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PROVIDING PRACTICAL SCIENCE EXPERIENCE AT HOME, FOR STUDENTS STUDYING SCIENCE THROUGH DISTANCE EDUCATION

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Date of Submission: June 2008

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 (Science Education)

DECLARATION

I declare that this research report is my own unaided work. All sources that I have used or quoted have been acknowledged by complete citation and referencing. This research report is being submitted in partial fulfilment of the requirements for the degree of Master of Science Education in the University of the Witwatersrand, Johannesburg. It has not been previously submitted for any degree or examination in any University, nor has it been prepared under the guidance or with the assistance of any other body or organisation or person outside the University of the Witwatersrand, Johannesburg.

Binaben Jayantilal Akoobhai

June 2008

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ABSTRACT

The role of practical work is crucial to the learning and teaching of science (Woolnough and Allsop, 1985). Depending on the design of the activity it can become a powerful tool for making concrete a subject which is abstract and inherently difficult to understand. The current practice in developing countries (including South Africa), for providing practical work experience for learners studying science through distance education, is a week long session where learners are bombarded with activities after activities the whole day long. This divorces the activity from the theory and thus one aim of practical work, the understanding of a particular theory or concept is not achieved. The microscience system, developed at RADMASTE (Research and Development in Maths, Science and Technology Education) Centre, Wits University, may be an answer to the problem mentioned above.

This system uses small-scale equipment which is cost-effective, versatile, convenient and robust, and demands no special infrastructure. Working on a small scale is now the norm in many branches of science: it costs less, it is safer, there is less damage to the environment, etc. It is accompanied with worksheets (written using a guided enquiry approach) as well as chemicals that would be required for the activities. To see its effectiveness as a tool for providing practical work experience for students studying science through distance education, it was used by educators who had registered for the ACE (Advanced Certificate in Education) for FET (Further Education and Training) level program at Wits University. This is an in-service training course for educators, most of whom qualified with a 3 year educators' diploma from an educators' training college.

The ACE program uses a mixed delivery approach. That is, 4 contact sessions (usually 5 days each, during the school holidays) are spaced throughout the year where educators come to the workshop. During the workshop, course workbook, assignments and portfolio activities for a particular course are given to the educators. For the rest of the period educators are required to work independently or with fellow students. The portfolio tasks and assignments are sent by post to the University by the educators, whereupon they are marked and resent to educators. During each year educators complete 3 specialisation courses (either in Maths or Science) and 2 education courses. The microchemistry kit (part of the microscience system) was used by educators at home for performing practical work activities for the science specialization course entitled, Chemical Reactions.

The current research aims to report on the use of the RADMASTE Advanced microchemistry kit by two groups of secondary school educators at home during their independent study. A questionnaire was designed to look at how the educators managed to use the kit on their own. To gain insight into their experiences an in-depth interview was conducted by visiting four educators at home when they were performing the practical activity. Another questionnaire was designed to ascertain the attitude of these educators towards practical work. A questionnaire was also answered to gain understanding of what the educators learnt after using the kit at home.

The results obtained for this study will inform the future for providing practical work experience for students studying science through distance education.

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CHAPTER 1

INTRODUCTION TO THE STUDY AND RESEARCH OVERVIEW

1.2 Introduction

This research aims to investigate if the microscience system can be used to provide practical work experience at home for students studying science through distance education. The microscience system includes various kits eg. chemistry, physics, biology, etc. For this research the microchemistry kit was used. The students in this study are educators from the Mpumalanga Department of Education (Mpumalanga is one of the provinces adjacent to Gauteng, where the researcher is based) who registered for the Advanced Certificate in Education (ACE) specializing in Science FET (Further Education and Training) level at the University of the Witwatersrand. The study attempts to find out what happens when educators use the microscience equipment at home to do specific experiments.

1.2 Statement of the problem

The complex and abstract nature of science makes the subject difficult to understand. Thus learners find it difficult to grasp the concepts. As reported in the TIMMS (Third International Mathematics and Science Study) by Howie (2001), the situation in South Africa is bad. Our learners are the world's worst performers out of 50 countries in this field. As the CDE (Centre for Development and Enterprise) report (Lee and Clynick (2004)) points out, there is a shortage of science educators, and we need to strengthen the capacity of science educators in South Africa. The scarcity of qualified science educators is prevalent in the African continent as a whole (eLearning Africa, 2006).

To address this problem it is important to improve the quality and qualifications of the science educators. It is imperative for educators, who can be thought of as the custodians of knowledge, to understand scientific concepts well themselves before teaching learners. These educators need to prepare science learners for the industry. The CDE report by Bernstein (2007) states, far fewer maths and science learners are produced by the schooling system than required by the South African economy.

The role of practical work is crucial to the learning and teaching of science (Woolnough and Allsop, 1985). Depending on the design of the practical activity it can become a powerful tool for making concrete a subject which is abstract and inherently difficult to understand. Those studying science for a teaching qualification in the sciences, need to be skilled and confident in performing practical work activities as they will need to perform or facilitate these in their teaching career.

Unfortunately, there are problems in the provision of practical science experiences for students studying science through distance education in South Africa. This impacts negatively on in-service training which is often provided through distance education.

1.3 Background to the problem

At the University of South Africa (UNISA), the largest South African institution providing distance education courses, students studying any science course must attend a compulsory laboratory course lasting 10 days (2 x Monday to Friday). This can be attended either at the University of Pretoria Chemistry Department laboratories or Pretoria Technikon (Tshwane University of Technology) in Pretoria during the period, end of November - beginning of December. During this period students are bombarded with one activity after another the whole day long. This divorces the practical activity from the theory and thus one aim of practical work, the understanding of a particular theory or concept, is unlikely to be achieved. This may have contributed to the unsatisfactory performance of students in Science, Engineering and Technology courses at UNISA and Technikon SA as reported by SAIDE (South African Institute for Distance Education) in 1994. Of the cohort of students enrolling for BSc (Bachelor of Science) in 1984 and 1985 at UNISA, only a small percentage had graduated by 1992.

A report by Jeschofnig (2005), gives a picture of a different approach, that is using science kits at home, as has been done by various Universities worldwide for their science distance courses. He states that for students of science to understand the changes that take place in nature, they need to do hands-on experimentation. For the distance learners, he initiated this process when he was asked to run a distance chemistry class at the Colorado Mountain College, America in the 1990s. He collected relatively safe chemicals, sealed them in convenient thin-stem pipettes, collected the necessary equipments and instructions for various experiments and sent it off to individual students. This led to the formation of his own company called At Home Science

(www.athomescience.com) in 1993, which now provides kits for distance courses in chemistry, physics and biology.

As reported by Jeschofnig (2005), The Open University in the UK, used to ship a mini laboratory to all science students to do practical work at home since the early 70's. Due to shipping restrictions they have also turned to providing practical work experiences at home using small non-returnable kits. As reported by Grose (1999), the kits are very popular with the science and technology students of the Open University in the UK. He acknowledges that simulations can be useful but states that it cannot replace a realistic environment to conduct experiments, measure results, etc.

Jeschofnig (2005), also reports on the successful use of science kits for distance students by Monash University of Australia. These kits are shipped to students throughout Australia, Singapore, Malaysia and the South Pacific. The kits are loaned to the students and need to be returned, at the end of the course, for a refundable fee.

A third approach is exemplified in Japan. The University of the Air in Japan has satellite centers all over the country where experimental practice in a basic chemistry course is carried out by microscale chemistry (Ogino, 2005a).

Microscale practical work is increasingly being used in face-to-face teaching and learning. In countries with a severe shortage of resources, practical activity in a conventional laboratory is generally unsustainable. For example, Mhalangu (1984), in Lewin (1992), reported on 12 schools in Malawi, where practical work was carried out as a demonstration by the educator. The classes were too large to see what the educator was doing. Ross and Lewin, estimated the cost of equipping a laboratory at about $107 800 (in 1992). Compare this to spending today (10 years later), about $6 000 per school in providing microscience kits (where learners may work alone or in groups). For countries in a dire economic situation, it seems a favorable solution, and this is one reason it is spreading world-wide. Therefore a proposal to use microscale practical work at home is not relegating distance education students to a second-class experience but rather it would be in step with a global trend in science education.

1.4 Rationale for the study

The predominant form of practical work experience provided for students studying science through distance education at tertiary level in South Africa is considered to be unsatisfactory. The microscience system, developed at the RADMASTE Centre (Centre for Research and

Development in Maths, Science and Technology Education), University of the Witwatersrand, may provide a more satisfactory practical work experience at home. Appendix A shows a) the components of the Microchemistry Advanced kit; b) chemicals which were used by the educators in the current study; c) an experimental set-up using the RADMASTE Advanced Microchemistry kit and d) a photo of a chemistry kit, distributed by At Home Science which was mentioned earlier (this kit also uses thin stemmed pipettes to distribute chemicals as was carried out in the current study). The results obtained in this study will give insight into whether or not the microscience system can provide the practical work experience at home. The study may be used as a basis to carry out a further investigation involving many more experiments and students who will perform them at home, to ascertain the feasibility of the methodology.

1.5 Aims of the study

The aims of the study are to analyse the attitude of a group of educators towards practical work before and after using the microscience kit at home to perform experiments, and to record and evaluate the experiences of the educators. The study also aims to find out what did the educators learn from using the kit at home.

1.6 Research questions

The study attempts to answer the following questions:

1.6.1 Can microchemistry kits enable science educators (those studying ACE through distance education) to experience practical chemistry at home?

1.6.2 How did the experiences of educators influence their attitude towards practical work?

1.6.3 What do educators learn from 'at home' practical activities?

1.7 Importance of the study

There is a shortage of adequately qualified educators of Physical Sciences in South African secondary schools (Lee and Clynick, 2004). In-service training of educators lacking the necessary skills, knowledge and attitudes is therefore important for the development of the

country. It is imperative therefore that new methodologies are sought in providing learning experiences to students at a distance that result in meaningful learning of concepts in science. This study will be informative in revealing the attitudes and experiences of the student educators who used the microscience kits. It will also provide insight into whether the microscience kits are viable to use at home.

1.8 Ethical considerations

Permission to collect the data (Appendix B) was sought from the Mpumalanga Department of Education, explaining the purpose of the research. This was granted (Appendix C). The questionnaires had a letter attached to the front explaining their purpose (Appendix D). Data was collected from educators who were willing to participate in the study. An indemnity form was signed by each of the educators who participated in the study (Appendix E). This form explained the precautions to be taken when doing the experiments with regards to the chemicals. Other ethical issues to be considered for the current research will be discussed in detail in Chapter 3.

1.9 Delineation of the study

Data was collected only from educators who had enrolled for the ACE course with specialization in FET science in 2005. The main instruments for data collection were three questionnaires and interviews with selected educators.

1.10 Limitations of the study

The results obtained in this study are subject to this particular sample. To generalize and extrapolate on the findings a study would need to be carried out with a larger sample group with varied demography. The study was conducted within the timeframe of the ACE course which therefore constrained the findings of the study. All the questionnaires could not be piloted but were reviewed by colleagues and a lecturer in science education research methodology for grammar correctness and appropriateness of the questions in terms of the language, bias, relevance, etc. The research aims to look at the educators' experience and attitude towards practical work in using the microscience kit at home in respect of conceptual

change in learning of science concepts. It does not claim to test if this change has occurred or not.

