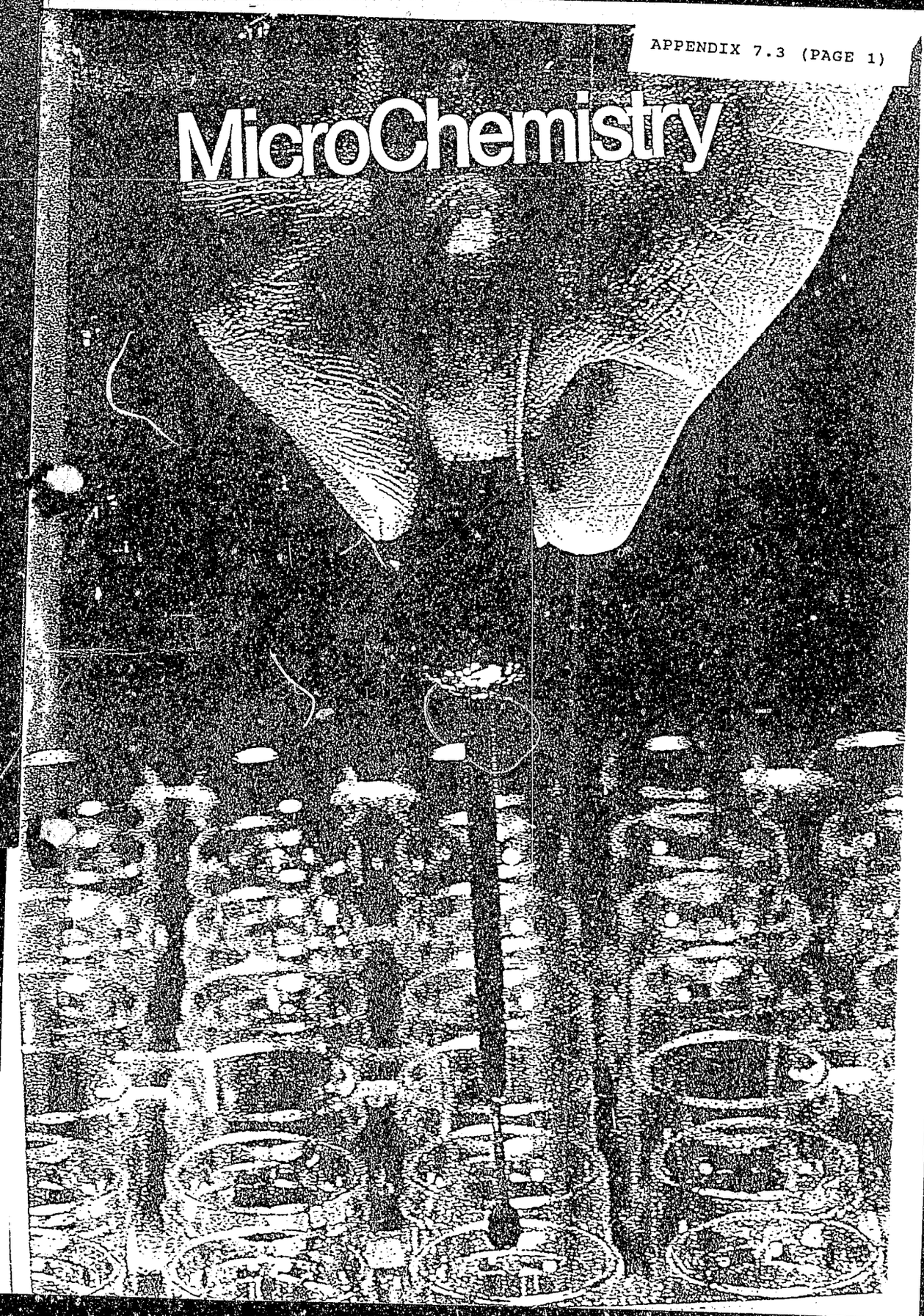
1.5.2 Teachers must at all times, but especially during the practical sessions, take the necessary safety precautions. Protective clothing should be worn. This warning applies especially with respect to the storage and handling of chemicals as well as to all types of experiments performed, during which poisonous gases or vapours may be released. Example of these are the following:

Heating of mercury (II) oxide;
Handling of tetrachloromethane;
Preparation of $C\ell_2$ and H_2S;
Handling of barium chloride.

(Refer to study guide No. 5 : Safety measures in the laboratory.)


Overlap Between Pages
Page Outlines
SOSHANGUVE
Key Plan to Atlas Section
0 50 100 150 200 Kilometres
ZIMBABWE
MOSAMBIEK
DUDUZA
Kruger
National
Park
Phalaborwa
Serowe
Palapye
Mahalapye
Mochudi
Molepolole
GABORONE
Kanye
Warmbad
Warm Bath
Rustenburg
Pretoria
Johannesburg
Lichtenburg
Potchefstroom
Klerksdorp
Vanderbijlpark
Sasolburg
Vereeniging
Nelspruit
Komatipoort
Maputo
Marracuene
Mbabane
Manzini
SWAZILAND
Piet Retief
Volksrust
Newcastle
Kroonstad
Bethlehem
Harrismith
Ladysmith
KwaZulu-Natal
Richards Bay
Kimberley
Free State
Bloemfontein
Maseru
LESOTHO
Estcourt
Pietermaritzburg
Durban
INDIAN OCEAN
INDIESE OSEAAN
Eastern Cape
Aliwal North
Port Shepstone
Port Edward
Block B
UMTATA
Queenstown
Cradock
East London/Oos-Londen
Grahamstown
Fort Elizabeth
Cape St Francis
Quissico
Macia
Xai-Xai
18
19
20
21
24
25
8
9
13
14
15

MicroChemistry



WELCOME TO THE WORLD OF MICROCHEMISTRY

WHAT IS MICROCHEMISTRY?

DEFINITION:

LOW COST, SMALL SCALE PRACTICAL CHEMISTRY FOR ALL!

WHY USE MICROCHEMISTRY?

All around the world (USA, Japan, France, India,.....) there has been a trend to SMALL SCALE practical Chemistry for a number of important reasons:

1) Low cost of most small scale equipment.

2) Reduction in chemical costs.

3) Reduction of waste disposal problems.

4) Elimination of safety hazards.
(Most items are plastic!)

5) It requires less time, storage space for chemicals and equipment.

6) It allows for individual hands-on practical work.

7) No conventional laboratories are needed.

8) Pupils really enjoy microscale practical Chemistry experiments.

DEVELOPMENT IN SOUTH AFRICA

For the past year and a half RADMASTE (Research and Development in Maths, Science and Technology) Centre and SOMERSET EDUCATIONAL have been researching and developing low cost practical Chemistry Methods to make Chemistry available to EVERY SCHOOL PUPIL in South Africa.

So far we have developed experimental Methods for most of the Std. 9 and 10 Science Syllabuses. Here are just a few of these experiments:

1) Equilibrium

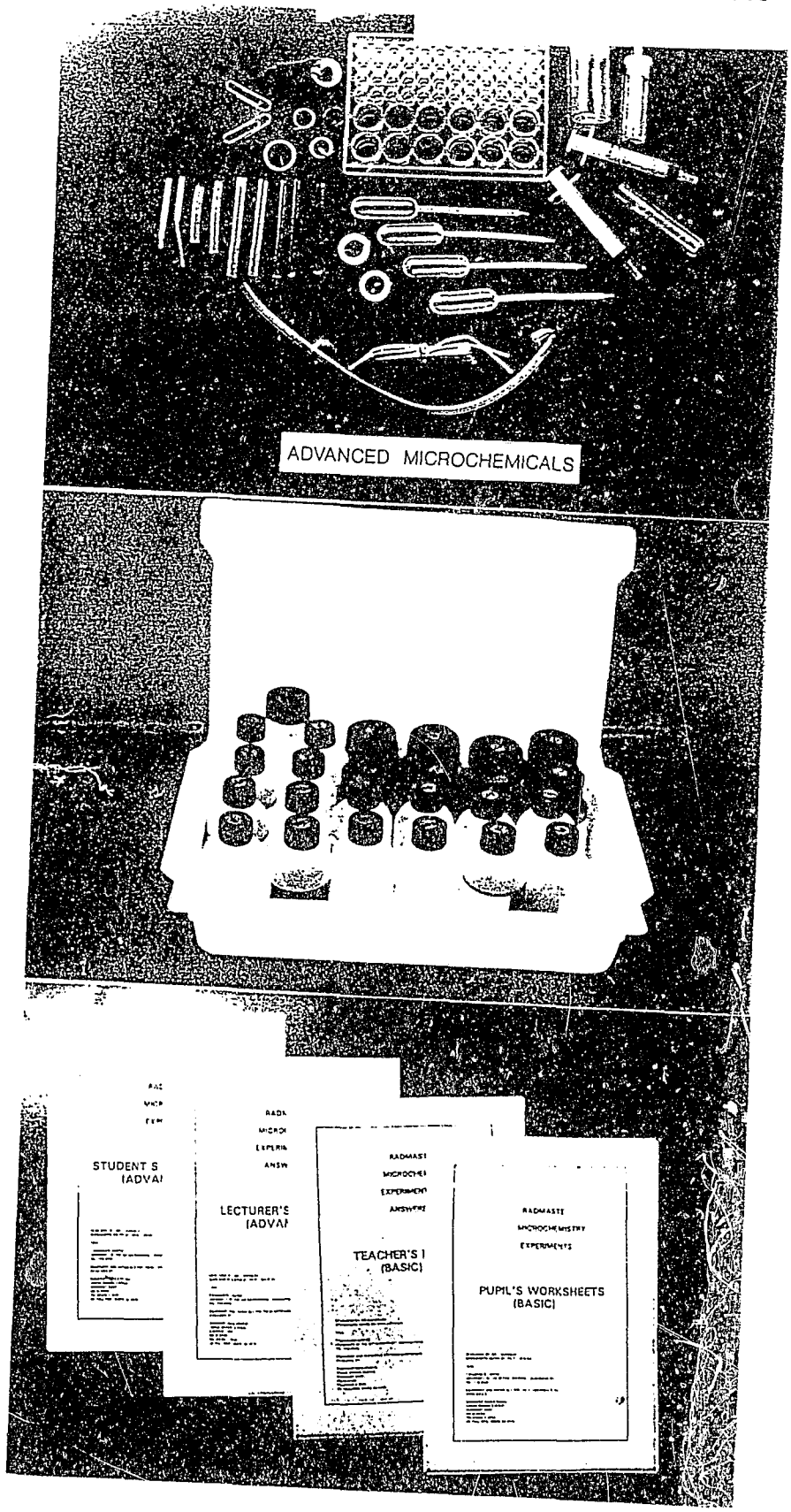
2) Acids and Bases (Titrations)

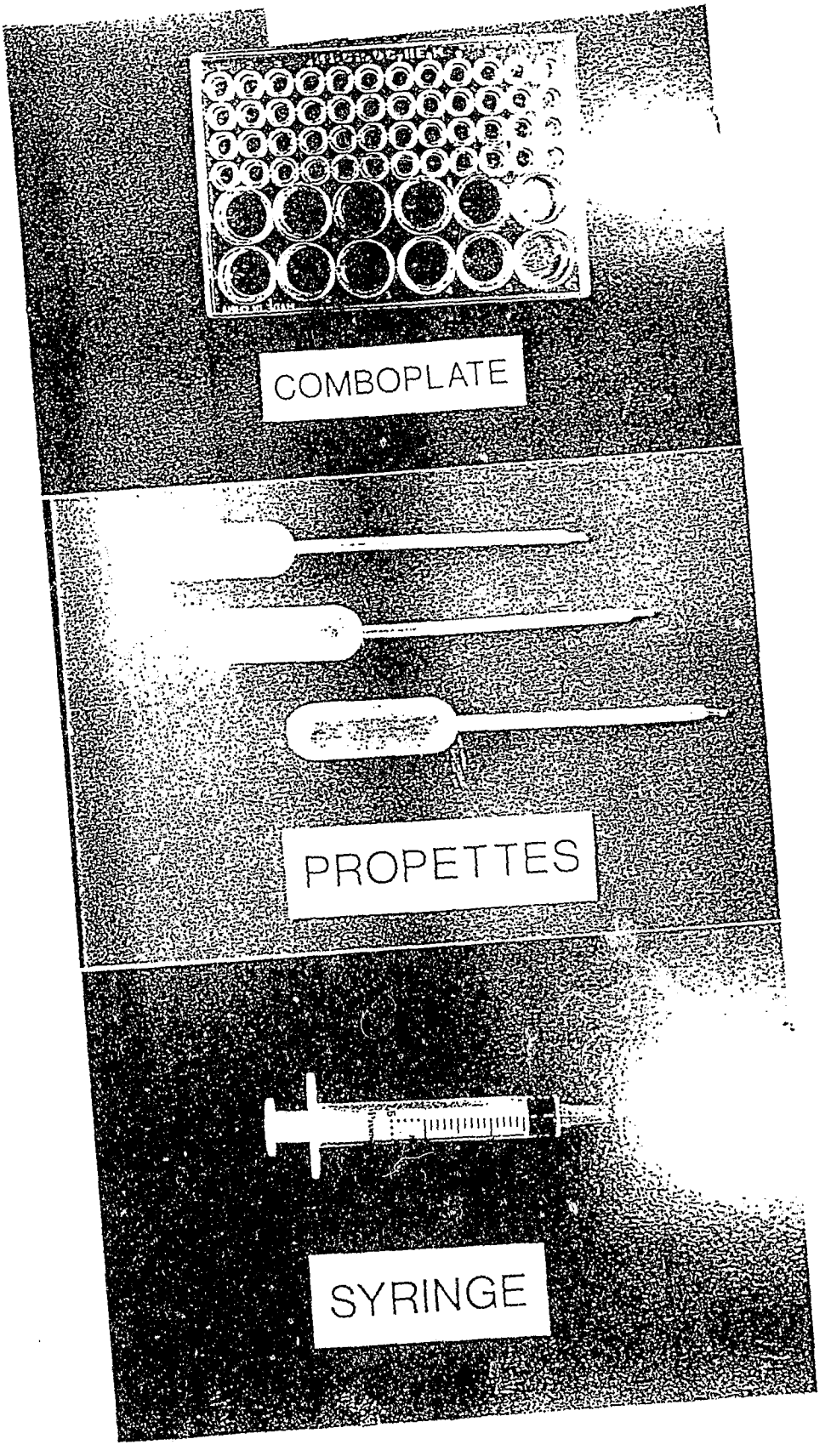
3) pH (Indicators)

4) Reaction Rates

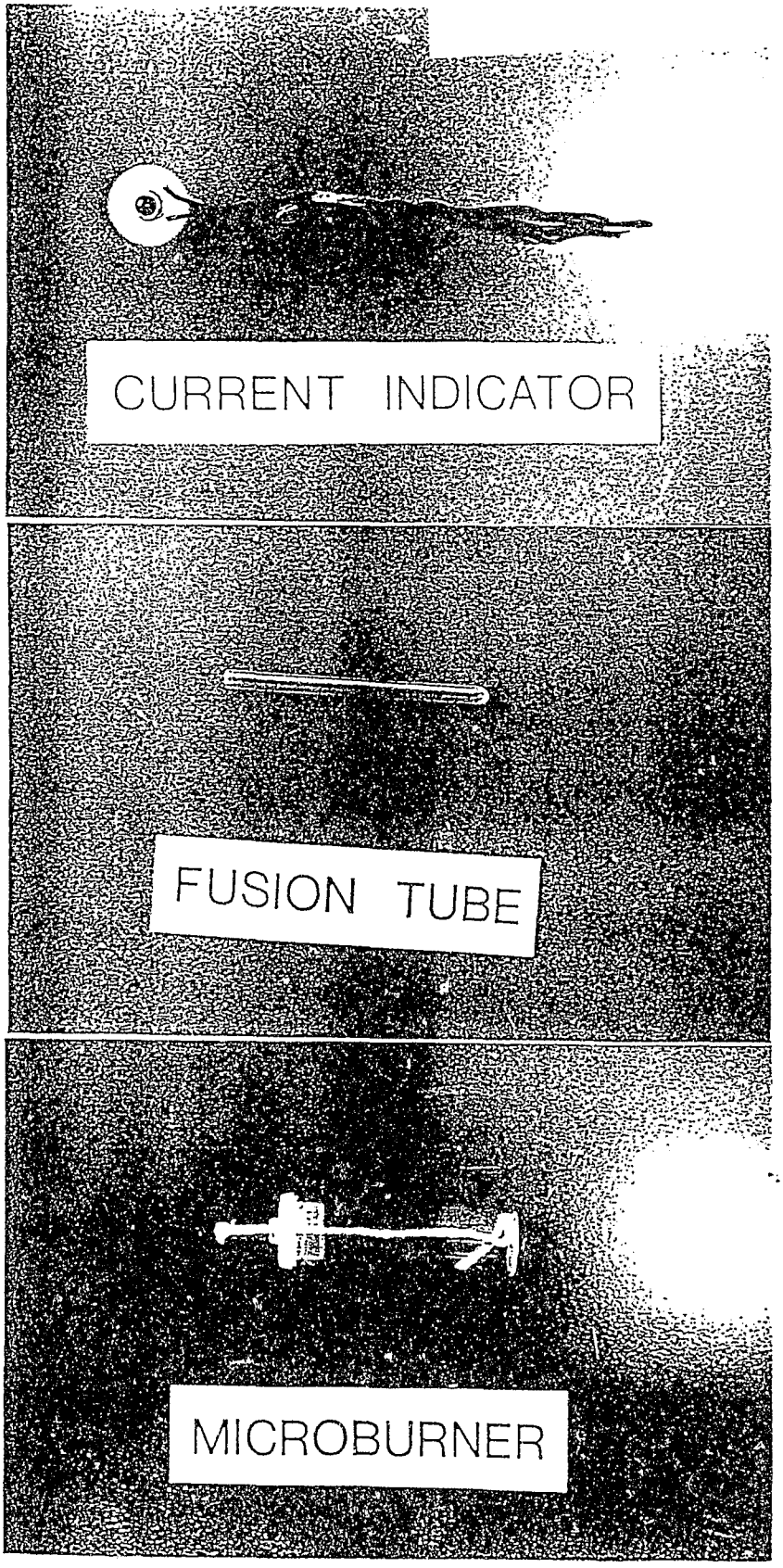
5) Generation of and test for Hydrogen sulphide

COMPONENTS OF MICROCHEMISTRY KITS TO COMPLEMENT METHODS


ADVANCED MICROCHEMICALS
STUDENT S
(ADVAI
LECTURER'S
(ADVAI
TEACHER'S I
(BASIC)
RADMASTE
MICROCHEMISTRY
EXPERIMENTS
PUPIL'S WORKSHEETS
(BASIC)


COMBOPLATE
PROPETTES
SYRINGE

GLASS ROD
MICROSTAND
GAS COLLECTING TUBE
PVC TUBING


CURRENT INDICATOR
FUSION TUBE
MICROBURNER

AIMS OF WORKSHOP

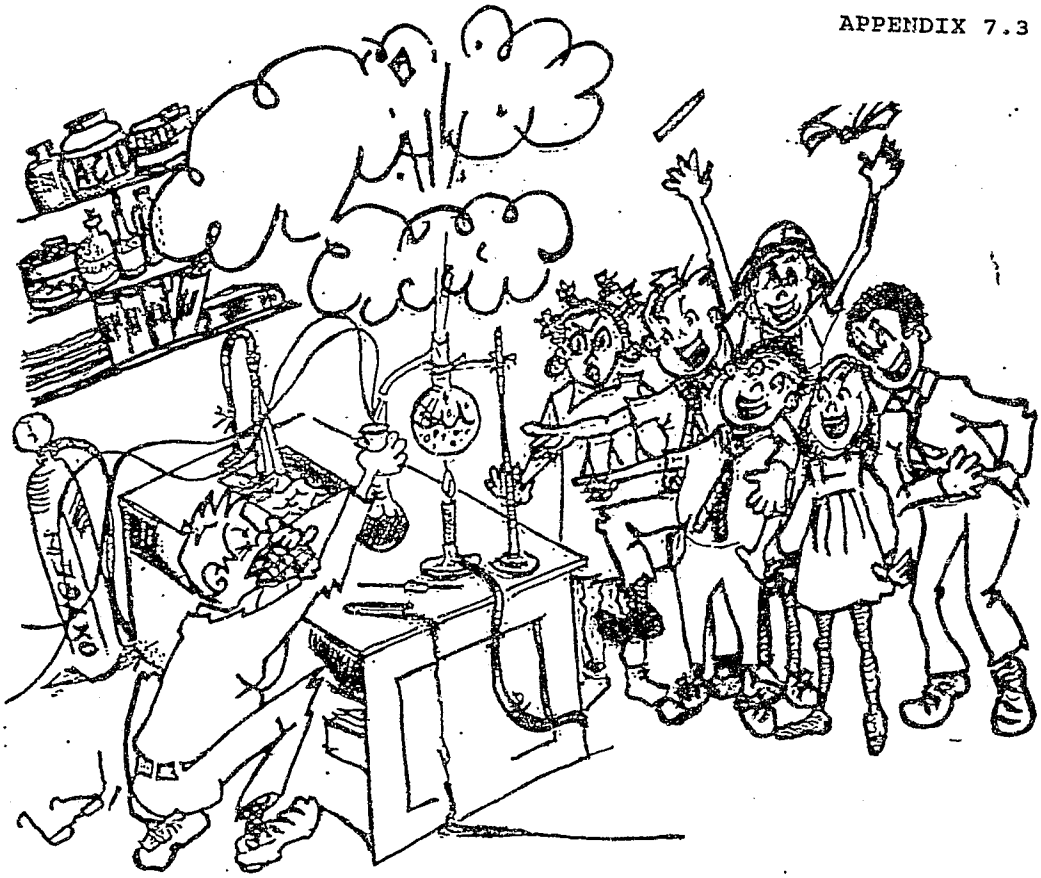
1) Introduction of MICROCHEMISTRY TECHNIQUES.

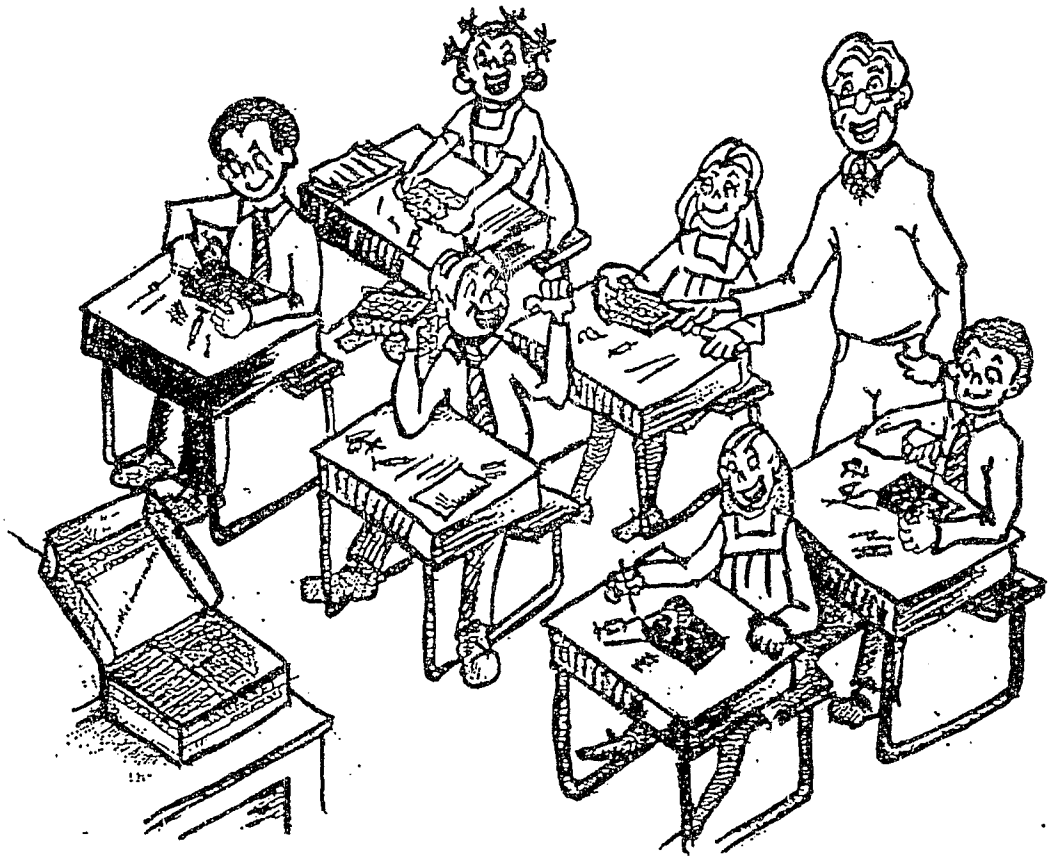
2) To promote CONFIDENCE in Chemistry practical work for the teacher.