1.11 Organisation of the Research Report

Chapter 1 introduces the study and exposes the lack of suitable practical work experiences for students studying science through distance education in South Africa. It presents the general problem statement, rationale and aim of the study. It also looks at the research questions, ethical considerations, delineation and limitations pertaining to the study.

Chapter 2 reviews the literature that is relevant to the study. This includes, the theoretical framework underpinning this study; the process of teaching and learning science; the role, aims and purposes of practical work in science; the new FET NCS (National Curriculum Statement) of South Africa; microscale equipment (particularly microscience kits) and the nature of studying through distance education.

Chapter 3 looks at the context, research design and procedure used to collect data. Ethical issues and rigor in research will also be discussed.

Chapter 4 focuses on the presentation and analysis of the data collected from the completed questionnaires. Analysis of the data is represented in the form of tables and graphs. It also includes data collected in the interviews in the form of a table. Discussion of the data obtained is also included in this chapter.

Chapter 5 summarises the main findings of this study, addresses the research questions and makes recommendations for further exploration in this field.

CHAPTER 2

LITERATURE REVIEW

Chapter 1 presented the problem statement for this study and stated the research questions. In this chapter, literature on the following aspects will be reviewed:

- Learning theories (Cognitive, Constructivist and Socio-cultural)
- The process of teaching and learning science
- The role, aims and purposes of practical work in science
- The new FET (Further Education Training) NCS (National Curriculum Statement) for Physical Sciences of South Africa
- Microscale equipment (particularly microscience kits)
- The nature of studying through distance education

2.1 Learning Theories

2.1.1 Cognitive theory

Piaget placed emphasis on the individual and a biological approach to learning and development. There are two aspects of the theory, the process of cognitive development and the stages of cognitive development. Piaget (1964) identified 4 processes of cognitive development. These are maturation, experiences (physical and logical –internal equilibration), transmission (by other person through language, education) and equilibration (self regulation). Equilibration occurs through a process of accommodation whereby the existing schema is modified to create new ones. If the existing schema is inadequate then a state of cognitive disequilibrium occurs. Therefore for learning to take place the educator must create disequilibrium.

The four stages of cognitive development according to Piaget (Huitt and Hummel, 2003) are; sensory-motor (infancy), pre-operational (toddler and early childhood), concrete operational (elementary and early adolescence) and formal operational (adolescence and early adulthood). At the sensory motor stage, intelligence is demonstrated through motor activity without the use of symbols. In the pre-operational stage, symbols are used, resulting in development of memory and imagination. At the concrete operational stage, a logical and systematic manipulation of symbols occurs. At the formal operational stage, logical use of symbols occurs through abstract thought. Thus, the educator needs to firstly assess the stage of the learners' development before teaching. The educator can then provide the physical experiences to assist development. Thus the educator does not pass on ready - made knowledge. Rather children discover the knowledge for themselves. Piaget does not specifically take into account the socially- constructed nature of knowledge.

2.1.2 Constructivism

Learning is a process of knowledge acquisition. Therefore it is important to know how this knowledge is acquired by the learner. Rote learning through which some of our knowledge is usually gained, is less meaningful than the constructivist approach to learning. The constructivist approach (Fensham et al 1994, Hewson et al 1998), considers that learners 'interpret and interact with the physical world through their conceptualisation of phenomena.' Knowledge construction is based on what ideas learners bring into the classroom about the world around them. It involves engaging in personal construction and meaning making. This leads to meaningful learning, whereby the new knowledge is substantively related to ideas already existing in the cognitive structure of the learner. Constructivist views of learning (summarised by Driver and Bell (1986) in Matthews, 1994) include the following points:

- Learning outcomes depend not only on the learning environment but also on the prior knowledge of the learner.
- Learning involves the construction of meanings. Meanings constructed by the learners from what they see and hear, may not be those intended.
- The construction of meaning is a continuous and active process.
- Meanings once constructed, are evaluated and can be accepted or rejected.
- Learners have the final responsibility for their learning.
- There are patterns in the types of meanings learners construct due to shared experiences with the physical world and through language.

Some constructivists are idealistic and believe that the world is created by and dependent upon human thought. These fall into the radical constructivism school of thought, radical because ' it breaks with convention and develops a theory of knowledge in which knowledge does not reflect an "objective" ontological reality, but exclusively an ordering and organisation of a world constituted by our experience' (Glaserfeld 1987, in Matthews 1994).

2.1.3 Socio-cultural theory

Vygotsky (in Wertch (1985)) says the ability to think and reason is the result of social interaction. It is the result of the active internalisation of problem solving processes. Vygotsky advocates social constructivism, which focuses on the social nature of thinking, recognising that how people think and learn is deeply influenced by the communities and cultures in which they interact. In other words, 'Vygotsky felt that the intellectual ways of knowing the world that a student displayed were not primarily determined by innate factors, that is, inherited intelligence or mental abilities. Instead, Vygotsky 'saw' patterns and levels of thinking as products of the activities practiced in the social institutions of the culture in which the

individual was immersed.'(Morris, 1998). Vygotsky, developed the concept of ZPD (Zone of Proximal Development) in order to conceptualise the role of mediation by others in the development of knowledge.

2.1.3.1 Zone of Proximal Development

The ZPD is the potential ability of the learner if guided (scaffolded) by a more able adult or peer. Learning and development is a social and collaborative activity that cannot be 'taught' to the learner. It is up to the learner to construct his own understanding in his own mind. There is external and internal socialisation. The educator acts as the mediator. The ZPD concept can be used to design situations in which the learners can be provided with the appropriate support for optimal learning. The educator can control the activities and thus challenge learners to go beyond what they can do when unaided. Language is important because without it thought would be limited to what could be learned through actions or images. Vygotsky's concept of ZPD needs to be examined in detail as it involves the interaction between the educator, the learner, the environment, the thought processes (reflection) of both the educator and the learner, the strategies and tools used by the educator etc.

The most widely known explanation of ZPD as noted by Vygotsky himself is the distance between the actual level of development as determined by independent problem solving [without guided instruction] and the level of potential development as determined by problem solving under adult guidance or in collaboration with more capable peers. Measurement of this distance would thus be achieved by comparing the student's performance on both tasks. This essentially means that a learner would use the technique(s) that is/are learnt during the collaborative effort with the companion when trying a similar problem independently. That is, *self review* by the learner is the internalization of *peer review*.

At a certain stage in development, children can solve a certain range of problems only when they are interacting with people and in cooperation with peers. Once the problem solving activities have been internalized, the problems initially solved under guidance and in cooperation with others will be tackled independently. The notion here seems to be that one's latent, or unexpressed ability could be measured by the extent to which one profits from guided instruction. That is, the ZPD is the distance between the "actual" developmental level as determined by independent problem solving and the level of "potential" development as determined through problem solving under educator guidance or in collaboration with more capable peers.

The socio-cultural theory stresses the importance of the community and the context within which the knowledge is acquired. Therefore the situated nature of learning needs to be examined. Doing practical work at home, situates the learning close to the classroom where the educator teaches. In fact several educators actually did the experiments at school, making the relevance of their experimental activity abundantly clear.

2.1.3.2 Situated Learning

Situated learning environments allow learners the 'ability to retrieve information when needed' (Choi and Hannafin, 1995). It gives meaning and promotes transfer of knowledge to day-to-day situations, but is not always guaranteed. The case study done by Carraher et al (1985) illustrates this where the aim of the study was to see if the children in the streets selling fruit would be able to transfer their maths knowledge to a formal setting. Situated learning enriches the learning process by providing practical experiences of real situations. Learning, both outside and inside school, occurs through social interaction and social construction of knowledge. Choi and Hannafin (1995) distinguished four key concepts related to, situated learning: these are context, content, facilitation and assessment. Context is the environment, the location or the setting in which learning takes place. Personal experiences allow learners to use a variety of methods to work through situations. Content is the specific concept that learners acquire. Facilitation allows learners to internalize the information. This is provided by the educator, in the classroom and depending on the facilitation strategy used, can impact on the internalisation process. Assessment can be used for many purposes but should be used for measuring cognitive growth rather than evaluation. The internalisation or self-regulation process by the learner has implications for metacognition, or thinking about thinking.

2.1.3.3 Metacognition

"Metacognition" refers to knowledge concerning one's own cognitive processes and products or anything related to them. Most researchers (Flavell, 1981) agree that differences exist between cognition and metacognition skills. Performing a task requires cognitive skills. To understand how the task was performed requires metacognition. Researchers also distinguish between two components of metacognition: (1) knowledge of cognition and (2) regulation of cognition. Knowledge of cognition tells us what we know about our own cognition or about cognition in general. It includes at least three different kinds of metacognitive awareness: declarative, procedural, and conditional knowledge Declarative knowledge refers to knowing "about" things. Procedural knowledge refers to knowing "how" to do things. Conditional knowledge refers to knowing the "why" and "when" aspects of cognition. For Vygotsky the self-regulation would first occur interpsychologically through social speech and then intrapsychologically through inner speech (when the learner tries to make sense of the social interaction on his/her own). The self-regulation that occurs intrapsychologically would probably apply to doing the experiments at home.

Science taught at school, does not unfold in isolation as children either confront the world or partake in certain cultural practices. Learners have difficulty trying to make sense of scientific ideas that transcend their experience, or maybe are an outright contradiction to their own experience. Learning of science concepts thus requires an initiation into a scientific tradition, which needs to be provided by school science educators (Matthews, 1994). This has implications for constructivist teaching practice.

2.2 The Process of Learning and Teaching Science

Depending on the school of thought a person comes from, will determine how s/he sees knowledge being obtained by learners of science.

2.2.1 Cognitive view

Those advocating cognitive development suggest that sciences should be taught according to the Piagetian schema of cognitive development. But, as reported by Shayer and Adey (1973) in Lewin (1992), it was found that even at the age of 16 years, learners in the UK were performing at late concrete operational level rather than formal operational level in Piagetian terms. This has implications on the design and appropriateness of science curricula.

2.2.2 Constructivist view

The other prominent view of teaching and learning comes from the works of constructivists who argue 'that science should start from the child's understanding of natural phenomena, not from attempts to emulate the reasoning of the professional scientist, who has developed adult understandings of causality, formal reasoning, etc.' (Lewin, 1992, pp 120). Much of the research on learners learning science suggests that learners bring their own conceptions of science to explaining the natural world (Driver and Oldham (1986) in Lewin, 1992).

Constructive learning can be practiced in the classroom by engaging learners with others to understand and interpret concepts and phenomena. The educator is there to provide the concepts and encourage reflection. Driver and Oldham (1986) in Matthews (1994), describe constructivist teaching as being characterised by a number of stages or steps:

- **Orientation**: This allows learners to develop a sense of purpose and motivation for learning the topic.
- **Elicitation:** This allows learners to make their current ideas on the lesson clear.
- **Restructuring of ideas**: This is the focus of a constructivist lesson. It consists of a number of stages: Clarification and exchange of ideas, construction of new ideas (learners can see there are a variety ways of interpreting phenomena or evidence), evaluation of the new ideas through experimentation or by thinking through their ideas.
- **Application of ideas**: Learners are given the opportunity to use their developed ideas.