3) Encourage individual practical work by pupils at school.

4) Make Chemistry at school more exciting and enjoyable.

LOW COST ≠ LOW QUALITY





Experiment B2: Procedure

Focus question 1): What volumes of sodium hydroxide solution are required to titrate equal volumes of two different acids of the same concentration?

Requirements:

APPARATUS:	CHEMICALS:
1 x comboplate 1 x plastic mixing rod 5 x thin stemmed propettes	Acid A (0.10 M) [Ch4] Acid B (0.10 M) [Ch5] Sodium hydroxide (0.10 M) [Ch6] Methyl orange indicator [Ch7] Tap water

*Let acid A be a monoprotic acid: HX.
*Let acid B be a diprotic acid: H_2Y.

NOTE: 1. The mixing rod should be cleaned before each use.

CAUTION !: If any acid or base is spilt on the skin, thoroughly rinse the affected area with water.

Procedure:

1. Add 5 drops of tap water into well A[1].
2. Add 1 drop of methyl orange indicator into well A[1].
   ☞ Answer Observation 1
3. Repeat steps 1) and 2) above in well A[2] using acid A instead of tap water.
   ☞ Answer Observation 2
4. Add a sufficient number of drops of sodium hydroxide solution to well A[2] to just cause the colour of the solution in well A[2] to be the same as that in well A[1].
   ☞ Copy Table 1 into your workbook. Carefully count the number of drops of sodium hydroxide used, then enter the number into Table 1 in your workbook.
   Use the plastic mixing rod where necessary.
   Repeat the titration you did in well A[2] two more times, in wells A[3] and A[4], as before.
   ☞ Write down your observations in Table 1 as before.
5. Repeat steps 3) and 4) on page 1, in wells A[5] A[6] and A[7], this time using acid B instead of acid A.
   ☞ Copy Table 2 into your workbook. Carefully count the number of drops of sodium hydroxide used then enter the number in Table 1 in your workbook.
   ☞☞ Answer Questions 1 to 6 in your workbook.
   ***Rinse the wells in the comboplate with tap water then shake them dry.

Experiment B2: Observations

Observations:

Obs.1: Note the colour of the solution in well A[1]
Obs.2: Note the colour of the solution in well A[2]

TABLE 1.

Acid used	N°. of drops of Acid A	N°. of drops of NaOH	Average N°. of drops NaOH
A	5 5 5	_____ _____ _____	_____

TABLE 2.

Acid used	N°. of drops of Acid B	N°. of drops of NaOH	Average N°. of drops NaOH
B	5 5 5	_____ _____ _____	_____

Experiment B2: Questions

Questions:

Q1: What is the answer to focus question 1) ?
Q2: What is the volume ratio of NaOH/acid A ?
☺ **Hint: see Table 1.**
Q3: What is the volume ratio of NaOH/acid B ?
☺ **Hint: see Table 2.**
Q4: Compare your answers to questions 2 and 3 above and then explain these results.

Extension questions:

Q5: Are the volumes of base, you used, as seen in Tables 1 and 2, precise or accurate? (Explain your answer and where applicable state if further information is needed to answer this question.)
☺ **Hint: What are the definitions of precision and accuracy.**
Q6: If the average number of drops of base required to titrate 6 drops of acid A was experimentally determined to be 8 and the true value should have been exactly 6, is the experimentally determined result imprecise or inaccurate?

END OF EXPERIMENT B2.

DISCUSSION TO BE HELD AT THE END
OF THE LABORATORY SESSION

Is the microchemistry equipment easy to handle? ----------

Is the procedure for the experiments easy to follow? ---------
If YES/NO please comment.

How are you going to distribute the chemicals in class?

You are given 1 set of worksheets per 20 microchemistry equipment kits. How are you going to distribute it to the pupils?

Do you think the Microchemistry concept is going to work with the pupils?

TEACHERS' INTERVIEW PROTOCOL

1. Please tell me what happened in the workshop where microchemistry was introduced to you.

-probe to find difficulties encountered and explanations together with the attitudes towards microchemistry.

-any chemistry in particular that you learned?

-how did you feel about microchemistry?

2. Do you usually do practical work in this school?

If no...Tell me about the problems you have.

If yes...Tell me about how you usually do it.

3. How do you think you will introduce microchemistry to your pupils?

(Make sure responses make sense with respect to question 2.)

-probe to find if the topic has been dealt with and how this will be linked to practical work.

S1 T1'S INTERVIEW

I: Please tell me about the workshop where microchemistry was introduced to you.

T1: Concerning microchemistry only neh?

I: Yes, that introduction workshop.

T1: Ehh...O.K. first of all it was explained to us what this RADMASTE is all about and what this microchemistry is all about. And ehh...obviously the advantages were stated, and ehh...I think we tried to...let me say to substantiate them through the the practical there to see whether what was said was really err true. And I think most of us who were there were impressed when we saw those advantages being sated there.

I: O.K. can you talk about doing the experiment in particular. Do you remember what...

T(joins in): Yah... O.K. I think the experiment we were doing...that that we were doing that is the comparing the...what you call the the I mean... let's say... the acid withhh two protons and then the other one with one proton and then checking the concentrations there and then really going through the experiment as you do it with the proper titration what you call...let me say the conventional titration apparatus.

I: O.K., can you tell me any difficulties that you encountered when you were doing that experiment?

T1: Well not so much that emm...well personally what I first noticed was that one will have to get used to those small something something... well let me call them small pipettes or small burettes, you know, because sometimes you are not sure whether the drop goes in or not and sometimes but after sometime you can see that you have to raise it higher and I think after some...handling the apparatus it'seasy I think those were only ones that were difficult.

I: What about concerning the worksheet?

T1: The worksheet itself?

I: Yes.

T1: No, I think the worksheet was..was O.K. I mean the instructions were

straight forward and especially the naming of the cells made it easier for kids to follow the instructions with a...minimum number of ...bers that errr.

I: O.K., is there any chemistry in particular that you can say you learned from that experiment?

T1: The experiment itself?

I: Yes

T1: Mmmm because I don't understand the question.

I: The chemistry as in the content itself?

T1: The content, is it something different to me or what?

I: Yyee..can you say it emphasised something or it made clear something that you already knew, or it made you learn something knew, something like that, one of those?

T1: One of those things?

I: Yes?

T1: Err...well, I've never done an experiment where one..one determines the what you call, the effect of concentrations when we've got a...different acids of different number of protons. Yah, I would say that was new...but I knew obviously that the results would be different.

I: O.K. and how did you feel about working with the microchemistry apparatus?

T1: Apparatus?

I: Yes.

T1: Yah, well... I think twass...twass good. I think also the kids will enjoy it as we enjoyed it ourselves.

I: O.K. Now, do you normally do practical work in this school?

T1: Yes we do..., yes we do.

I: Tell me about it, how do you normally do it?

T1: Ammm, well...depending on circumstances or and a...and a... the experiment itself, sometimes we use the laboratory, and sometimes we use the class itself that is really...cause I teach six up to six. I teach sixscience and sc..a..science ten. So usually six I take the apparatus to class and then demonstrate. Kunjalo (meaning it's like that) so.. ngeteacher idemonstration (meaning I teach in demonstrations) normally.

I: So it is basically demonstration in standard six.

T1: Yah. Then with ten sometimes you know, we do give them a chance because some you know...I think in standard ten why we give them a chance is because the experiment requires so much of the values not having little meaning so...for instance things like we do an experiment on Newton's laws you've got to measure the tapes and what have you. So we involve the students then, but still, the apparatus is one in that sense. 'Cause it's only one trolley, one what, one what, one what.

I: Then how do you involve them then? What happens in such classes?

T1: I mean they have a...to do the measurements themselves, you see?

I: So do you divide them into groups? What happens?

T1: Yah, may be two...may be the first group will do the first measurement, the second...you know? And then the others concentrate on putting the values in their...exercise books.

I: So, how big is your class?

T1: In standard ten?

I: Yes?

T1: There are...thirty two who do physical science. And the sixes, they are about fifty five minimum...sixes' class so...(can't hear)

I: So that one you only teach through demonstration.

T1: We have to demonstrate.

I: And then for standard ten sometimes you actually have students doing the practicals themselves.

T1: Yah...the standard ten do sometimes, but not on an individual basis still, it has to be groups may be two groups. We can't afford too small groups.

I: O.K. How are you intending to introduce this microchemistry to your pupils?

T1: Well, first I want to do it as it was done there neh? I'm not going to...because I'll sss...you know what I prefer is that the kids themselves must tell me how they feel about this so I'm going to...introduce it as it was done there.

I: What do you mean?

T1: I mean I'm not no...what I'm trying to say is let the kids experience on

their own without me you know directing them to the answer so that now they can feel whether there is a difference with the experiment you see, unlike channelling them they must carry out the experiment themselves.

I: O.K. what I want to know is can you exactly tell me how you are going to do it? What is going to happen with the worksheets and what is going to happen with the kits.

T1: The worksheets...aaa the kits...O.K. Yah basically what I'll do is I think we'll first do the experiment in the conventional way.

I: O.K.?

T1: O.K. and then from there...

I: You will be demonstrating this?

T1: Obviously I will be demonstrating because we don't have enough apparatus and enough chemicals. And in any case that will require an extensive preparation if we want to do it individually for kids also that I think that is a problem, also. Besides, even if we can have the apparatus, the the preparation for each individual child is going to be difficult. But...then from there, then I'll tell them that we've got this new method of doing the experiments which I think it's going to be the thing of the future and then in that case may be they'll have...since they're about thirty...thirty two neh? So about forty kits so I'll give each child his own what you call...kit, yah and do it on his own. And then, I'll explain to them what is going on, how the cells work and what have and what have you and then they do the experiment on their own they'll have to follow the instructions from the worksheets on their own..because my believe is that the instructions there are clear and if I'm going to explain the instructions then it means I'll also be destroying the the what you call... the purpose of of seeing whether the worksheets are clear or not clear to the kids. So let them do it and they make mistakes then I'll know where the mistakes come from, unlike channelling them too much eliminating the errors which I feel they will be able to make it clear whether the apparatus are easy to handle for the aaa the the the worksheets are easy to follow without too much instruction from the the demonstrator.

I: Have you taught the topic , the acid-base titrations?

T1: I haven't done that one, that, why I was thinking that's why I was thinking that if if if really one would look for an experiment which I would adapt to that, but then if I don't get one because I don't have time well...these examinations and ...the the what you call the feedback (meaning the follow-up workshop) is on the twenty first neh? And its already the sixteenth, so if I don't get one I'll have to explain to them briefly what the experiment is all about and then let them do it, just to get a hands-on experiment on that. But if...I think I can get one which they can do which has got to do with the syllabus which they can do on their own which the kit can do.

I: You can get what?

T1: An experiment.

I: O.K., what I'm particularly interested in is this particular experiment on acids and bases titrations which you did in the workshop.

T1: This particular one, yah I'll have to explain to them basically.

I: So you haven't done any acid-base titrations with the kids in theory?

T1: No I haven't, I haven't.

I: O.K. So how are you intending to link the practical to the theory? When will you be teaching?

T1: Aaaa (silence for six seconds) you see to be quite honest with you, with our schools here this err thisss syllabi are not finished in our classes you see, so in some instances sometimes you have to start backwards before you can continue. You can get a class which have never done acids in standard eight so it becomes your (can't hear) to start afresh with those kids. So I basically I don't know whether they know any acids or not.....(not relevant) I think they know something about acids and I think I could explain more or less briefly to them the experiment what's going on. These kids, they now know chemical bonding and I think I can just explain briefly what are acids and what have you...because this goes with the first definition of acids neh? That acids are protons. So I don't think I can...'twon't 'twon't be difficult for them to understand what what's happening.

I: So you are first going to brief them about acids?

T1: Yah, about acids neh? And what have you briefly about indicators what

what what and these are just stories which don't need some...some...deep thinking.

I: O.K. thank you.

T1: O.K.

S2 T2'S INTERVIEW

I: Good afternoon.

T2: Yes, good afternoon.

I: I'd like to ask you a few questions about the workshop that you attended at the Resource Centre and how this is going to be joined to your science teaching here in your school.

T2: No the workshop it was o'right O.K. compared O.K. to the one O.K. which we get from ilona (meaning this thing) that is the... what you call the subject advisers. At least O.K. yours was fruitfull than what we get from the subject advisers.

I: O.K. then, can you tell me about it? Can you tell me what you remember doing at that workshop, especially the microchemistry part?

T2: The microchemistry?

I: Yes.

T2: No, the microchemistry it was interesting, even I myself O.K. I did apply it to the children and they enjoyed it very much.

I: O.K.

T2: Especially O.K. the part of the experiment O.K. they are used O.K. to large testubes now looking at that combo... what is it called? Combo...?

I: Comboplate?

T2: Comboplate O.K. it is amusing to them. They are seing it for the first time O.K. with their eyes.

I: So what happened? Did you show them the kit or they actually did the experiment?

T2: First O.K. I did explain, O'right? Why O.K. why the kit was implemented instead of the testubes. And then after that O.K. I showed them how does it work and after that O.K. I gave them that O.K. the experiment and then O.K. and then they did that.

I: Which experiment did you give them?

T2: Ahh?

I: Which experiment did they do?

T2: They, they concentration on the rates of chemical reactions.

I: O.K. they haven't done the acids and bases titrations?
T2: Acids and bases?
I: Yes the one we did in the workshop?
T2: No, they didn't.
I: O.K.
T2: In actual fact O.K. as you know, our time to cover all the syllabus, somewhere somewhow there are distabances inbetween. Hence O.K. they should be doing the acids and bases right now, but now due the fact of the distaburnces we have not O.K. reached the acids and bases.
I: So what you are telling me is that you haven't done the topic acids and base titrations?
T2: Sorry?
I: You haven't taught the pupils acids and base titrations? You haven't taught it to the pupils?
T2: I haven't taught it to the...?
I: Pupils?
T2: Pupils O.K. right. Yah, as far as the syllabus is concerned, I haven't reached that topic, I'm still far behind.
I: O.K. so is it going to be possible for you to do the acid and base titrations experiment before you go to the workshop on Wednesday?
T2: To the?
I: Workshop on Wednesday?
T2: Workshop. No it is possible.
I; It is possible?
T2: It is possible.
I: So how are you intending to introduce that to your pupils?
T2: Intend to introduce what, the topic acids and bases?
I: No the experiment on acid and base titrations.
T2: The experiment O.K Ehh... acids and bases titrations O.K. it forms a link with O.K. what they have learned in standard eight O.K. I think O.K. it is not going to be a problem a much problem to do that. In standard eight we used a burette O.K. conical flask and the indicators, now they are going to do that on their own with myself supervising. It's not going to be a problem.

I: So...

T2: They've got the knowledge of acids and bases especially the titrations, in standard eight we did not call it a titration, we said it is just neutralisation.

I: Oh, neutralisa..

T2: Just neitralising, neutralising O.K. acid with a base.

I: So you are just going to give them the worksheets and the kits and then ask them to follow the instructions in the worksheets?

T2: Yes, of course. Those are standard tens O.K. so I don't think they'll give me a problem much.

I: O.K.

T2: They know how to read O.K. and so on and so on.

I: Are there any difficulties that you yourself encountered in the workshop?

T2: In the workshop?

I: Yes, regarding the experiment?

T2: No no I don't think so, no difficulties at all.

I: Is there any chemistry in particular that you learned from doing that experiment?

T2: Chemistry?

I: As in the chemistry content?

T2: The chemistry content? Yes, (quite for about 3 seconds) in short wasss (quite for about 2 seconds) it was amusing in actual fact O.K. to find the number of moles especially O.K. withh the second acid. The first one O.K. it was one to one and the second one it was two against one.

I: So which was two and which was one?

T2: Which was two and which was one? No the base it was two and then the acid it was one.

I: O.K. and then how did you feel about working with the micro apparatus?

T2: Ahh it was interesting, working with the things.

I: It was interesting? So did you like working with them?

T2: Yes I did like them.

I: O.K.

T2: So as the kids they loved them, to use them to such an extent O.K., I'm having a problem, some of them aasked to carry them home.

I: Laughs. O.K.

(Arrange a suitable date for Interviewer to observe the pupils doing the experiment off the tape and then he decided to teach the pupils before they are exposed to the experiment) then...

I: On Thursday you will do the acids and bases titrations experiment?

T2: Yah I'll do the experiment acids and bases O.K. on Thursday with the pupils, because O.K. on Friday (June 16th) I don't think we will be in a position to come to school.

I: So would you like to tell me what in particular will you be doing about the acids and bases with the pupils before they get exposed to the experiment?

T2: With the pupils? Before they get exposed to the?

I: Experiment? The acids and bases?

T2: O.K. just the introduction first.

I: So you want to introduce it to them?

T2: Yes.

I: O.K.

T2: Yes I want to introduce the acids and bases to them.

I: What in particular?

T2: What in?

I: What will be introducing in particular?

T2: In particular I'll be introducing the properties because it is very important that they know the properties of an acid and a base before we can get to the actual experiments O.K.?

I: O.K. So are you going to tell them anything about the experiment, are you going to breif them about the experiment?

T2: Breif them about?

I: The experiment?

T2: No, after o'right I'll introduce it to them and then O.K. we will be doing the experiment together as a class.

I: O.K.

T2: In short, I'm going to take the whole morning, from eight o'clock to eleven o'clock.

I: You will be doing acids and bases?

T2: Yah from eight o'clock to eleven o'clock.
I: O.K.
T2: Yah.
T2: Doing the experiment we need we are having a problem O.K. and especially unless we do it in the afternoon.
I: Ohh! And how do you normally do your practicals?
T2: My practicals, I normally do them in the afternoon.
I: How? What do you normally do?
T2: Sorry?
I:What do you do?
T2: Especially the experiments aft. err I do them in the afternoon.
I: Yes, I'm saying are you demonstrating to the pupils...
T2 No no no no no I'm not demonstrating. In short O.K. and the children are also involved o'right, they are taking part in the experiment itself.
I: How are..
T2: Although they are working in groups. Right now, due ,to the introduction of these comboplate I think now it is much easier because all along O.K. I've made them to work in groups.
I: So in these groups, were you giving them say something like worksheets and apparatus to work with?
T2: Yes, I give them apparatus and then O.K. the instructions are also there, and then instead of the worksheets they use O.K. the classwork exercise books that forms part of their worksheets.
I: O.K, so you give them instructions and then you devide them into groups and then they work together?
T2: They work together o'right O.K. with myself O.K., the supervisor for going to assist O.K. the group that is encountering some problems.
I: How big is your class?
T2: Thirty nine.
I: Thirty nine?
T2: Thirty nine.
I: So how many groups do you normally have?
T2: Mmmm a group of six.

I: A group of six?
T2: Yah because O.K. more than that you know there is no work done. The bigger the group others are just depending on what o'right especial... I see let O.K. the leader... if they are more than six, the rest O.K. they rely on the leader. They take whatever the leader is saying is correct, they don't take themselves. They don't take for themselves.
I: Are you having any problems with that method of practical work?
T2: Yes, the time factor.
I: It takes a longer time?
T2: Time factor time factor.
I: O.K.
T2: The problem is the time factor.
I: Is it time only?
T2: Time factor plusss the chemicals and the apparatus, let me say the apparatus.
I: What about the apparatus?
T2: We don't have enough.
I: For doing...
T2: For physics and chemistry we don't have enough apparatus.
I: O.K.
T2: We are having a problem as far as the experiments are concerned.
I: So in in in this case where they will be doing microchemistry, how are you going to distribute the chemicals and the worksheets and the kits?
T2: Ehh the kits O.K. right, ehh the kits O.K. are easy to distribute, the problem no, it won't be a problem O.K. O.K. the chemicals we can stir it up.
I: Yes, how are you going to distribute them?
T2: I'm going to make out large quantities, the large quantities and pour them into a beaker. So in the beaker, each one is going to come with the pipette and suck the chemical and go and work.
I: So how are they going to work this time?
T2: This time?
I: Yes.
T2: They are going to work individually.

I: Individually?

T2: Individually.

I: Will they be sharing anything?

T2: No, they won't be sharing anything.

I: Each one will be having their own kit and worksheet?

T2: Yes.

I: O.K. Thank you

T2: Errr the chemistry it was of great help to such an extent O.K. it has releived me especially on the side of preparation bringing testubes, O.K. burrettes O.K., all sorts of bottles O.K. beaker chemicals, you know it has helped me a lot. It has relieved me.

I: So you won't be having to do any preparations this time?

T2: Preparation, no...I do have to prepare.

I: What?

T2: Sorry?

I: What will you be preparing?

T2: Especially the presentation part of it you see. I have to prepare presentation and the lesson. Ahh it will be a little bit offf ehh organising O.K. some of the chemicals because O.K. some of them are not enough there. And then after that O.K., they're going to work fast. I think so, they are going to work fast.

I: O.K.

T2: Within the month O.K. I think I will be through with all the chemistry.

I: Thank you.

(Tape was tuned off as the discussion was no longer relevant to the interview. Then the interviewer found the discussion relevant (the teacher was talking of selecting a number of pupils from his class to do the experiment so that it could be done before he attended the second workshop) and therefore turned on the tape recorder).

T2:...give me a problem.

I: So how are you going to select them?

T2: You know, I trust them, I'm going to select at random.

I: At randomn?

T2: Just five or six or seven. So O.K. I'll select eight to make an even number. I'll select eight.

I: You will select eight pupils, introduce acids and bases to them and then give them the experiment to do?

T2: All right.

I: Will you brief them about the experiment?

T2: No, they must find out first.

I: So they will read the worksheets on their own?

T2: They will read the worksheet O.K.? They must find out first before I brief them about what's going on here. They...a..actually O.K. right they must give me a feedback you know.

I: O.K.?

T2: Yah, they must give me a feedback after the thing , then we discuss. After that...and then in in the summary part of it, and then after that I'll be telling them O.K. right what's going on there, when I summmarise.

I: O.K.

T2: And then after that they might give them work.

S3 T3'S INTERVIEW

I: I'd like to talk about the workshop where microchemistry was introduced to you. So I'd like you to tell me about it.

T3: Everything from scratch?

I: Anything that you'd like to tell me about it.

T3: Emmmm...firstly I...we were introduced to.... the the the two acid, the monoprotic and diprotic acids. And thereafter we did one experiment.

I: Tell me about the experiment itself.