- **Review:** This is the final stage where learners are asked to reflect on how their ideas have changed from the beginning of the lesson to the end.

2.2.3 History and philosophy of science

This above sequence fits in well with the concept of paradigm shift in science as developed by Thomas Kuhn. Many prominent scholarly constructivists have appealed to the history and philosophy of science (most embrace the post-positivist philosophy) to establish their epistemological and ontological claims (Matthews, 1994). It is important for learners to know the products as well as processes of science and the history and philosophy of science should be integrated into their learning process. The term 'paradigm' used by Kuhn is indicative of a conceptual or theoretical framework in which scientists can be working. A paradigm can consist of a set of concepts and hypotheses, which will form a mental mind set (Hung, 1997). According to Kuhn, scientists can work within a paradigm whilst occupied with observation, reasoning, problem formulation and problem solving. A paradigm therefore refers to the activities (observing, reasoning and problem solving) of scientists ((just as learners observe, reason and solve problems) (Hung, 1997). The human mind and senses are regarded as intertwined and knowledge is the end product of a constructive collection of both the ideas from the mind and the input through the senses. The Weltanschauung Thesis of Kuhn (which resembles constructive learning in the sense that new concepts are assimilated according to the learner's prior or alternate knowledge) can be summarised briefly as follows (Hacking 1999):

1) Theories are regarded as generic or specific.
2) Over time, a number of vague, generic theories will be proposed.
3) A paradigm is therefore a social construct, which allows scientists to perceive their work in terms of the paradigm theory.

Anomalies can emerge (as with alternate concepts by learners), leading to a crisis with respect to the continuation of the paradigm. A new paradigm emerges, followed by normal science, anomalies, crisis, etc. Awareness of this process sensitises learners to the fact that theories (paradigms) that they are currently using may change as scientists discover something new and the current theory may be refined. It also sensitises them to the likelihood that their own paradigms may need to change in the face of anomalies they encounter.

2.2.4 Conceptual change

Learning for conceptual change is what is usually desired and this involves providing learners with physical experiences that may induce conflict and thereby encourage learners to develop new knowledge that is better accepted to their experience.

In teaching for conceptual change three domains have been identified (Lunetta and Hofstein, 1980). These are cognitive, affective and psychomotor. For any conceptual learning to take

place all three domains need to be addressed in order to address the person as a whole. Table 1 looks at the aims within each domain specific to the science discipline.

Table 1: Aims of teaching (adapted from Lunetta and Hofstein, 1980)

Domain	Aims
Cognitive (intellectual)	1) Meaningful learning of science concepts 2) To convince students of the intelligibility (makes sense) plausibility (reasonableness) and fruitfulness (usefulness) of the educator's conception of the nature of things (as opposed to their own conceptions) by falsification or confirmation.
Psychomotor (manipulative)	1) Meaningful learning of the scientific method and science inquiry skills 2) Meaningful learning of specific practical skills (eg. use of a burette) and other techniques and procedures commonly used by scientists.
Affective (attitudinal)	1) To enhance attitudes towards science 2) To promote positive perceptions of one's ability to understand and to affect one's environment.

According to Lunetta and Hofstein (1980), providing appropriate practical work activities can address the three domains mentioned above.

2.3 Role, Aims and Purposes of Practical Work

2.3.1 Role of practical work

As the maxim 'I hear, I forget; I see, I remember; I do, I understand' illustrates, the integration of practical work in science education is important. It also lends itself well to creating the social interaction through group work essential to social constructivism. This may be achieved in distance learning where students may form study groups. Talking with and working with other learners enables them to:

- Share their interpretations, experiences, metaphors.
- Discuss their planning – the goals of the current activity, where they are in their knowledge, how to best go forward.
- Use other students as an audience, one for whom they can summarise/express their understanding, and one that can help with testing their knowledge.' (Malcolm, 1998, p65)

In regular classes learners' attention may be diverted but the concrete nature of laboratory work helps learners focus their attention on the task at hand. Kreitler and Kreitler (1974), argue that laboratory experiences help students establish the accuracy of their beliefs as well as providing them with direct experience with concepts. In other words, the role of practical work is to provide the link between the two domains of knowledge: the domain of objects and events on the one hand and the domain of ideas on the other (Millar et al, 2002)

Gott and Mashiter (1991), believe that practical work can reveal the mismatch between learner's perceptions and the content which is the desired learning objective. Its role is to facilitate the change in conceptual understanding.

As appears in Woolnough (1991), Herron (1971) arranged types of activities by the degree of openness and the demand for inquiry skills in four levels as shown in Table 2.:

Table 2: Types of Laboratory Investigations

Level of Inquiry	Problems	Procedures	Conclusion
0	Given	Given	Given
1	Given	Given	Open
2	Given	Open	Open
3	Open	Open	Open

In Level 0, problem, procedure and conclusion are given. Learners only need to collect data.

In Level 1, problem and procedure are given. Learners have to collect data and draw a conclusion.

In Level 2, only the problem is given. Learners have to design the procedure, collect data and draw conclusions.

In Level 3, the highest level of inquiry, the learners have to do everything by themselves, beginning with problem formulation and ending with drawing conclusions.

In schools most experiments are performed at level 0 and level 1. Level 2 and 3 demand formal reasoning and cognitive skills which are often difficult for learners. The experiments designed for the current research are based at Level 1. Without guidance Level 2 and 3 would become even more difficult to perform at a distance.

2.3.2 Aims of practical work

The aims of practical work have been categorised by Woolnough and Allsop (1985) as:

- Stimulating interest and enjoyment
- Learning experimental skills and techniques
- Teaching the processes of science
- Supporting theoretical learning

In achieving these aims learners should 'be able to master useful skills which they would apply in life in various ways. They should adopt a scientific attitude and approach, they should observe, collect information, draw conclusions and apply what they know' (Allsop, T. in Woolnough (1991), pp 32). These aims also apply to students doing practical work at home. The aims of practical work are also influenced by the pedagogic practice of a country. For example in a study conducted by Swain et al (1999), UK educators reflected on investigations; Korean educators emphasise on factual recall and illustrative practicals ; Egyptian educators show concerns in the aims of practical work which can be traced to the lack of practical work in current Egyptian science education.

2.3.3 Purpose of practical work

In teaching science at school, much time may be set aside for doing practical work (Lubben and Millar, 1996; Gott and Mashiter, 1991; Hodson, 1990). This emphasises the importance of practical work in teaching science.

However a review carried out by Ross and Lewin(1992) on some of the studies carried out on practical work paints a completely different picture. Yager et al. (1969) suggests that it does nothing much more than develop manipulative skills. Others go as far as saying it serves no purpose at all. White (1988) reports that laboratory work may not achieve the aims expected from it because laboratories themselves are inappropriate. They seem divorced from the materials and experiences that students encounter in their daily lives. If everyday common materials are used it may achieve some of the various functions expected of it. Walburg (1991) reports that practical work in schools often follows a recipe approach. Experimentation thus becomes a pursuit of trying to produce expected results by data fudging or wrong interpretation of one's observations.

As the above review reflects, laboratory work is not without its intrinsic problems. As pointed out by Roth et al (1997), in a traditional lab, discovery of a phenomenon guides the experiment but the learner does not know the principles guiding the phenomena so how does he discover the phenomena? Another problem mentioned is the difference in theoretical framework of the educator and learner. Currently, worldwide there is a move away from the traditional discovery strategy to inquiry based, open - ended investigations. For distance education science courses, inquiry based, open-ended investigations may be difficult to perform as they are likely to be without guidance. Learners are active and involved in the processes of scientific investigations. But it is important to stress that learners will not rediscover science in the lab without the

guidance and theoretical understanding. The educator needs to operate within the ZPD of the learners, so that the learners can reach their, maximum potential. One way of achieving this is by scaffolding.

Scaffolding involves the learner working with a more capable other (educator) on challenging tasks s/he could not solve independently. The educator continuously assists (when he observes that the learner is struggling) the learner and as the learner becomes confident in developing his own knowledge and skills, the assistance is removed (Wood, 1986). Learners are able to learn and discover content for themselves and are able to work on their own. This has its own implication for the educator as to how much assistance should be given, when to pull back, when to interrupt, etc. The educator needs to be sensitive to the learner's capabilities and assist accordingly. As noted by Ben, the educator in Jaworski's (1997) study, the educator needs to be aware of each child's capabilities and create the ZPD accordingly. The learning process needs to be monitored in some way and this can be done through assessment. This can be done either diagnostically, summatively or formatively depending on what the criteria of the assessment are. Within the constructive framework, diagnostic assessment can be used to place the learner at his mental capacity level and formative assessment can be used to assess the progress of the learner, which will inform the educator what assistance a particular learner requires. For the science distance courses, the scaffolding can only be provided during the contact sessions, unless electronic communication is readily available.

Woolnough and Allsop (1985), identified three concerns pertaining to the way practical work is carried out in schools. Firstly, much of the practical work in schools appears to have very little to do with the activity of the practicing scientists. It assumes that scientific knowledge is objective and detached and learning science is a matter of attaching that which is known by others onto learners who previously did not know it. Secondly, research suggests that practical work is not an efficient way of transmitting an understanding of concepts. Children come into the classroom with their own firmly held views about the many scientific topics prior to being taught science. These ideas can be tenacious and resistant to change. Thirdly, much time, money and effort is spent by educators on practical work.

If current research suggests that the current practice of practical work does not contribute to learning science at schools then why do curricula still include it? Perhaps it's the way practical work is carried out in schools which needs to be examined.

Woolnough and Allsop (1985) report that schools tend to over-emphasise academic knowledge, assumed to be the foundation stone for the pure scientist, and under-emphasise the instinctive, tacit knowledge acquired and applied by the engineer and in the personal activity of the creative scientist. Both the explicit and tacit knowledge need to be emphasised in our school teaching. Practical work can be meaningful if it can be used to ascertain and disentangle

preconceptions/misconceptions learners bring into the classroom. If more materials from nature are incorporated into practical activities learners will have opportunities to explore everyday materials and scientific principles embedded in everyday phenomena.

The role of practical work was succinctly summarised by Ramsey and Howe in 1969. Forty years on it remains a relevant summary:

> 'That the experience possible for many students in the laboratory situation should be an integral part of any science course has come to have a wide acceptance in science teaching. What the best kind of experiences are, however, and how these may be blended with more conventional classwork, has not been objectively evaluated to the extent that clear direction based on research is available to educators'. (p.75).
>
> Microscience kits may well be suited to achieving this blending role because they are readily used in ordinary classrooms and in the home

2.4 The new FET (Further Education Training) NCS (National Curriculum Statement) for Physical Sciences of South Africa

The new FET curriculum, introduced in 2006, places some emphasis on learners being able to carry out practical investigations. The document states that the purpose of the Physical Sciences curriculum is to equip learners with investigating skills relating to physical and chemical phenomena. Learning Outcome 1 (LO1) is geared towards acquiring skills and the application thereof. It states that a learner should be able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts. These skills can primarily be achieved by carrying out practical activities. This has implications for the educator who needs to be geared towards carrying out these practical activities so that he/she is able to help the learners achieve this outcome. The external examination of Grade 12 has a weighting of 30% each in Chemistry and Physics for Learning Outcome 1. For all these reasons, in-service training of FET Physical Sciences educators, should contribute to preparing them effectively for teaching towards achieving Learning Outcome 1. Providing the opportunity to do practical work at home for educators studying at a distance can achieve many of the skills geared for achieving LO1.

2.5 Microscale Equipment (especially the microscience kits)

2.5.1 History

Science kits, as reported by Ross and Lewin (1992), have many definitions but their key feature is that they comprise a pre-selected collection of items designed to illustrate particular scientific principles, usually linked to curriculum material.

According to Ross and Lewin (1992), Rangoon Arts and Science University in Burma started to make and produce science kits in 1965. The curriculum reforms of the 1970's, resulted in international aid agency support in terms of one-off supply of kits in many developing countries. In Africa, curriculum development projects resulted in local production of low-cost equipment and science kits. In 1968, Kenya established an equipment production unit. In 1970, Nigeria established the Science Equipment Centre in Lagos with UNDP/UNESCO support. In 1980, UNESCO listed 21 countries which had established low cost production and development units for school science equipment. According to Ross and Lewin (1992), there is much information about the availability of science kits but it is isolated and scattered. Worldwide development can be monitored by compiling a more comprehensive list of activities involving science kits.

2.5.2 The RADMASTE Microchemistry kit

The Microchemistry kit was developed at the RADMASTE Centre, South Africa in about 1992. It has evolved steadily over the past 15 years. Local manufacture started in South Africa at more or less the same time. The concept has gradually become known and accepted in South Africa especially at secondary school level, but also at primary school and university first year levels. Whilst the national Department of Education does not prescribe any particular type of equipment, the microscience kits are approved and several provincial departments of education have purchased them. In addition a large number of schools have purchased them with their own funds and/or received them as donations. At the present time there are about 400 000 kits distributed within South Africa. Appendix F shows the dissemination of the microscience kits concept with the aid of UNESCO throughout the world. This has been achieved through introductory workshops in 77 countries to date (Bradley and Vermaak, 1996). At the conclusion of the workshops, it is up to local parties to decide what, if anything, they will do. Without fail the microscience kit concept has gained local approval. In 38 countries they have somehow found the money to launch pilot projects in local schools.

2.5.3 Why use microscience kits?

The attraction of science kits is that pre-selection is preferable for educators who cannot make their own selection due to lack of experience. They can be easily packaged and distributed. In addition microscience kits are low-cost, environmentally friendly, user-friendly, etc. The quantities of chemicals used with microscale equipment are far less than what the macroscale experiments require. As reported by Ogino (2005b), the benefits of microscale chemistry include reduced waste, reduced times, improved safety and major cost reduction. The pedagogical reasons for promoting use of low-cost equipment as reported by Ross and Lewin (1992) are:

- Provide simplified and more relevant science learning experience,
- Make science education more attractive and enjoyable,
- Overcome psychological barriers to using equipment.

There are additional reasons more specific to low-cost science kits; they can:

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

According to Bradley et al. (1998), microscale experiments help to solve many of the problems that educators encounter when planning practical work, e.g. shortage of equipment and chemicals, lack of laboratory space, lack of laboratory assistants, shortage of time, lack of confidence by educator, etc. Some claim that it is difficult to work with small-scale apparatus but there is no substantial evidence to support this claim (Bradley et. al. 1998). The range of experiments can also be extended to all sciences. For example in Biology, experiments like food tests, enzyme experiments, etc. may easily be carried out on microscale (Bradley et. al. 1998). And in Physics, electricity experiments lend themselves naturally to small scale work. Mocellin and Russel (1996) go as far as saying that the use of more sophisticated microscale chemistry kits at Deakin University, Australia, provides an ‘environmentally conscious vehicle

to subjugate the amalgamation of the practical disciplines of synthesis and instrumental characterisation of products.'

2.5.4 Research on use of microscience kits

There is a considerable amount of research which has been undertaken which has shown the effectiveness of the use of the kits, provided educators are suitably trained.

Bradley and Vermaak (1996) looked at whether microscale techniques could be used as an alternative strategy for providing practical work where laboratories, equipment and funds are limited. They also looked at whether hands-on activities could result in positive attitudes towards science and increased understanding of certain concepts. The sample consisted of more than 600 standard nine (grade 11) learners from 30 South African schools, including schools from former 'white' and 'black' education departments from urban, peri-urban and rural areas. The results obtained, showed overwhelmingly positive attitudes towards practical work with microscale equipment. An improvement in subject knowledge and understanding was observed in all experiments. It was concluded that good science teaching does not depend on sophisticated equipment.

Sebuyira (2001), conducted a similar study as above but the sample consisted of first year Chemistry Major students at the Chemistry Department, University of the Witwatersrand. Sixty-five students performed 4 experiments, 2 on macroscale and 2 on microscale. The results obtained showed that both demonstrators and students expressed positive attitudes towards microscale experiments. In this particular study greater knowledge gains were obtained from microscale work. The study also reported on advantages and disadvantages of the microscale kits relevant to the kit employed. The advantages included, less contamination using the comboplate compared to traditional test tubes, and the kit was safer to use. The Bar LED Microconductivitiy kit provided a very convenient, semi-quantitative way of comparing conductivities of aqueous solutions. Some of the plastic items from the kit went missing, but when compared to traditional breakages of glassware the replacement cost would be minimal. The quantity of chemicals used for microscale experiences is much less than that required for macroscale experiences. An important result of the study is that students felt safer using the microscale kit.

Mkhwanazi SJ (2003), looked at the factors affecting the use or non-use of microscale science equipment supplied to Mpumalanga secondary schools. He reported that from the 20 schools in

his study, 55% of the educators were using the kits supplied. He assumes that this percentage may hold for the rest of the schools supplied with the equipment. He noted that training in the use of the kit, monitoring the implementation and continuous support to educators are key factors in the successful use of the microscience kits. Mkhwanazi V. (2003) looked at the practices of some secondary school educators who use the microscience equipment and factors influencing its use. A questionnaire was administered to thirty educators in schools which received the microscience equipment. The study revealed that the kits were extensively used by educators for group sessions and for demonstrations. There was an overwhelming support for the kits from educators. She also reports that the kits seem to also achieve some of the affective aims of practical work.

The lack of chemistry practical work in many Mozambican junior secondary schools, prompted Madeira (2005) to use the microchemistry kits in schools and observe their influence on the learning and teaching of chemistry. Four schools in the city of Beira were chosen for the study, whereby two schools served as an experimental group where the microchemistry kits were used and the other two were used as the control group where no microchemistry kits were used. The influence was measured by administering a pre-questionnaire and after eight weeks of intervention in the experimental group (where the microchemistry kits were used to support the teaching of chemistry) a post-questionnaire in all four schools. The results reveal that the learners from the experimental group performed better on average than learners from the control group in the questions which required conceptual understanding and in laboratory-based knowledge questions. This difference was attributed to the use of the microchemistry kits.

Thus microscale kits have many advantages for performing experiments. Not only are they much less costly, but they use less chemicals than traditional equipment. They are also safer to use and do not require a laboratory – both important advantages for home use by distance learners.

2.6 The nature of studying through distance education

2.6.1 Definition

Many definitions have been formulated for distance education, but as appears in Otto (1993), it is a special form of education in which:

- Educators and students work apart from each other – at a distance;

- Educators and students do not communicate ‘eyeball to eyeball’ with each other;
- Letters (and other printed material) are exchanged with the help of the mailing system including electronic mail;
- The learning usually takes place in the homes of the students;
- The teaching-learning process assumes the form of self-study, but may be guided by the educator;
- The teaching-learning process allows a degree of openness with regard to access, goals and methods;
- The student does not have to cease work for a living as study can continue alongside work.

The apartness of the educator and learner, eliminates the emotional dimensions of instruction. The advantage is that a student can study while working at his/her own pace. Most courses are modularized, and therefore there is a degree of freedom in choice of subjects.

2.6.2 Interactions within distance education

Moore (1993), identified three types of interaction within distance education:

Learner-content interaction – this is the process of the learner intellectually interacting with the content or subject of study, which results in the learner’s understanding.

Learner-instructor interaction – regarded as essential by many educators, distance instructors seek to stimulate and maintain the learner’s interest, to motivate the learner to learn, including self-direction and self-motivation via specially designed material, tutorial letters, feedback on assignments, etc. But the responsibility of learning lies with the learner.

Learner-learner interaction – This can now be achieved with peer group interaction by e-mail and computer chatting.

2.6.3 Structure of self-study material

Studying through distance education has gradually increased internationally due to economic constraints, a desire for flexibility, etc. Studying is difficult, but becomes more so for a distance learner who cannot easily turn to someone for assistance. Thus the structure of the self-study material becomes very important. According to Bennett and Klease (1996), it should

motivate the learner, build confidence by letting students themselves assess how much they really know, be student friendly and interactive.

For science learning this becomes more vital as the learning of science is hierarchical. Science is often regarded as abstract and difficult to understand. Thus the writers of study material need to make it more creative and exciting for the learner to want to study it.

2.6.4 Practical work in distance education

How can the distance learner experience practical science? In the seventies, The Open University in the UK used to ship off mini-laboratories to distance science learners. Due to legislation on shipping of chemicals other ways were sought (verbal communication with Bennett in 2004). Bennett (1994), reports on the success of using microscale equipment at home by students studying science through distance education. The majority of the students liked the flexibility and convenience. Comments such as 'take-home labs are really neat and fun' were frequent.

With the advance in technology, using multimedia for experiments was also developed. As discussed by Bennett (1994), experimental simulation systems have been developed which allow students to select chemicals, calculate quantities, design apparatus, perform analysis, etc. But simulation systems do not allow science students to feel like a real scientist, performing experiments with real chemicals, nor to learn how to handle chemicals responsibly. Other factors influencing use of simulations is that a particular software may not be able to obtain quantitative data for an experiment and some software may not be economically viable as it is expensive (Moodley et al 2004). Experimental simulation may be well out of reach for most South African schools as it would need a computer lab to access the software and not many schools have a computer lab.

In developing countries most distance students do not have access to a computer. According to a survey carried out by Gunter (2005), only 32% of the educators that formed the sample group for the current research had access to a computer. This may be at the school where they are teaching but more often than not it is locked away in the strong room for security reasons or reserved for administration. Hence access is severely limited to South African educators for study purposes at the present time.

2.7 Conclusion

This chapter looked at the theoretical framework underpinning the current study. The literature reviewed in looking at the various aspects will inform the interpretation of the data collected for the study. The next chapter looks at the context, research design and methodology used for the current study.

CHAPTER 3

CONTEXT, RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In chapter two the literature related to the study was reviewed. It outlined the theoretical framework related to the study, the importance of practical work, the past experiences in using microscience equipment and some of the special features of learning through distance education.