T3: Ehh...the experiment was to determine the monoprotic and diprotic and diprotic ehmm acids so I did it.

I: So did you encounter any difficulties using the microchemistry apparatus?

T3: No, the the one thing that was hard to use was the the the (sguezes his fingers as if squeezing a propette) what is that called?

I: You mean the propette?

T3: Yah, getting drops out of the propette.

I: What is your attitude towards microchemistry?

T3: No, I think it will be helpful for the students because they will do the experiments.

I: What about the chemistry content, did you learn anything from that experiment?

T3: I think... ehhh... I learned something really, to be able to see whether you have a mono or a diprotic acid.

I: Do you usually do practical work in your school?

T3: Not at all.

I: Tell me about the problems you have.

T3: The problem is we don't have...ehh we didn't have laboratories.

I: How do you think you will introduce RADMASTE microchemistry to your pupils?

T3: Firstly by demonstrating and then showing the experiment.

I: You demonstrate a particular experiment (T3(interrupts): Yah I(continues):...or how to use the apparatus?

T3: Yah yah, how to use the apparatus as well as to explain how to use.. it seems like I'm repeating the same thing (both laugh) yah, I will show them

neh, how to use the apparatus and then, how to use the apparatus and know some of the apparatus even their names their names and so on.

I: So in terms of the kit, how are you going to distribute them to your pupils?

T3: Yah, when it comes to the kit, I am going to group the students.

I: How many students do you have in your class?

T3: I'm having thirty..thirty eight.

I: What will be the sizes of your groups?

T3: Ahh...approximately ten

(Tape got cut and the interview was continued on another c...).

I: So how do you think you will introduce microchemistry to your pupils?

T3: I will ehmm, firstly familiarise them with the..the..the.., I might say the equipment? Yah, so that they should know...what they are going to use. For example the...comboblast, they should know what these are meant for and...then err let's say the pippette, what they are going to use for, and so on, the spatulas and err they have to know them before they can actually use them.

I: So how are you going to distribute the kits?

T3: Err, I'm going to...err... group the students, in other words err...two students will get one kit, err including the worksheet.

I: The worksheet?

T3: Yah.

I: So two students will get one kit and one worksheet?

T3: Yah, one worksheet.

I: O.K. And then how are you going to link the theory to the practical?

T3: Err...I'm going to link it in this fashion, I'm going to allow them, after introducing the...the topic I'm going to allow them to do the experiment (unclear). And thereafter, by asking quetions, (unclear) show them the link (unclear).

I: So they will link the results to...to (unclear).

T3: Yah.

Obs 1 orange
Obs 2 pink

Acid used	N° of drops of Acid A	N° of drops of NaOH	Average N° of drops NaOH
A	5	5	= 5,7
	5	9	
	5	5	

Acid used	N° of drops of Acid B	N° of drops of NaOH	Average N° of drops NaOH
B	5	11	10
	5	9	
	5	10	

Q_1 : Different volumes of Sodium hydroxide.
Q_2 : 5:7
Q_3 : 10
Q_4 : The results in table 1 & table 2 are precise
Q_5 : Precise because there're more or less precise
Q_6 : Imprecise

ACID USED	N° OF DROPS OF ACID A	N° OF DROPS OF NaOH	AVERAGE N° OF DROPS
A	5	7	6
A	5	5	
A	5	6	

TABLE B

ACID USED	N° OF DROPS OF ACID B	N° OF DROPS OF NaOH	AVERAGE N° OF DROPS
B	5	9	9,3
B	5	10	
B	5	9	

QUESTIONS

Q1 I THOUGHT TO BE EQUAL BECAUSE THEY HAVE THE SAME CONCENTRATION BUT THE VOLUMES ARE DIFFERENT

Q2 THE VOLUME RATIO OF NaOH IS 1,2 IN A

Q3 THE VOLUME RATION OF NaOH IS 1,56 IN B

Q4 THE RESULTS ARE NOT THE SAME COZ ACID B IS WEAKER THAN ACID A

Q5 PRECISE > THE NUMBERS ARE CLOSE TO EACH OTHER

Q6 THE EXPERIMENT IN ACCURATE I MEAN THE RESULT ARE CLOSE TO EACH OTHER

Acid used
A

OBSERVATION A → Tab H_2O + indicators ⇒ it turned Yellow
OBSERVATION B → Acid A + " ⇒ Reddish.
CH_4 -.

ACID USED A:	N° OF DROPS OF ACID (A)	N° OF DROPS OF NaOH	AVERAGE N° OF DROPS NaOH
A(2)	5	7	5,3
A(3)	5	5	
A(4)	5	4	

TABLE 2

ACID USED B	N° of drops of Acid (B)	N° of drops of NaOH	Average N° of drops NaOH
B	5	5	6
	5	6	
	5	4	

OBSERVATION A →
(5) 5
(6)

Q(1). They needed to be the equal since the concetration was the same.
Q(2). The NaOH volume ratio is 1,06 in (A)
3 the NaOH volume ratio is 1,2 in (B)
Q4 Firstly my results are not the same. The Acid B is weaker ¢ Acid A is stronger
Q5 PRECISELY. The numbers are closer to each other.
Q6 The experiment is inaccurate. I mean the result are are close to each other.

N-B Meshiane.

TABLE 1.

Acid used	N° of drops Acid A	N° of drops of NaOH	Average N° of drops NaOH
A	5	6 drops	
	5	5 drops	6,66 drops
	5	7 drops	

TABLE 2.

Acid used	N° of drops of Acid B	N° of drops of NaOH	Average N° of drops NaOH
	5	12 drops	
B	5	8 drops	10,3 drops
	5	11 drops	

Question 2

1. The N° of drops of NaOH are different.
2. $\frac{6,66 \text{ drops}}{5}$ = 1,332 volume ratio.
3. $\frac{10,3 \text{ drop}}{5}$ = 2,06 volume ratio.
4. The results are not the same. Acid B is stronger than acid A
5. The volumes are precise. The Numbers are closer
6. It is inaccurate

Acid used	N° of drops of Acid A	N° of drops of NaOH	Average N° of drops NaOH
A	5	8	
A	5	5	6,66
A	5	7	

Acid used	No of drop of Acid B	N° of drops of NaOH	Average N° of drops NaOH
B	5	12	
B	5	8	10,3
B	5	11	

Question

1. The average of drops of NaOH are different

2 $\frac{6.66}{5} = 1,332$

3 $\frac{10,3}{5} = 2,06$

4 The result are not the same because the Acid B is stroger than Acid A

5 The volume are precise because the number of drops of NaOH are closer

6. inaccurate

TABLE 1

Acid used	Nº of drops of acid A	nº of drops of NaOH	Average Nº of drops NaOH
A	5	3	9,3
	5	5	
	5	5	

TABLE 2

Acid used	nº of drops of acid A	Nº of drops of NaOH	Average Nº of drops NaOH
B	5	5	10,3
	5	6	
	5	5	

Question 1

1. 9,3
2. 10,3
3. 2,06
4. They are not the same
5. Accurate because they share the same volume of the base but not exactly.
6. Accurate

Johan Themba Ntabile

Acid used	No of drops of Acid A	No of drops of NaOH	Average No of drops NaOH
	5	6	
A	5	7	6,7
	5	7	

i) The colour is orange (light) in well [A1]
ii) The colour is pink in well (A2)
iii) The colour is orange (light) in wells [A3] & [A4]

Acid used	No. of drops of Acid B	No of drops of NaOH	Average No of drops NaOH
	5	13	
B	5	12	12,7
	5	13	

D

2) The volume ratio for NaOH/Acid A is 1,34
3) The volume ratio for NaOH/Acid B is 2,34
4) They are not the same. It is because acid B is stronger than acid A
5) The volumes of the base used in Table 1 and Table 2 are precise. They are not neccesarily equal but they are almost the same

A. B C H_2O NaOH

Observation 1

A_1 Orange

Observation 2.

A_2 Red

Table 1

Acid used	N° of drops of Acid A	N° of drops of NaOH	Average N° of drops NaOH
A	5	3	3.7
	5	3	
	5	5	

Table 2

Acid used	N° of drops of Acid B	N° of drops of NaOH	Average N° of drops NaOH
B	5	8	8.3
	5	7	
	5	10	

Questions:

Q_1 3.7.

Q_2 0.74 ~~1.66~~

Q_3 1.66

Q_4 Are not the same

Extension questions

Q_5 A not accuracy because we used the same acids, NaOH but different results

Q_6

Petros Gweba Petros Gweba

Table 1

Acid used	N° of drops of Acid A	N° of drops of NaOH	Average N° of drops NaOH
A	5	7	7
	5	7	
	5	7	

i) The colour solution in well A[1] is slightly orange.
ii) The colour solution in well A[2] is one
iii) slight orange

Table 2

Acid used	N° of drops of Acid B	N° of drops of NaOH	Average N° of drops NaOH
B	5	8	9,6
	5	9	
	5	12	

Q1.

2. The volume ratio of NaOH/Acid A is equal to 1,4
3. The volume ratio of NaOH/acid B is equal to 1,9
4. The answers are not the same in question 2 and 3
* Acid B is stronger than acid A
5. The volumes of the base used in table 1 and 2 are precise. They are not necessarily equal but they are almost the same
6. Inaccurate

TABLE 18 5

ACIDS USED	N° of drops of Acid A	N° of drops of NaOH	Av. N° of drops NaOH
A_1	5	5	
A_2	5	6	
A_3 & A_4	5	9	6,1

1&2 Observation 1 & Orange
3 Observation 2 & Reddish colour
4 Observation of 3 & 4 Orange colour

TABLE 28

ACIDS USED	N° OF DROPS OF ACIDS B	N° OF DROPS OF NaOH	Av. N° OF drops NaOH
B5	5	14	
B6	5	14	
B7	5	15	14,3

Questions

Q1. Different volumes
Q2. The volume ratio of NaOH /Acid A 1, 34
Q3. The volume ratio of NaOH /acid B 2, 86
Q4. Explanations
Question 3 differ more than Question 2

Extension Questions

Q5. Accurate they don't differ too much from one another.
Q6. Inaccurate

TABLE 1

Acid used	N° of drops of Acid A	No of drops of NaOH	Average n° of drops NaOH
A	5	5	$\frac{21}{3} = 7$
	5	9	
	5	7	

TABLE 2

Acid used	N° of drops of Acid B	No of drops of NaOH	Average no of drops NaOH
B	5	11	$33/3 = 11$
	5	12	
	5	10	

Questions

1) The number of drops of NaOH are not the same
2) NaOH / Acid A = $7/15$ = 0,46
3) NaOH / Acid B = $11/15$ = 0,73
4) The volume ~~of~~ ratio is not the same
Volume of 2B is less than the volume of 3

Extension Questions:

5) They are precise, the number of NaOH in table one is almost a
6) Inaccurate

Acid A	Acid B
5	5
NaOH 8	NaOH 16
5	5
NaOH 12	NaOH 24
5	5
NaOH 16	NaOH 32

Acid A

5
NaOH 16 drops
5
NaOH 14 drops
5
NaOH 14 drops

Acid B

5
NaOH 30 drops
5
NaOH 35 drops
5
NaOH 40 drops

Acid A	Acid B
5	5
NaOH 12 drops	NaOH 30 drops
5	5
NaOH 12 drops	NaOH 30 drops
5	5
NaOH 12 drops	NaOH 30 drops

CIDS AND BASES

CID-A
5
AOH 15
5
AOH 14
5
AOH 12

ACID-B
5
NAOH 30
5
NAOH 20
5
NAOH 18

Acid A		Acid B	
	5		5
NaOH	13	NaOH	20
	5		5
NaOH	14	NaOH	22
	5		5
NOOH	16	NaOH	29

ACID A

5 drops
NaOH 15 drops
5 drops
NaOH 15
5
NaOH 15 drops

ACID B

5 drops
NaOH 30 drops
5 drops.
NaOH 30 drops
5 drops
NaOH 30 "