This chapter looks at the context, research design and methodology used in this study of providing practical experience for students studying science through distance education. The instruments used and the data collection process are also discussed.

3.2 Context

RADMASTE Centre at Wits University in collaboration with the Mpumalanga Department of Education (MDE), (Appendix G shows the general map of Mpumalanga province) are running the ACE (Advanced Certificate in Education) course for educators in Maths and Science from that province. This is a certificate course to upgrade the educators' qualifications. The MDE had invited educators who were interested to do the ACE to apply. Forty educators for each class [Maths GET (General Education Training) and FET (Further Education Training); Science GET and FET] were chosen depending on their previous qualification, teaching experience, etc. In the event, thirty seven educators from the Mpumalanga province, teaching Physical Science at FET level, formed the sample group for the current research.

The ACE course at Wits University uses a mixed-mode delivery approach and extends over two years. That is, four contact sessions (usually five days each, during the school holidays) are spaced throughout each year, where educators come for the face-to-face interactions. For the rest of the period educators are required to work on their own or with fellow students. It is assumed that the educators would be operating at the formal operational stage according to Piaget's stages of development. For each course, portfolio tasks and assignments are set which are sent in via post, marked and sent back to educators. During 1 year educators complete 3 specialisation courses (either in Maths or Science) and 2 education courses.

The researcher is a tutor for two of the FET courses being offered, namely 'Structure and Properties of Matter' and 'Chemical Reactions'. All the practical activities (see Appendix H for the practical manual) that were done at home (the basis of this research) using the RADMASTE Advanced Microchemistry kit (one of the kits of the RADMASTE Microscience system), were related to the 'Chemical Reactions' course.

3.3 Research Approach

There are various approaches to carrying out research, for example, case study, action research, experimental, etc. The current research used a 'quasi' experimental approach.

A 'true' experiment uses randomization so as to try and ensure a greater chance of equivalence of the groups being looked at. Educational research often does not allow this kind of randomization, therefore it is often a 'quasi' experiment. In this the groups being studied are as equivalent as possible.

3.4 Research design

3.4.1 Paradigm of Enquiry

The paradigm of enquiry can be characterized by two modes. The one is rationalistic and the other is naturalistic.

According to Kember et al (1990), in a rationalistic enquiry, each variable of a facet is isolated and then used to draw a conclusion. The context in which the variable is embedded is ignored. Usually quantitative methods are used to gather information within this mode with items that have Likert scale responses. Evaluations usually test a hypothesis the researcher has posed.

The research design can be specified before the data is collected within a rationalistic enquiry. The disadvantage is that the responses cannot be checked for accuracy and thus the questionnaire needs to be carefully designed to make sure the findings reflect what the researcher really wants to achieve.

Kember et al (1990), describe a naturalistic enquiry as one in which the phenomena under investigation must be studied as a whole and not out of context. Thus an interview, in which the inquirer is an integral part of the investigation, is essential to the naturalistic mode of enquiry. The interview data cannot be used to make generalizations beyond that bounded by the study. Usually qualitative evaluation is used for a naturalistic enquiry. The naturalistic

designs do not start with a hypothesis, but usually it emerges from the data. Thus the theory is grounded in the data. The research design develops as the study progresses. An advantage to this type of enquiry is that answers can have great depth, but it is time consuming and the generalisability of the findings is not guaranteed.

For the current research a blend of both modes of inquiry has been adopted so that responses in the questionnaire can be checked for accuracy during the interview. The two modes complement each other.

3.4.2 The design and piloting of questionnaires

To answer the three research questions, data was collected using questionnaires and supplemented by interviews. According to Opie (2004), the questionnaire is the most widely used procedure for obtaining information. It is economical, standardized, assures anonymity and questions can be written for a specific purpose. It can be used to collect a variety of information in a short period of time. The guidelines provided by Opie (2004) for constructing good questions were considered for the questionnaire. These included, keeping questions unambiguous and precise; avoiding bias terms and emotional language; using closed questions with at least three choices, keeping questions short and simple; asking general questions before specific; etc. In considering the format of the questionnaire, suggestions given by Opie (2004) were also considered. These included, having a cover letter to inform the participant about the purpose of the questionnaire; giving clear instructions for answering the questions; ensuring that items in the questionnaire related to the objectives of the study; recognizing that questions should be woven together and flow smoothly. According to Opie (2004), points to consider when administering the questionnaire, include, making conditions under which the questionnaire is administered as similar as possible (for example pre- and post- questionnaire should be carried out in similar conditions in terms of place, time taken to complete the questionnaire, layout of questionnaire, etc.); making sure that the group that is being used as the sample knows something about the information to be obtained for the research; pre-testing the questionnaire with a small group similar to the sample group. These points were considered for the current research.

The questionnaire (Appendix I) used for answering research question 1, comprised of seven questions which allowed the educators to note their experiences in using the microchemistry kit at home. Six of the questions were open-ended, thus allowing for a richer collection of

information. The one question asks their opinion in using the kit with regards to easiness, safety of use, caring for the kit, etc. It consists of fourteen items, and uses a 5 point Likert type scale. These experiences are implicitly linked to the question (Appendix J, Question 7) which looked at the attitude of educators' views towards practical work in learning and teaching science.

The questionnaire (Appendix J) used to answer research question 2 comprised of seven questions. Five questions give access to number of years of teaching experience, state of laboratory in the school they are teaching, pre-service laboratory experience, etc. One question is designed to ascertain the educator's confidence towards practical work. Another question consists of five items on the three point Likert type scale, which look at the role of practical work in learning and teaching science. This questionnaire was used as a pre- and post-questionnaire to see if the educator's views towards practical work changed after using the microscience kit at home. This change in attitude is compared to their experiences in using the kit at home to answer research question 2.

The questionnaire (Appendix L) used to answer research question 3 comprised of 10 questions. All the questions were open ended with the aim of collecting richer data. If the question asked the educator to answer YES or NO, they were required to justify their choice. Thus it allowed the educators to justify their attitude and experiences in a more open manner. The cognitive, psychomotor and affective domain of learning and teaching of science formed the basis of phrasing the questions.

The questions in the three questionnaires were designed such that the first would provide their experience, the second would ascertain their attitude and the third would provide an opportunity to elaborate on their attitude and experience.

Due to time constraints all the questionnaires were piloted using 15 colleagues in the research methodology course which forms part of the Masters in science Education degree. Their comments and suggestions were considered in redesigning the questionnaires.

3.4.3 Interviews

As Opie (2004) suggests a questionnaire can answer the questions What? Where? When? and How?, but it cannot answer Why? Thus to answer research question 2, where the personal experiences of the individuals were sought, interviews were conducted to gather information. Interviews allow respondents to develop their own ideas, feelings, attitudes, etc. With probing

from the interviewer much information can be gathered that would be impossible with using a questionnaire. There are three types of interviews: structured (uses standardized, short questions, requiring short answers, it is often unbiased); semi-structured (similar to structured but is more flexible), allowing for probing and thus expanding the interviewee's responses, it needs to be carefully worded to prevent miscommunication; and unstructured (this flows from the interviewee's idea on a particular topic).

The disadvantages of interviews are that they are time-consuming, subject to bias and interviewers' interpretation. They may also be difficult to interpret and analyse. The interviewer needs to have good interpersonal skills. Things to consider for interviews are (as discussed by Opie (2004)): contextual factors, stages in preparing for and carrying out interviews, collecting interview data, etc. These factors were considered when interviewing the educators. Cresswell's (1998) procedure was used for analyzing the data. The procedure includes: organization of data; categorization of data; interpretation of data; identification of patterns and synthesis.

Due to time constraints it was impossible to interview all the educators. As noted by Opie (2004), it is the relatability of the findings to similar settings, rather than the generalisability, which should be considered as an important outcome in this instance. Therefore 4 educators, representative of the group, were visited at home (with their permission) to gain an insight into their background, setting, etc. The educators were viewed performing experiments and interviewed (see Appendix K for interview questions) on their experiences, challenges, suitability of the kit, etc. The comments given by the educators were viewed as objectively as possible.

3.5 Research Methodology

In the contact session, at the beginning of the Chemical Reactions course, the pre-questionnaire for answering research question 2 was administered to obtain the educator's attitude towards practical work, before they were exposed to the microchemistry kits.

To introduce them to the microchemistry kit, an experiment was carried out in the session. Each educator was given a kit and set of instructions for the experiment (Electrolysis of Water). The researcher was at hand to supervise while the educators carried out the experiment. If any difficulties with using the kit were noted, this was clarified. The questions relating to the experiment were discussed by the educators in groups and, at the end of it, a plenary was held

to clarify any enquiries. A video showing various simple experiments was also viewed by the educators. A practical activity booklet containing 5 experiments (The experiments chosen were at Level 1 of Inquiry (Woolnough,1991)), was given to each educator, with chemicals that they would require to complete these experiments at home. The aims of practical work (Woolnough and Allsop, 1985) were also taken into account in the design of the experiments to be performed at home. Conducting practical work at home embeds it in the educators' daily life and thus may be more meaningful to learning. It may also create a situated learning environment (Choi and Hannafin,1995).

Small plastic bottles, plastic vials and the bulb of sealed propettes (sealing the tip of the propette, by passing through a flame after the chemical was drawn in the bulb), were used to package the chemicals for the educators (Figs. 1 and 2)

Fig 1a: Chemicals being packed for the educators to take home

Fig. 1b: The microchemistry kit with the chemicals packed for distribution to educators

The same method is used by the At Home Science company to distribute their chemicals (Appendix A). Each experiment was studied to see the exact quantity of each chemical which would be required. The educators were supplied with twice the quantity that should be required so that, if they made a mistake doing the experiment once, or if they wanted to confirm their results, they could do the experiment a second time. They were required to complete the worksheets for each experiment and submit them at the next contact session, as it formed part of their assessment. By doing the experiments at home while working through the Course Workbook, educators were provided the opportunity to construct their own knowledge which is a continuous and active process.

The period between the first and second contact session was about 3 months. During this period the researcher kept in contact with the educators via a bulk sms messaging system. A message was sent approximately every three weeks. The messages served as a reminder for the educators to keep on track with the course workbook material as well as the experiments. For example a typical message would read:

'Hi, by the end of this week you should have completed Chapter 3 and Experiment 2.'

The educators were encouraged to sms the researcher if they experienced any difficulties and in this way interaction was frequent. No major enquires were received with regards to the practical work at home.

At the second contact session, the questionnaire for answering research question 1, relating to the experiences in using the microchemistry kit at home, was administered. The post-

questionnaire for research question 2 was administered at the same time. There was no time limit set for answering the questionnaire. For those educators that did not complete the questionnaires during the contact session, they were allowed to bring them to the session the next day. The experiments done at home were also discussed in detail during this session. This was done to provide the opportunity for restructuring and application of ideas (Matthews, 1994).

The questionnaire to answer research question 3, pertaining to what the educators learnt from 'at home ' practical activities, was administered to another group of educators who had enrolled for the same 'Chemical Reactions' course in the following year. The background of these educators was inherently the same as the first group.

To interview the educators in their homes, 4 educators enrolled for the Chemical Reactions course were randomly chosen. Each educator was called and permission was sought to visit him/her at home. Only those educators that were willing to be interviewed were chosen. The educator was visited at home according to the day and time mutually agreed by the educator and researcher.

3.6 Presentation of data

Research data can be presented in two ways, either quantitatively or qualitatively (Opie, 2004). Most research may require a combination of the two. Quantitative analysis requires some form of statistical analysis. It is a statistical measurement of the interaction between independent and dependent variables as a result of some treatment or intervention. These results are often valid and reliable. Statistical analysis includes descriptive and inferential statistics. Descriptive analysis, includes calculation of the percentages, mean, median, and standard deviation, etc. Inferential analysis involves two types of tests: non-parametric and parametric. According to Opie, (2004) 'Non-parametric tests are associated with nominal or ordinal data obtained from populations where no assumptions are made about the distribution within these populations'. The findings cannot be extrapolated to other populations. Parametric tests allow for extrapolation from sample populations to whole populations. Before doing complicated statistical analysis it is important to know what the analysis is going to serve. For the current research descriptive analysis was employed.

Qualitative analysis involves text which may be collected from open questions in a questionnaire, interview transcripts or descriptions from observational research (Opie, 2004).

Because it is descriptive it is dependent on the researcher's interpretation. Its subjective nature may result in lack of validity and reliability. As noted by Hair et el (2007), analysis of qualitative research involves three steps: data reduction, data display and conclusion. Data reduction consists of several interrelated processes: categorization and coding; theory development; and iteration and negative case analysis. According to Dey (1993) in Basit (2003), categorization and coding involves sub-dividing data and assigning categories. This leads to organization of the data which results in finding commonalities and patterns.

For the current research both qualitative and quantitative analysis was employed.

3.8 Ethical issues

When looking at ethical issues (especially for qualitative research), the following criteria should be taken into account (Opie, 2004):

Informed consent

Confidentiality

Dignity of research participants

Anonymity of the research participants

Minimization of harm

Trust

Transparency

Each criterion will be examined in detail to see how it was addressed in the current research. The criteria were used to plan the research in a way that would not compromise the dignity, privacy and rights of the participants.

3.8.1 Informed consent

A letter was written to the Head of Department, Mpumalanga Department of Education to obtain permission to conduct research using the educators from that area. To obtain consent from the educators (the sample group), the attitude survey had a letter attached to it which informed the educators about the purpose of the research and also that the information gathered would be used for research. The researcher had verbally informed the participants beforehand

explaining in detail the research being conducted. During the contact session the researcher identified the educators that would be interviewed for the case study. They were informed in detail about the intended form of the interview and permission was taken from each individual to visit their home for the interview. The researcher phoned each individual to set up a time for the appointment when it would be suitable for them.

3.8.2 Confidentiality

The educators were told that their opinions, performance and answers would not be made available to the Department of Education or to any other person whatsoever, besides the researcher.

3.8.3 Dignity of research participants

The researcher is also a learner and understands the importance of being respected at a human level. The researcher at all times maintained a high level of dignity and morality in the class during contact sessions when participants answered the questionnaires and when the selected individuals were interviewed.

3.8.4 Anonymity of the research participants

The participants were told that their names would not appear in the research report, neither for the questionnaire nor the interviews.

3.8.5 Minimization of harm

For the purpose of the current study, the researcher stressed the importance of practicing the safety rules when handling chemicals (the experiments were carefully chosen to avoid chemicals which may pose significant danger to the research participants). Though the rules and regulations were written in the workbook the researcher spent considerable time going over each point in detail with the educators during the contact session. The educators signed an

indemnity form which stated that they would behave in a responsible manner to avoid damage to self and property.

3.8.6 Trust

The trust can be built through the researcher being approachable, with communication that is two-way and letting the participants see that the researcher is also human and anything said to him/her will be confidential. The researcher worked at these points in the contact sessions. The contact sessions were used to get to know the educators on a personal level.

3.8.7 Transparency

The educators were informed from the beginning about the research and were asked to give their input that may enhance the research. At the contact session it was ascertained that most educators did not have much experience with practical work. For that reason a session was devoted to doing an experiment that would allow the educators to familiarize themselves with the equipment. They showed much enthusiasm and a lengthy discussion followed on the pros and cons of practical work.

3.9 Rigor in Research

In order to ensure rigor in research, reliability, validity and trustworthiness need to be considered. Let us examine each in detail and how it was addressed in the current research.
Reliability: According to Opie (2004) the main criteria for reliability are repetition and consistency. This means can the research, if conducted in a different setting, yield the same results. Is it transferable?
According to Wellington (2000), as quoted in Opie (2004) ‘ Validity refers to the degree to which a method, a test or research tool actually measures what it is supposed to measure’

Trustworthiness, according to Opie (2004) refers to whether the findings are worth paying attention to. This transforms to whether the data reported is credible, transferable, dependable and confirmable.

Reliability, validity and trustworthiness have relation to whether the research is quantitative or qualitative. Quantitative research is usually valid and reliable but not so qualitative, as the results are dependent on the interpretation of the researcher. To assess attitudes towards practical work a questionnaire is a valid instrument to use. The same questionnaire was used after the treatment (doing practical work at home) to see if there was any change. The questionnaire to gain insight into their experiences in using the microscience kit at home was again quantitative. As noted, questionnaires are quite reliable as they are objective and can be used in different settings, if designed properly. The data collected may differ in the extent to which the attitude of educators may change in a different setting, but it will measure this change in attitude.

But often researchers use a mixed approach (qualitative and quantitative) as a question can be answered with one method and the results understood using another method. For example in the current research the questionnaire aimed to ascertain the attitude of educators towards practical work before and after the treatment (quantitative), but the reason for any change (to include a human aspect) can only be understood from the interviews (qualitative).

The interview (case-study) to reveal what educators learn from at-home practical activities, may be subjective (as interviews tend to be), but the researcher tried to ensure that the responses were interpreted in the way the respondent intended. With interviews there is an advantage because, if the response given is not clear, it can be clarified with the respondent instantly. The ethical issues discussed above had to be taken into consideration for the data collected to be reliable and valid.

The current research is a first of its kind, therefore will not make wide and general claims but will claim for the particular group. For that reason there will be no benchmark against which it can be measured. Perhaps it can be used for future studies of similar kind using a different sample group. The comparison of the findings may then be applied to a larger group and thus make it more trustworthy.

In conclusion, this chapter looked at the context, research design and methodology, ethical issues, etc. used in the current research.

The next chapter will look at the presentation, analysis and discussion of data obtained via the questionnaires and interviews.

CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

4.5 Introduction

The previous chapter looked at the context, research design and methodology used to collect data for the present study. This chapter will present, analyse and discuss the data collected from the three questionnaires and interviews. It also includes a report on the completed experiment worksheets submitted by the educators.

4.6 Questionnaire for the attitude towards practical work

The questionnaire to ascertain the change in attitude towards practical work was firstly administered before any exposure to the microchemistry kit, to see the educator's attitude towards practical work in general. The same questionnaire was administered after they had completed the 5 experiments (for the Chemical Reactions course) at home, using the microchemistry kit, to ascertain if their attitude towards practical had changed, either positively or negatively, under these circumstances. 37 educators answered the questionnaire. Appendix M shows a sample of the questionnaire answered by one of the educators. The data obtained from the pre and post questionnaires are presented (in percentages) below in table format. Where appropriate, the data is presented graphically to compare pre and post results. Responses from educators during the interviews have been incorporated to illuminate their responses in the questionnaire.

Question 1 asked the educators to state the number of years of experience in teaching science at FET level. The results are presented in Table 3.

Table 3: Experience in teaching science at FET level

No of years of teaching FET science	Percentage (%) (n =37)
0 -5	65
6 -10	22
11 -15	8
16 -20	5

From table 3, it can be seen that two thirds (65%) of the educators have only 5 years or less experience in teaching science at FET level. 22% of them have 6 to 10 years of experience.

Question 2, asked the educators to state if the school at which they are teaching has a fully functional laboratory. The results were categorised as in Table 4.

Table 4: Schools with a fully functional laboratory

Categories	Percentage (%) (n = 37)
Laboratory – not fully functional	91
Laboratory – functional	3
Laboratory – only chemicals	3
Laboratory – microscience kits	3

All the educators indicated that they had some form of laboratory. Only 3 % (1 school) claimed to have a fully functional laboratory. 3% do have microscience kits at school, but it can not be concluded that the educator uses the kits in his/her everyday teaching. A very high percentage (91%) does not have a fully functional laboratory at their schools. From this it can be inferred that these educators do not have the opportunity to use practical work as a tool for teaching science.

Question 3, asked the educators to state (if they answered that they have a laboratory in Question 2) whether they used demonstrations (where the educator stands in front of the class and performs the experiment and the students watch) for teaching or did the students perform their own experiments. The data collected indicate that 86% use demonstrations to teach science, whereas 14% stated that the students perform their own experiments. Since only 3 % have a fully functional laboratory, this indicates that most of the educators make use of

whatever resources they have to either carry out demonstrations (86%) or allow students to perform their own experiments (14%). The high percentage of educators that carry out demonstrations may also be seen as consistent with the laboratories not being fully functional in 91% of schools.

In Question 4, educators were asked if they performed their own experiments during their pre-service training course. They were further asked to elaborate in Question 5, if the amount of practical work they did in their pre-service training course makes them feel competent or not in performing experiments. The results are presented in Table 5.

Table 5: Performance of experiments during pre-service and level of competency

Categories	**Percentage (%) (n = 37)**
Performed own experiments during pre-service course	86
Did not perform own experiments during pre–service course	14
Feel competent	62
Don't feel competent	38

As Table 5 indicates, 86% of the educators performed their own experiments, but only 62% of them feel competent to do their own experiments. Many explanations are possible for this difference. It may be that they did not do enough experiments to feel competent to do it on their own, or they may have done it long ago and due to lack of equipment at the school where they teach, they do not feel competent any longer to do the experiments.

Question 6 asked them to expand on whether they felt confident or nervous about doing practical work themselves; demonstrating in front of the class or supervising while the students performed the experiments. This question was asked to see if their view would change after using the kit. If their experience in using the kit was positive this might show up in the results as an increase in their confidence in performing experiments in all three categories. Table 6 indicates the results obtained.

Table 6: Confident/nervous of doing practical work

	Confident (n = 37)		Nervous (n = 37)	
Categories	**Before (%)**	**After (%)**	**Before (%)**	**After (%)**
Yourself	81	95	19	5
Demonstration (in front of a class)	92	97	8	3
Supervising (your learners are doing it in the class)	86	95	14	5

The results indicate that the level of confidence of the educators is high in performing experiments themselves, demonstrating and supervising. This feeling of confidence is higher than that noted in Table 5. This could be due to gaining more experience and thus more confidence as their teaching experience increases. This high level of confidence, increased further after they had used the microchemistry kit at home to perform experiments on their own. These results suggest that their experiences in using the microchemistry kit must have been positive.