ACID A

5 drops
NAOH 15 "
5 drops
NAOH 15 drops
5
NAOH 15 drop

Acid B

5 drops
NAOH 30 "
5 drops
NAOH 30 "
5 drops
NAOH 30

Acid A	Acid B
5	5
NaOH 15	NaOH 40
5	5
NaOH 14	NaOH 35
5	5
NaOH 12	NaOH 25

Acid A	Acid B
5	5
NaOH 10	NAOH 25
5	5
NaOH 15	NaOH 30
5	5
NaOH 45	NaOH 60
5	5

Acid A (5)	Acid B (5)
NAOH 15 drops	NAOH 30 drops
NAOH 14 drops	NAOH 35 drops
NAOH 14 drops	NAOH 40 drops

Acid A	Acid B
Acid A 5	Acid B 5
NaOH 15	NaOH 20
Acid A 5	Acid B 5
NaOH 17	NaOH 30
Acid A 5	Acid B 5
NaOH 19	NaOH 34

ACID A	Acid B
Acid A 5	Acid B 5
NaOH 15	NaOH 30
Acid A 5	Acid B 5
NaOH 15	NaOH 30
Acid A 5	Acid B 5
NaOH 15	NaOH 15

Acid A	Acid B
5	5
NaOH 15	NaOH 35
5	5
NaOH 15	NaOH 35
5	5
NaOH 15	NaOH 30

ACiDA

5

laOH 15 drops

5

laOH 14 drops

5

AOH 14 drops

ACiD

5

NaOH 30 drops

5

NaOH 35 drops

5

NaOH 46drops

Acid A 15

NAOH 18drops

5

NAOH 13 drops

5

NaOH 18 drops

Acid B

NaoH 0f drops

5

NaoH ~~10~~ 30 drops

5

NAOH 35 drops

Acid A

Acid A 5

NaOH 5

acid 5

Na OH 5

Acid A 5

NaOH 5

Acid B

Acid 35

Acid A 30

Acid 35

NaOH 30

Acid 35

NaOH 15

Acid A	
	5
NaOH	15
	5
NaOH	15
	5
NaOH	15

Acid B	
	5
NaOH	35
	5
NaOH	35
	5
NaOH	35

Acid B	
	5
NaOH	15
	5
NaOH	15
	5
NaOH	15

Acid B	
	5
NaOH	35
	5
NaOH	35
	5
NaOH	35

Acid A	
Acid A	5
NaOH	15
acid A	5
NaOH	15
acid A	5
NaOH	15

Acid B	
Acid B	5
NaOH	30
acid B	5
NaOH	30
Acid B	5
NaOH	30

GROUP: A

Observation No

i) Methyl orange plus 5 drops of Water the colours are same.

ii) In Well A(2) We ~~used~~ add Acid A 5 drops and one of Methyl orange colour change to red.

iii) In Well A(2) We added 5 drops of Sodium hydroxide the colour change to orange

Acid used	No of drops of Acids A	No of drops of NaOH	Average No of drops No
A	5	A(2) 4	4
	5	A(3) 4	
	5	A(4) 4	

Acid used	No of drops of Acids B	No of drops of NaOH	Average No of drops No
B	5	A(5) 9	10
	5	A(6) 10	
	5	A(7) 11	

Observation No2

Acid A is Stronger than Acid B which means Acid A is More Concentration than Acid B

ANSWERS

The volume of sodium hydroxide solution is 7
Volume ratio of NaOH/Acid A is 12
Volume ratio of NaOH/Acid B is 20
The volume of B is almost twice that volume A (Acid A is stronger than Acid B)

GROUP B

Observation 1. After pouring methyl orange indicat in to water the colour changes to Pink

Observation 2. After pouring methyl orange indicator in to acid A the colour changes to red

ACID USED	Nº OF DROPS OF ACID A	Nº OF DROPS OF NaOH	AVERAGE Nº OF DROPS NaOH
A	5 5 5	~~4~~ 5 ~~3~~	4

ACID USED	Nº OF DROPS OF ACID B	Nº OF DROPS OF NaOH	AVERAGE Nº OF DROPS NaOH
B	5 5 5	6 ~~8~~ 8	7,1

Question 1. When we mix methyl orange the colour chang to pinkish and when we add NaOH the colour changes back to orange.

Question 2. The volume are not the same

Question 3. The volume are not the same.

Question 4. Because the number of drops of NaOH are not equal.

Question 5. The volume of base are precise because the numbers of drop of NaOH are not equal and the colours are not the same.

Accurate means equal/.

Precise means di...

Question 6. Inaccurate.

Observation No. 01 GROUP

In A[1]. When mixing 5 drops of H_2O and 1 drop of ~~acid~~ methyl orange the colour remains orange.

In A[2] When mixing 5 drops of ~~H_2O~~ acid A and a drop of methyl orange the colour change to be red.

Observation No 02

After adding 6 drops of sodium hydroxide in A[2] the colour change to be the same as A[1]. (orange)

Acid used	No of drops of Acid A	No of drops of NaOH	Average No of drops NaOH
A	5	6	5.7
	5	6	
	5	5	

TABLE 02

Acid used	No of drops of Acid B	No of drops of NaOH	Average No of drops NaOH
B	5	~~10~~	10
	5	10	
	5	10	

~~1. All the colours are the~~

~~2.~~ The V

Q1 6

Q2 ~~(a) Acid A~~
(a) The volume ratio of Acid A = 5
(b) The volume ratio of NaHO = 5.7

Q.3 (a) The volume ratio of Acid B = 5
(b) The volume ratio of NaHO = 10

Q4 (a) Acid B is more concetrated than Acid A
(b) In table 02 NaHO is more concetrated than that in table 01.

Q.5 ~~Accurate~~ Precise, because the volumes are the same but ~~and~~ the volume are not the same. and different acids. Acid B is stronger than Acid A.

Q.6 Inaccurate

PUPIL INTERVIEW PROTOCOL

Hellow! How are you?
Thank you very much for making yourself available to me. I really appreciate that.
I will be recording our conversation since this will be needed for my report.
This is not a test and I would also appreciate it if you be as open as you can.
Your teacher will not know what you have told me.

1. Lets talk about microscale apparatus.
Is there anything you especially liked? Why?
Is there anything you really didn't like? Why?

2. Let's talk about the worksheet.
Were you able to follow anything?
If yes.....Good.
If no.....Ah! Let's find some of the difficulties. Here is a highlighter pen. (Do you know how these are used? If no, then show them). What I'd like you to do is to highlight any words or phrases that gave you problems.
(Probe as marks are made).

3. So we can talk about the experiment then.
What did you do?
Can you tell me the name of this procedure?

At the end: a) Record whether student used worksheet to help 'recall' or not.
b) Record whether student seemed to understand the interviewer and was especially relaxed or nervous.

S1 P1'S INTERVIEW

	KITS	WORKSHEET	CONTENT	COMMENT
I: Hello?				
P: Mmhh.				
I: How are you?				
P: I'm o'right.				
I: (unclear)...that we talked about. It's not a test or anything, I just want your opinions, so can you please be as free as you can. Right?				
P: O.K.				
I: I first want to talk about the kit that you used. Is there anything that you really didn't like about them?				
P: No, I like everything in it beautiful. It's good actually, I think it's good to have them.	✓ ✓			
I: O.K., is there anything you really didn't like?				
P: No, I liked it. I should think it's beautiful.	✓			
I: O.K. And then about the worksheets, were you able to follow everything in the worksheets?				
P: I beg yours?				
I: In the worksheet, the worksheet...				
P: Mmmhh?				
I: ...were you able to follow everything?				
P: Yes, we were able to follow everything and answer every question.		✓		
I: Are you sure?				
P: Yes.				
I: O.K., is there anything that you would probably need more clarification on in the worksheet?				
P: In the worksheet? No. Actually, we didn't understand the...		✓		
I: Will you please just highlight with this pen, the parts that you didn't understand. This is the worksheet that you used.				
P: OK, mmmm. ...we didn't understand, understand here, where they said question...the focus question one. We didn't actually have a problem, we did solve it, it's question one here.		✓ ✓ ✓		

		KTS	WORKSHEET	CONTENT	COMMENT
32	I: O.K.,...				
33	P: ...question 1 and then question 2 again, question 2 is on the next page.				
34	I: O.K., can you just highlight them on this paper.				
35	P: Where, here?				
36	I: Is it, is that the one that you didn't understand?				
37	P: No, we didn't...actually we thought that question one maybe refer to		✓		
38	question one (turns the page), and then another question two maybe on the		✓		
39	next page maybe question two again.		✓		
40	I: O.K. Can you just highlight that for me.				
41	P: It's like...maybe they can say question one A, and then question one B,		✓		
42	like that. ..we can see it easily.		✓		
43	I: O.K. Then ehmm, what about the experiment itself, can you tell me what				
44	you did in the experiment? Tell me about the experiment.				
45	P: What we...we did?				
46	I: Yes.				
47	P: We said mmm, errr...our teacher told...told us about our authorities, what				
48	is what like errr what is comboplate, and after that we...we we added...he			✓	
49	he gave us theee let me say theee all the apparatus that we used. And we			✓	
50	errr, we did take these things and we added as they have said here. Drops			✓	
51	of water, of water, first it was water then ...like that. We followed the			✓	
52	instructions.			✓	
53	I: O.K., can you remember, in summary, what the experiment was all about?				
54	What you were doing in the experiment?				
55	P: What we were doing in the experiment?				
56	I: Yes, can you tell me a summary of the experiment?				
57	P: By the way...I can say... w we were...how can I put it? To, to sum				
58	everything we did?				
59	I: Yes, just to tell me the steps that you went through. Err if say someone				
60	says, I hear you were doing a practical, chemistry practical, what was it all				
61	about, can you be able just to tell the person what the experiment was all				
62	about?				
63	P: The experiment, what we d we did?				
64	I: Yes?				

		KITS	WORKSHEET	CONTENT	COMM
65	P: The end product is it?				
66	I: What you did and then the end product.			✓	
67	P: O.K., we've taken theee, hmm, I don't know whether I'll be able to tell.			✓	
68	I: You want to look at the worksheet?				
69	P: Yes.				
70	I: O.K.			✓	
71	P: First we added theee, we added water, from the tap, pure water, not			✓	
72	mixed pure pure from the wat...from the tap.				
73	I: O.K.?			✓	
74	P: Then we added the water, frommm from the propettes, then we added			✓	
75	emmm one drop of of a a indicator, we added a drop of it then we went to			✓	
76	another step and then we added, we added emm as we've done in the first,			✓	
77	we added water then we added emmm excess (not clear) acid, because			✓	
78	emmm we were told that if it was acid from which acid and in that case			✓	
79	then we added thee the acid on the test water, and then weee stir,			✓	
80	everything. Then weee weee, I think I (not clear) saw the the results. We			✓	
81	differentiated actually, the the results. With thee like comparing at first			✓	
82	we've added a drop of water, drops of water maybe five, drops of water			✓	
83	then we added aaa that indicator in the case offf of acid, actually we wanted			✓	
84	to see the difference between the two. Then, we went on and theee, and			✓	
85	theee, we went on and we added some...on.. another another on another			✓	
86	...O.K., in our comboplates,...				
87	I: Mhh?	✓			
88	P: ...they were...actually they wereee showing us where we must add and	✓		✓	
89	where and what to put what and where we must put what. Then in in the			✓	✓
90	next step we we take we've taken theee the sodium hydroxide. Then, and			✓	✓
91	we added actually we added ahhh drops of sodium hydroxide in that, in that			✓	✓
92	case, after that weee we compared everything and hhh I don't know				
93	whether I still remember it clearly. But we did again...				
94	I: O.K.				
95	P: ...then, I think, when we were comparing them aaa (not clear) actually...			✓	
96	I: You were comparing what?			✓	
97	P: Aaa that, aaa that tap...aaa what, that water and aaa that indicator.				

I: OK.