Question 7, asked educators to give their views on whether practical work was essential for learners in learning science. The question had 6 criteria listed, pertaining to the cognitive, psychomotor and affective domains of learning or teaching for conceptual change (Lunetta and Hofstein 1980). The same question was administered after they had used the microchemistry kit at home to see if they still held the same views. This question is valid because the educators themselves are learners doing the Chemical Reactions course (and performing experiments) within the ACE course. The results obtained are as indicated in Table 7. None of the educators disagreed with any of the criteria.

Table 7: Attitude on whether practical work is essential for learners, in learning science

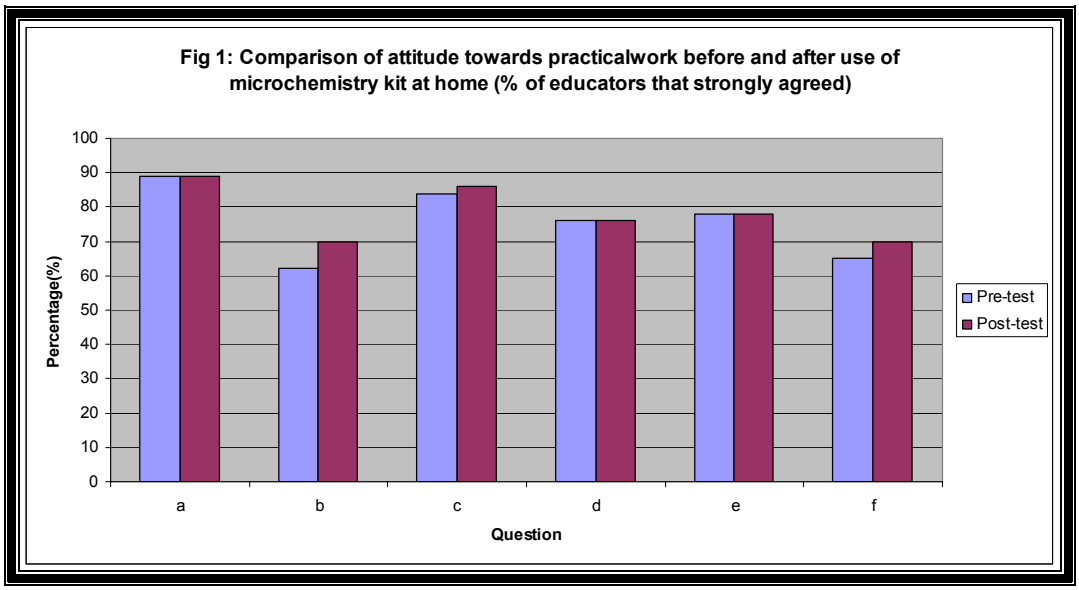
Criteria	%Strongly Agree (n=37)		%Agree (n=37)	
	Before	**After**	**Before**	**After**
a) Improve conceptual understanding	89	89	11	11
b) Improve psychomotor skills	62	70	38	30
c) Allow learners to learn process skills of science	84	86	16	14
d) Make the learners more confident	76	76	24	24
e) Make learners enjoy the subject matter more	78	78	22	22
f) Provide learners with life skills related to safe handling of chemicals	65	70	35	30

From Table 7 it can be seen that initially a high percentage of the educators agreed with all the criteria. After doing practical work at home using the microscience kit this remained unchanged or changed towards a higher percentage of educators agreeing. Thus it can be concluded that their home experience confirmed their initial beliefs, and did not negate their attitude towards practical work in general. These strong agreements confirm previous reports. The studies by Bradley and Vermaak (1996) and by Sebuyira (2001) showed that the use of microscience kits increased understanding of science concepts and achieved greater knowledge gains respectively. Bradley et al (1998) stated previously that use of microscience kits makes learners more confident about doing practical work. The enjoyment of subject matter is supported by the view of Ross and Lewin (1992), who state that use of science kits makes science more attractive and enjoyable for the users. Bennett (1994) reports that the use of a microscience kit at home, made learning flexible and attractive.

It can be concluded that the educators strongly agreed with all the criteria listed on the importance of practical work in learning science thus confirming the aims of practical work categories listed by Woolnough and Allsop (1985).

Their personal use of the kits in fact, overall, made a positive impact on their views on the importance of practical work in learning science. No negative indications of any kind appeared. Fig 1 summarises the comparison of the pre and post test results (% of educators that strongly agreed) of the 6 criteria listed in Question 7. The results indicate that educators do find the 6 criteria listed in Table 7 important for practical work. This, together with their increased level

of confidence in performing experiments themselves, or demonstrating or supervising practical work, after the use of the kit at home (Table 6), is a definite indication that the kit was successful as a tool for doing practical work at home for these distance learners.



4.7 Questionnaire for experiences in using the microchemistry kit at home

The questionnaire on the experiences in using the microchemistry kit at home was administered at the contact session after the educators had completed the 5 experiments at home during the self study period. 37 educators answered the questionnaire. Appendix N shows a sample of the questionnaire answered by one of the educators. Where appropriate, responses from educators during the interviews, have been incorporated to shed further light on their responses in the questionnaire.

4.7.1 Question 1

Question 1 referred to their experiences in performing experiments at home using the microchemistry kit for the ACE course, Chemical Reactions. The question had 15 statements of experience with which educators could express agreement or disagreement on a 5-point Likert scale. Most statements could be linked explicitly or implicitly, to the 6 criteria in Question 7 of the questionnaire to ascertain the attitude towards practical work . They were

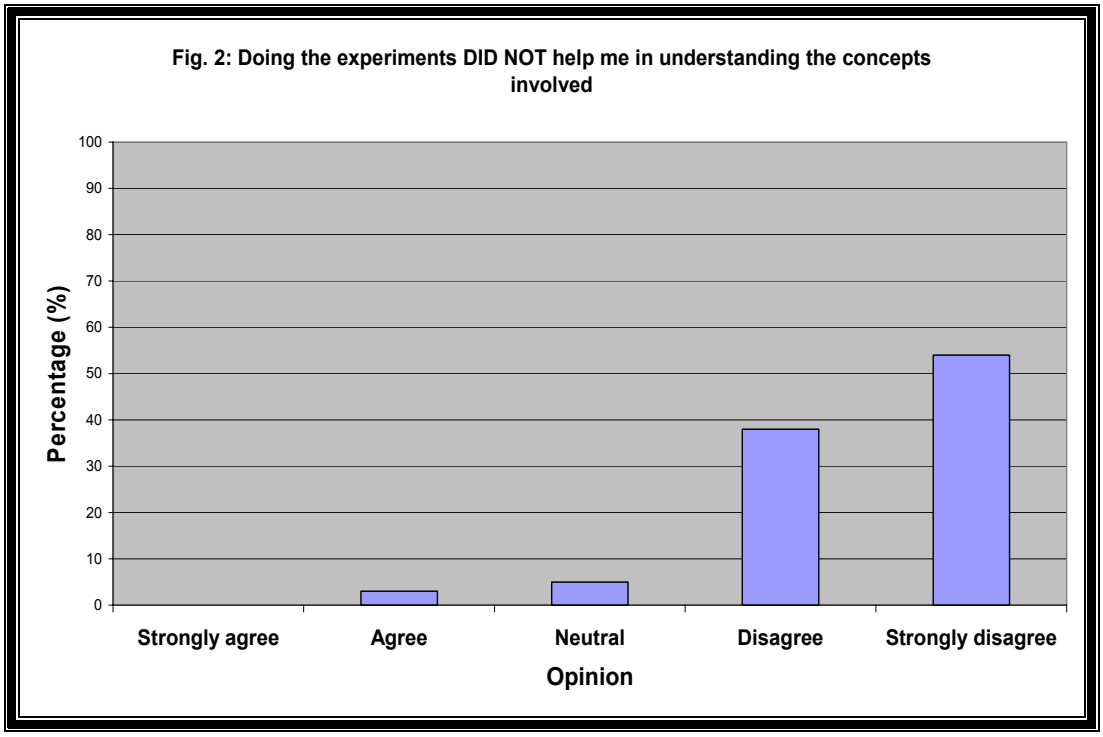
required to tick (✓) the appropriate box to show their opinion. The responses are indicated in Table 8.

Table 8: Experiences in using the microchemistry kit at home

Criteria	%Strongly Agree (n=37)	%Agree (n=37)	%Neutral (n=37)	%Disagree (n=37)	%Strongly Disagree (n=37)
1) It was easy to handle	32	58	5	0	5
2) The reactions were DIFFICULT to observe	3	20	22	41	14
3) It was safe to use	27	41	22	7	3
4) Experiments took LOTS of time to complete	3	19	22	51	5
5) The equipment was easy to clean	36	51	8	5	0
6) Instructions were easy to follow for each experiment	59	31	5	5	0
7) The disposing of chemicals was a PROBLEM	5	27	11	51	6
8) It was easy to store the kit	22	38	16	16	8
9) It was easy to care for the kit	35	30	19	13	3
10) It was fun to use the kit	35	43	8	11	3
11) I am keen to do more experiments using the kit	58	30	8	3	3
12) It did NOT HELP to develop my practical skills	3	10	11	49	27
13) It assisted in developing my confidence in practical work	54	30	8	5	3
14) Doing the experiments DID NOT help me understand the chemistry concepts involved	3	3	3	37	54
15) I would NOT like to have to do experiments with other ACE courses	3	3	2	38	54

As the results in Table 8 indicate the experiences in using the microchemistry kit at home were generally very positive. To ascertain how the experience (1-15) in using the microscience kits at home influenced their attitude, experiences will be compared with particular attitude criteria (a-f). The attitude after the use of the kits will be influenced by this use of kits, thus this data (the attitude after the use of the kits) will be used in the comparison of experience versus attitude. Since more than one experience is linked to a particular attitude, the attitude criterion will be taken as the starting point.