P: And aaa and sodium hydroxide, (quiet for four seconds) that sodium hydroxide with aaa water, and acid...is it acid? An acid with above water and we compared both of them with aaa then we saw the two.

I: O.K. So what can you say the difference was?

P: I can say the difference was that...in their concentratio..., actually the difference was in aaa in thee concentrations, they were not the same actually we add..we added same concentrations but they were not the same in volumes...in the volumes they were not the same.

I: The volumes of acids were not the same?

P: Yes.

I: O.K., but the concentrations were the same?

P: Were the same, because we added five drops of water and again we added five drops of water, but in the sodium hydroxide...other hydroxide, we added more, acid but they were not the same in the volumes. Because we had counted the number of it...they were not the same.

I: O.K., can you say why they were not the same?

P: I I shou...I should think, why they were not the same? (Turns the worksheet) (murmur something to herself)...they were not the same because when we were adding sodium hydroxide, we added, first time, not the same as we've added emmm an indicator. No. Sorry. ...sodium hydroxide, we added more sodium hydroxide than we've added an ind..that indicator.

I: O.K. Do you know the name of that procedure? What it is called, adding sodium hydroxide to the acid? What is the procedure called?

P: The procedure?

I: Yes.

P: (Sighs)

I: You have an acid, and then you add a base. What is the procedure called?

P: It uses a titration.

I: Titration?

P: Mm.

I: O.K., thank very much.

P: O.K.

KITS	WORKSHEETS	CONTENT	COMMENTS
		✓	✓
		✓	✓
		✓	✓
		✓	✓
		✓	
		✓	
		✓	
		✓	
		✓	
		✓	
		✓	
		✓	
			✓
			✓
			✓
			✓
		✓	

S1 P2'S INTERVIEW

	KITS	WORKSHEET	CONTENT	COMMEN
I: Hello?				
P: Hello.				
I: How are you?				
P: Fine thank you, how are you?				
I: I'm fine. Thank you very much for giving me this time, I really appreciate it. I'll be recording our conversation because I need it to answer some questions. This is not a test, I'm not going to give you marks for it. And I'm not going to tell your teacher about it. I want us first to talk about the microscale apparatus, you remember that? Is there anything you especially liked about it?				
P: Oh yes, I love them very much.	✓			
I: O.K. Since you used them you liked them?				
P: Yah, I like them and I like chemistry.	✓			
I: You are interested in chemistry?				
P: Yah.	✓			
I: O.K. Anything you really didn't like about them?				
P: No, there is nothing except getting the acids inside the combo..	✓			
I: In the propette? Are you talking about the propette?				
P: Yah the propette.	✓			
I: O.K.				
P: Cant we mark the acids which..	✓			
I: ...a way of marking the propettes s ...at you know what is in them?	✓			
P: Yes.				
I: I want us to talk about the worksheet now. Were you able to follow everything?			✓	
P: Yes, I was able to...it was easy to follow.		✓		
I: It was easy?				
P: It was easy.				
I: Is there anything that gave you problems, that you would like to show me? You might want to look at the worksheet...				

P: That gave me problem?

I: Yes, anything about the instructions. You can just highlight it with this pen if you come across it.

P: No, nothing.

I: Everything was clear?

P: Everything was clear.

I: O.K.

P: Except, giving another suggestion that if we could give an experiment and after you've answered, you must know whether you've answered correctly or what.

I: O.K. Your teacher has got the answers.

P: Oh, he's supposed to give to us?

I: Yes, he can discuss it with you after you've done the experiment.

P: O.K. Thank you very much.

I: And then, can we talk about the experiment. Do you remember what you were doing in the experiment? (unclear) the first one, which I was present when you did it?

P: (Quiet).

I: Would you like to look at the worksheet?

P: Yes.

I: (unclear), or I can say the summary of the experiment, just in short, what was happening...

P: O.K.

I: ...and what did you find?

P: Well thee experiment we had the titration of the acid (unclear) with the (unclear) drops of acid A. And acid B we added (unclear).

I: What can you say you found out from the experiment?

P: We found out?

I: What can you conclude about the experiment?

P:

KITS	WORKSHEET	CONTENT	CONNE
	✓		
	✓		
	✓		
	✓		
		✓	
		✓	

S2 P1'S INTERVIEW

I: Hello?

P: Hello.

I: How are you?

P: Fine thanks and you?

I: I'm fine. I really appreciate your coming here to work with me. I just want your opinion regarding the RADMASTE microchemistry.

P: Mmm?

I: It won't be a test, I just want to know how you feel about working with microchemistry. I won't tell your teacher what we talked about. And also, I want to record our conversation.

P: Mmmm?

I: So first I want us to talk about the microchemistry kit. Is there anything you especially liked about the kit?

P: Yah, yah.

I: Can you tell me about it?

P: Mmm, everything because it was the first time that we used the comboplate, mixing rods...yah we we were used to mmmm test tubes yah. So it was interesting.

I: O.K. Is there anything that you didn't like?

P: No.

I: O.K. And then about the worksheet, were you able to understand everything?

P: Yah, yah. I was able to understand everything because...everything was clear.

I: In this experiment?

P: Yah...yah, yah.

I: O.K. I would like us to talk about this experiment, acid-base titrations? Can you tell me about that experiment?

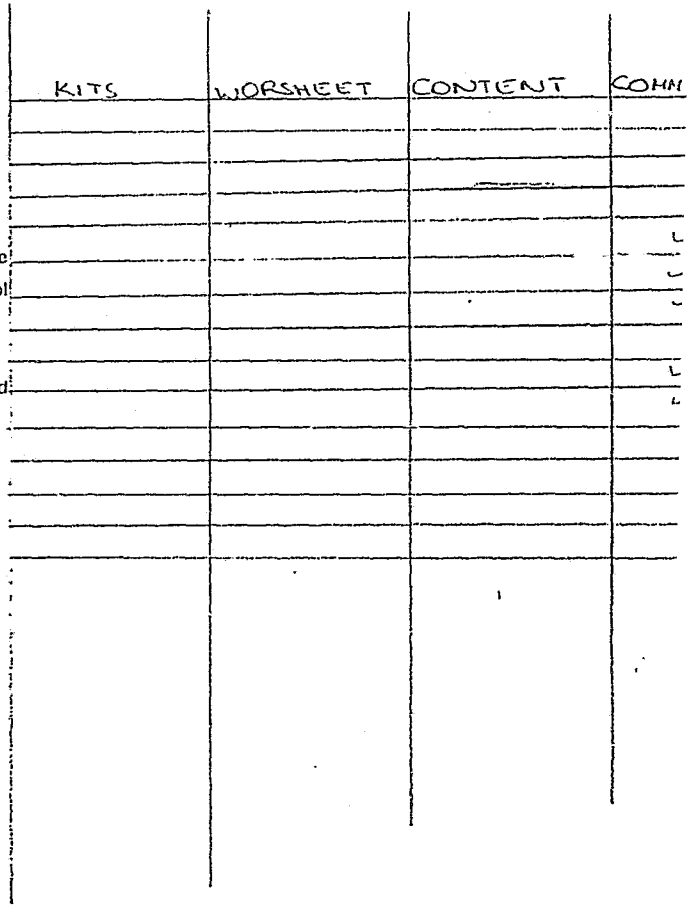
P: (Quiet for seven seconds) Mmmh, I don't remember anything.

I: I think you did it on Thursday, that's what your teacher told me.

P: On Thursday I was sick, I was not at school.

KITS	WORKSHEET	CONTENT	CO
✓			
✓			
✓			
✓			
✓			
✓			
✓			
✓			
✓			
✓			
✓			✓
✓			✓
✓			✓

I: You were not at school?
P: Mmm.
I: O.K. But you also did it on Tuesday.
P: Tuesday?
I: Last week.
P: (Quite for five seconds) Mmmm, I was only at school on Monday because I was sick the whole week, I didn't come to school. So I only came to school today.
I: So you mean last week you were not here?
P: Last week I was not here. So... I told my teacher I was sick, so he said he will repeat the experiment for me.
I: O.K.
P: Yah.
I: Thank you.
P: Thank you.



S2 P2'S INTERVIEW

KITS	WORKSHEET	CONTENT	COMME

I: Hello?

P: Hello.

I: I would like us to talk about the experiment on acid- base titrations that you did.

P: O.K.

I: I just want your information regarding the whole use of microchemistry apparatus. So, first of all, I would like to tell you that it is not a test. I'm just looking for opinions...

P: O.K.?

I: ...and secondly, I'm not going to tell your teacher what we talked about.

P: O.K.?

I: O.K. Firstly I would like us to talk about the microchemistry kit.

P: That we are using?

I: Yes. Is there anything that you particularly liked about it?

P: Yes because...with the the apparatus that we used, it's used alone. So so that we can not copy from one another person. (Unclear) should copy, not able to do that on their own. That is why I think it's good for a person to work alone with this apparatus.

I: O.K. So you work alone and that's what you like about them?

P: Yes.

I: And then is there anything you really didn't like about it?

P: Some of this apparatus, (unclear) we have, it was the first time using this thing so...we are not even used to them so.. sometimes when you...like the propettes, when you are using them sometimes you just squeeze too much drops over to the right and this is what adds to (unclear) to work on.

I: O.K. So you have problems with using the propette?

P: Yah, if you take your time and do that. I think it will come better to do that afterwards.

I: O.K. About the worksheet for that experiment, were you able to understand everything?

		KITS	WORKSHEET	CONTENT	COMMENT
32	P: Yes, some of the the I did understand.	✓			
33	I: Can you be able to show me the parts that you did not understand by				
34	highlighting...				
35	P: From the...				
36	I: From this experiment by marking them with the pen?				
37	P: O.K. Can I start here from the beginning?				
38	I: Yes, anywhere, from the beginning, if there are things that you did not				
39	understand, just mark them with the pen.				
40	P: (Quiet for thirteen seconds) O.K., first, are these these two.	✓			
41	I: The monoprotic and the diprotic acids?	✓			✓
42	P: Maybe it's because I didn't listen to the teachers when he was explaining	✓			✓
43	these things.				
44	I: O.K.				
45	P: But according to the whole procedure, I do understand what was..we	✓			
46	were required to do.				
47	I: O.K. So you were able to find out finally what monoprotic and diprotic				
48	acids are, or you still don't understand them?				✓
49	P: Not really, I don't understand the terms. But I do understand the	✓			✓
50	procedure of doing this experiment.				
51	I: Of doing the experiment. O.K., is there anything else that you did not				
52	understand?				✓
53	P: (Quiet for twenty eight seconds) Yes, because aa... even if you go back	✓			✓
54	to the first (unclear) acid A and acid B. Acid A it was five drops of...of of of	✓			✓
55	it into well A then (unclear) several drops of, five drops of sodium hydroxide	✓			✓
56	so...we had fifteen drops I I don't know why, why we do that because...				
57	I: Fifteen drops of?			?	
58	P: Sodium hydroxide.				
59	I: O.K. In another well?				
60	P: In another well.				
61	I: O.K.				
62	P: I think (unclear) in another well. But according to this procedure, I do	✓			
63	understand what we were required to do. But the problem is is monoprotic	✓			
64	and diprotic.	✓			

		KITS	WORKSHEET	CONTENT	COMMENT
65	I: O.K. So can we talk about the experiment then? Can you tell me what the				
66	experiment was about?				
67	P: The experiment was about..aaaa you would say to to to deduce out if we	✓			✓
68	are using two different a chemicals to find out whether...if we are adding	✓			✓
69	this and this what what are you going to get afterwards. If you are adding	✓			✓
70	this and that, what are we going to do afterwards. We are going to get a	✓			✓
71	colours and at the same time with the calculating of the concentration of	✓			✓
72	this experiment and working with them accordingly.	✓			✓
73	I: Can you explain a little bit further about the experiment, I didn't				
74	understand you.				
75	P: It's just that I don't understand.				
76	I: My question is: can you tell me about the experiment? What I'm saying is				
77	I understand what you are saying but my problem is you are making it too				
78	short. So can you explain a little bit further?				
79	P: O.K.				
80	I: Do not just say adding this and that. Please tell me what were you				
81	adding and what was the difference? Something like that?				
82	P: O.K. Here we used acids and acid A acid B, something like that. So				
83	so...it's just that I have a problem with (unclear) to see but I do understand.				
84	I: O.K. can you explain to me what you do understand about the				
85	experiment?				
86	P: I understand how to to go about with the experi...with the		✓	✓	✓
87	experi...experiment.		✓	✓	✓
88	I: Mhh?				
89	P: And then adding five drops of acid on A on on well A.		✓		
90	I: Mhh?		✓		
91	P: And then adding acid B on another well at the same time using an		✓	✓	
92	indicator which is methylated a... methyl orange indicator.		✓	✓	
93	I: Mhh?		✓	✓	
94	P: And trying to find out if we add this methyl orange indicator, what		✓	✓	
95	colours change are you going to experience or are you going to see on these		✓	✓	
96	wells.		✓	✓	
97	I: O.K.				

		KITS	WORKSHEET	CONTENT	COMMENT
98	P: Yes.				
99	I: Now do you know what the name of the procedure is called?				
100	P: You mean...				
101	I: The name of the procedure of adding the base to acids, what is the name				
102	of that procedure?				
103	P: I ththink titration is the procedure.			✓	
104	I: Titration?				
105	P: Yes.				
106	I: O.K. Thank you very much.				
107	P: O.K.				

		KITS	WORKSHEET	CONTENT	COMMEN
1	S2 P3'S INTERVIEW				
2	I: Hello?				
3	P: Hello.				
4	I: How are you?				
5	P: I'm fine, and you?				
6	I: I'm fine thank you. Thank you very much for coming for the interview. It				
7	is not a test, I just want your opinion regarding RADMASTE microchemistry.				
8	I will be recording our conversation just for my records, but I won't tell your				
9	teacher what we talked about.				
10	P: O.K.				
11	I: First of all I will like us to talk about the microchemistry kit that you used.				
12	Is there anything that you especially liked about them?				
13	P: Yah. They are helping me very much.	✓			
14	I: O.K. Can you tell me more on how they help you?				
15	P: Yes, actually, they are helping me when I'm doing my calculation.	✓		✓	
16	I: Mhh?				
17	P: A for instance, a chemical reaction equilibrium and the acid-base titration.	✓			
18	I: O.K. Is there anything that you didn't like about them?				
19	P: Not yet.	✓			
20	I: Not yet. O.K. Now can we talk about the worksheet? Were you able to				
21	understand everything?				
22	P: Yah.		✓		
23	I; Especially on this experiment on acid-base titration?				
24	P: (Sounds of paper and pupil quiet for eighteen seconds).				
25	I: This one. Were you able to understand everything in this experiment?				
26	P: Yah.		✓	✓	
27	I: O.K. And now I would like us to talk about the experiment itself. Can you				
28	tell me about the experiment, what you did in that experiment?				
29	P: Aaa I was aa checking the rate of concentration and different...			✓	✓
30	*comparing the ratios.*			✓	✓
31	I: The ratios of?				
32	P: Monoprotic and diprotic.			✓	

I: O.K. Can you say more about what you actually did in that experiment?

P: Yes. Aaa we were using a (quiet for five seconds) acid A...acid A and acid B. But their concentrations..their ratios were not were not the same.

I: Mhh?

P: And we were using (quiet for four seconds) I don't what's solution.

I: What was that solution doing?

P: Aaa bromothymol and...bromothymol blue and phenolphthalein, I now remember their names.

I: O.K. And then what did you do in that experiment?

P: Aaa we were checking time...of their reaction, and the volume, the colour change...

I: O.K. in this (unclear) you remember this experiment where you were adding sodium hydroxide to acid A and acid B..

P: Yes.

I: You see, that is the one we are talking about.

P: O.K.

I: So what is the name of that procedure called, that you used in that experiment, adding base to acid?

P: Mmmm, Hmm, I don't knew it.

I: You don't know the name?

P: Mmm.

I: O.K. But what was happening in that experiment, what were you doing basically?

P: Yah and we were we were (unclear) water.

I: O.K. O.K. Thank you very much.

P: O.K.

	KITS	WORKSHEET	CONTENT	COMM
			✓	
			✓	✓
			✓	✓
			✓	✓
			✓	✓
			✓	✓
				✓
				✓
			✓	
			✓	
				✓

S3 P1'S

	KTT.	WORKSHEET	CONTENT	COMMENTS
I: Hello?				
P: Hi!				
I: How are you?				
P: I'm fine thank you.				
I: O.K. I appreciate your coming here to be interviewed. I will be recording our conversation because I need it for my records.				
P: O.K.				
I: It is not a test, I just want to get your opinions about RADMASTE microchemistry, and your teacher will not know what we talked about.				
P: I understand!				
I: O.K. thank you. First I will like us to talk about the microchemistry apparatus, that kit you used to do the experiments. Is there anything that you especially liked about them?				
P: Yes. There's a lot of things that I...I like or liked. May be it can help you maybe next year you want to continue doing chemistry. Then you...now it makes me to be able to to mix them...how to mix them.				
I: Mhh?				
P: And to have a...to work with acids and something like that.				
I: Mmm?				
P: It will help you.				
I: Is there anything you really didn't like?				
P: No.				
I: No?				
P: Yes.				
I: O.K. Let's talk about the worksheet. Were you able to follow everything?				
P: Yes I was I was able to follow.				
I: You had no problems on the instructions in the worksheet?				
P: Mhh.				
I: O.K. So the experiment, can you tell me what you did in the experiment?				
P: In the experiment? A...				
I: Would you like to look at the worksheet?				
P: You mean I must tell you how many drops...				

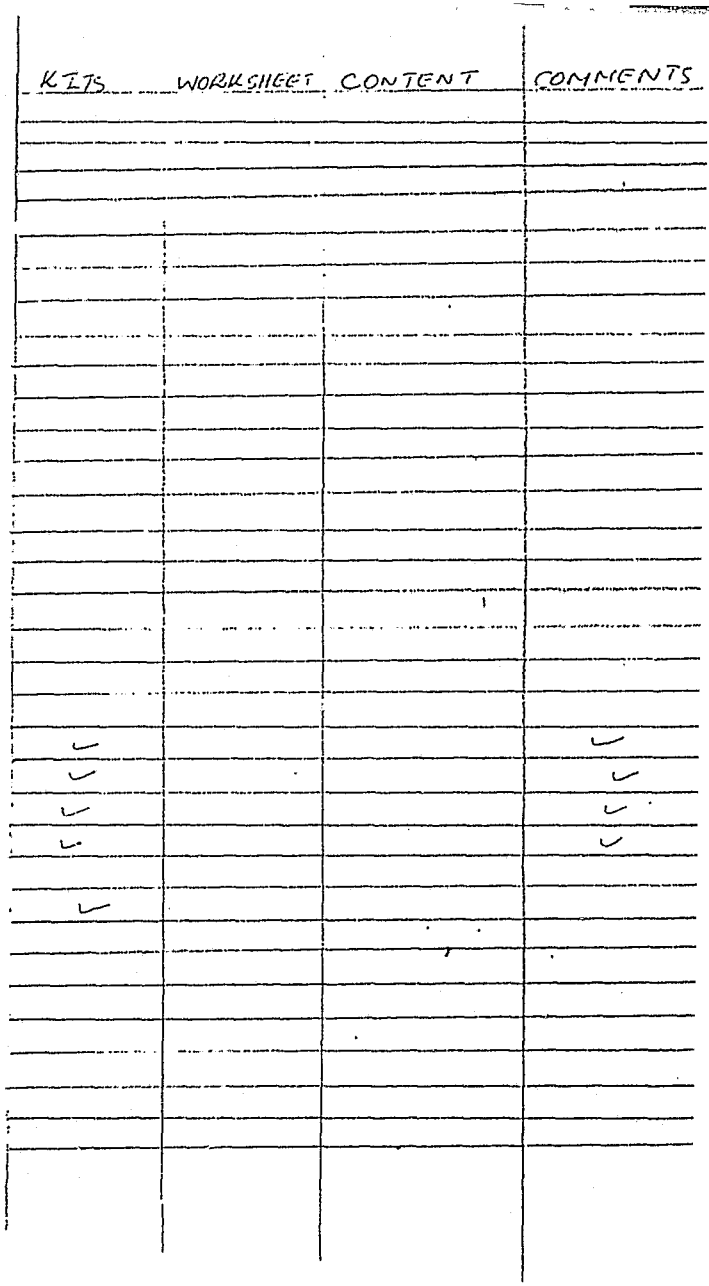
		KITS	WORKSHEET CONTENT	COMMENTS
34	I: I want you to give a summary of that experiment if you can remember.		✓	
35	P: Summary? The summary was about mmm...titration...that's a		✓	
36	titra...titration. O.K.?			
37	I: Mhh?			
38	P: Then, we add water from somewhere (unclear) where it change in		✓	
39	the...I'm not sure...I don't remember well...is it this one?		✓	
40	I: Yah.			
41	P: (Quiet for ten seconds) I think it was to show whether...which which		✓	
42	mmm acid is is strong when the...they are all concentration O.K.?		✓	
43	I: They are all?			
44	P: Concentrated.		✓	
45	I: O.K.			
46	P: Concentrated, yah. Then we had mmm acid A and acid B.		✓	
47	I; Mhh.			
48	P: Then, in acid A, we pour aaa methyl orange...one drop of methyl orange.			
49	Then...when I pour aaa five drops of aaa what is it? Hydrox....			
50	I: Sodium hydroxide?			
51	P: Yah, sodium hydroxide O.K.? And when I..I pour five drops it changed its		✓	
52	colour.		✓	
53	I: You pour five drops of sodiun hydroxide into?			
54	P: A acid B.			
55	I: O.K.			
56	P: O.K. It changed it's colour.		✓	
57	I: It changed it's colour?			
58	P: Yah. But in acid B,...		✓	
59	I: Mhh?			
60	P: I pour mmm five drops neh? It doesn't change (unclear). Then I pour aaa		✓	✓
61	about ten, then it changed it's colour.		✓	✓
62	I: It changed it's colour?			
63	P: Yah.			
64	I: O.K.			
65	P: So, I think I can conclude that I think... acid...A is more stronger than		✓	
66	acid B.		✓	

67 I: That's your conclusion?
68 P: Yah.
69 I: O.K. So what did you say is the name of that procedure?
70 P: Procedure?
71 I: Yes?
72 P: Titration.
73 I: Titration?
74 P: Yah.
75 I: O.K. Thank you very much.
76 P: O.K.

KITS	WORKSHEET	CONTENT	COMMENTS

S3 P2'S INTERVIEW

I: Hello?
P: Mhh.
I: How are you?
P: I'm fine.
I: I'm fine thank you. I appreciate your coming here and being available for the interview. I will be recording our conversation because I need it for my report, I hope you don't mind.
P: Mmmm.
I: This is not a test, I just want to find out your opinion about microchemistry.
P: Mhhh.
I: And your teacher will not know what we talked about.
P: O.K.
I: So I would like you to be free to tell me anything you want to tell me.
P: Mhh.
I: Firstly, I would like us to talk about the RADMASTE microchemistry apparatus. Is there anything that you especially liked about them?
P: Yes, I like it. Mmmm you are talking about the equipment which we used?
I: Yes.
P: Mmm I like it because fromm from standard nine, we didn't use it. So now, aaa we can see that...mmm which what is an acid and what is an...what is a base. Something like that. Because using formula aaaa theory without using without drawing it, you cannot understand very well.
I: O.K. Is there anything that you really didn't like about them?
P: No.
I: No?
P: Yes.
I: O.K. Let's talk about the worksheet. I would like us to concentrate on the experiment you did on Monday.
P: On titration?
I: Yes. Were you able to follow everything in the worksheet, or did you have problems somewhere?



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