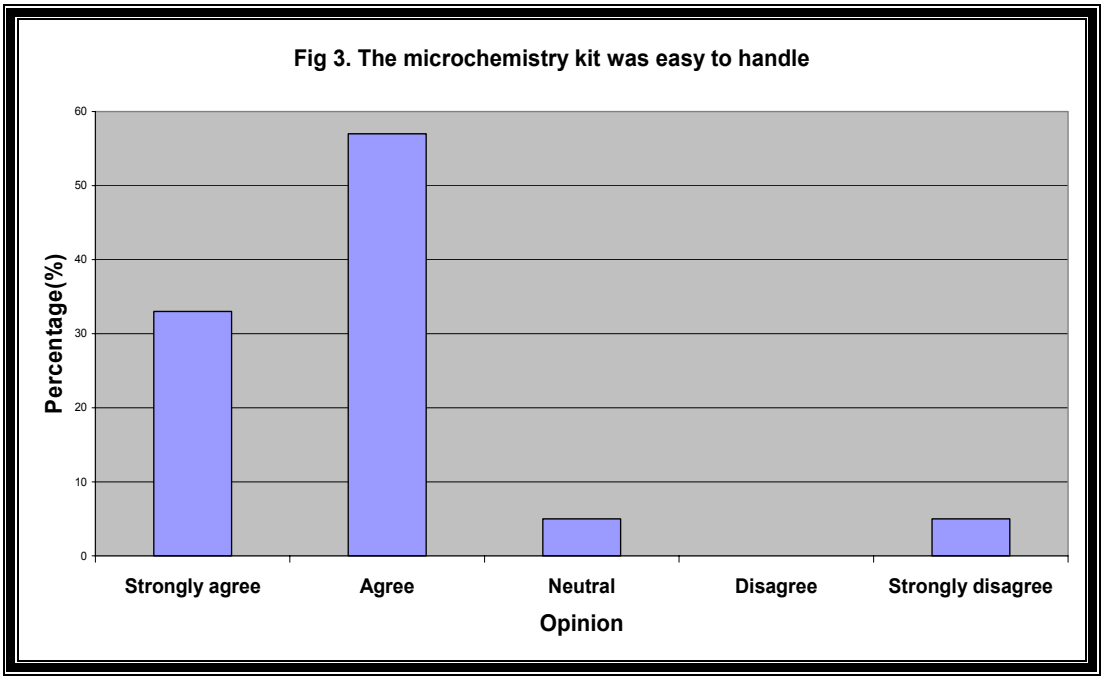
The results obtained for attitude criterion **a** (Improve conceptual understanding, Table 7) after the use of kits is, directly linked to experience **14** (Doing the experiments DID NOT help me understand the chemistry concepts involved, Table 8). The results obtained for this experience is represented in Fig 2.



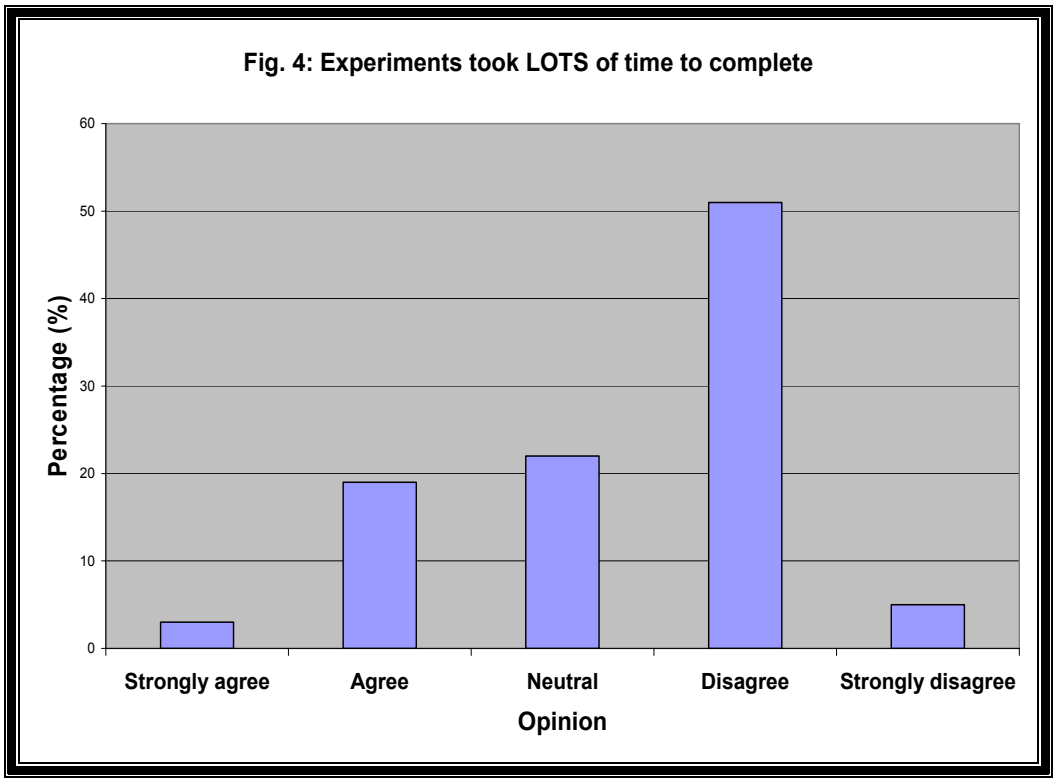
As Fig. 2 shows, only 3% (1 student) agreed that doing the experiment did not help to understand the concepts better. A high percentage of students disagreed with the statement, suggesting that they feel doing the experiments did help them understand the concepts involved. This relates well to their attitude (89% strongly agreed before and after doing the experiments).The unaltered attitude before and after using the kits suggests that their experience matched their conventional attitude toward practical work. The study reported by

Bradley and Vermaak (1996), also showed that the use of kits increased understanding of concepts by learners.

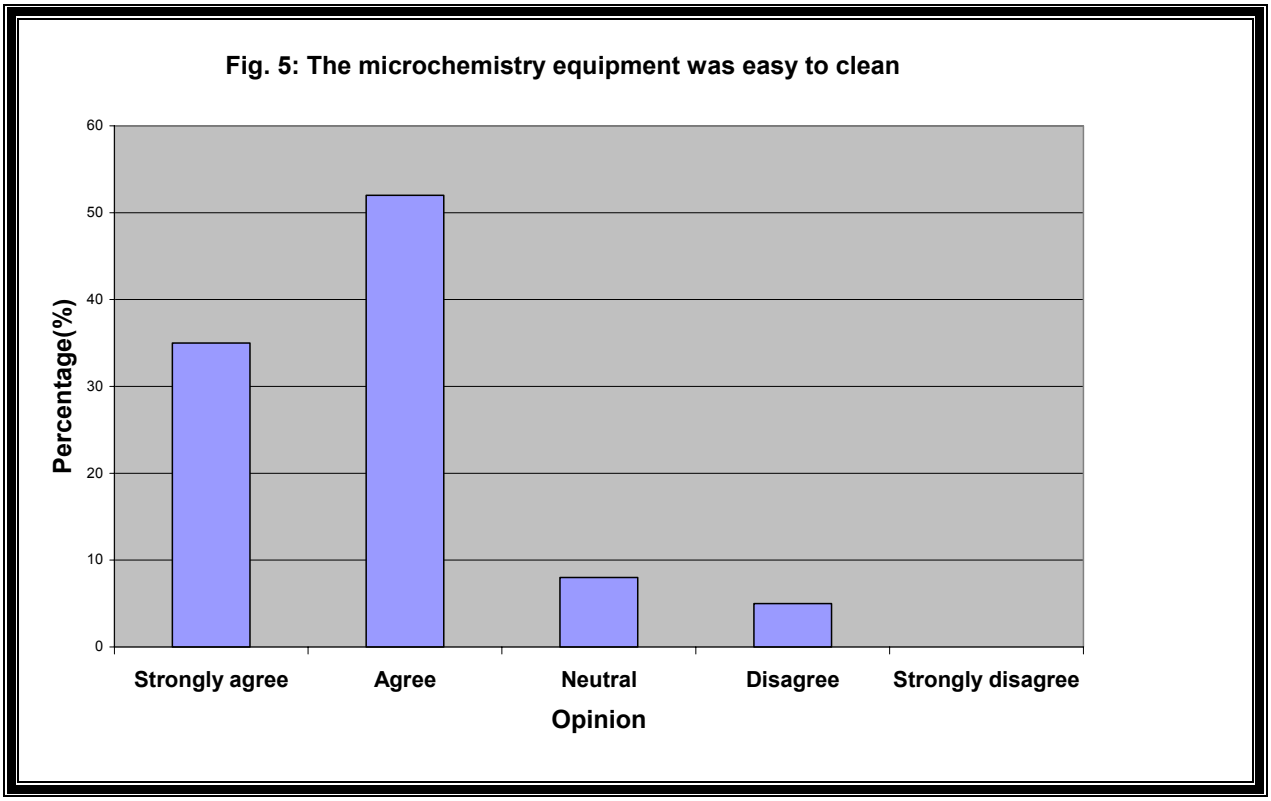
Attitude Criterion **b** (Improve psychomotor skills, Table 7) could be influenced by experiences **1** (It was easy to handle), **4** (Experiments took lots of time to complete), **5** (The equipment was easy to clean), **9** (It was easy to care for the kit) and **12** (It did not help to develop my practical skills) (Table 8). Experiences 1 and 12 are directly related to psychomotor skills, whereas Experiences 4, 5 and 9 are indirectly related. The results obtained for these experiences are presented graphically in Fig. 3, 4, 5, 6 and 7.



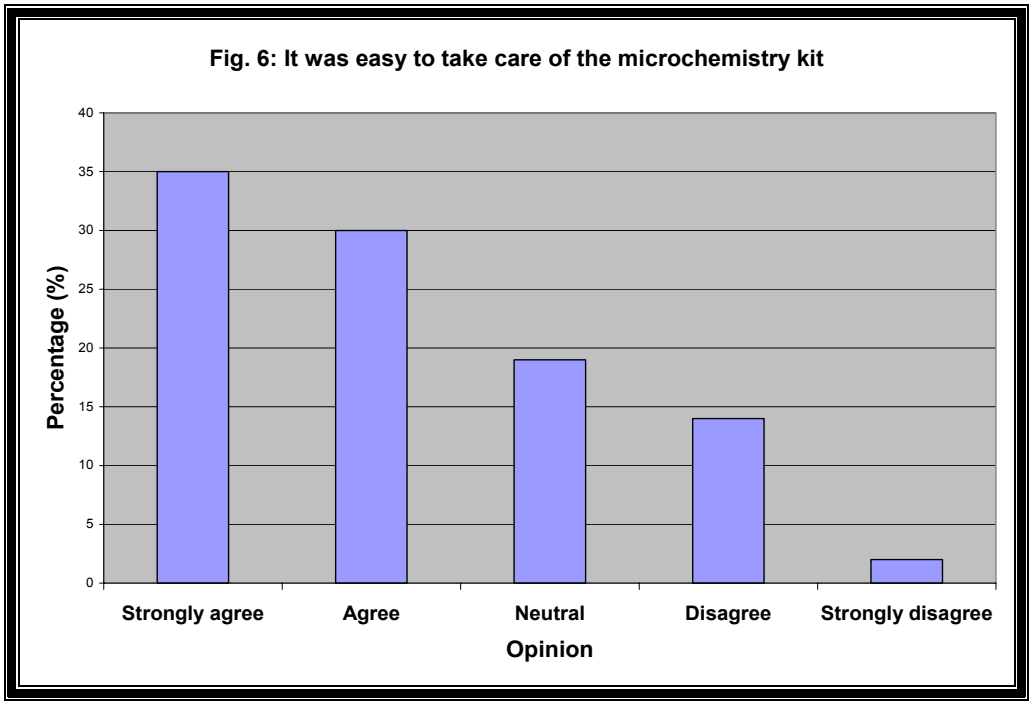
The ability to handle equipment requires fine motor skills. No less than 90% were able to handle the components of the kit easily. However 5% strongly disagreed (Fig.3). The reason for this may be that they found the components to be very small, as was stated being one of the reasons in the interview. However the positive change in attitude to improving psychomotor skills (62% strongly agreed before and 70% after) suggests that handling the small components of the kit was not a deterrent in improving psychomotor skills for most educators.



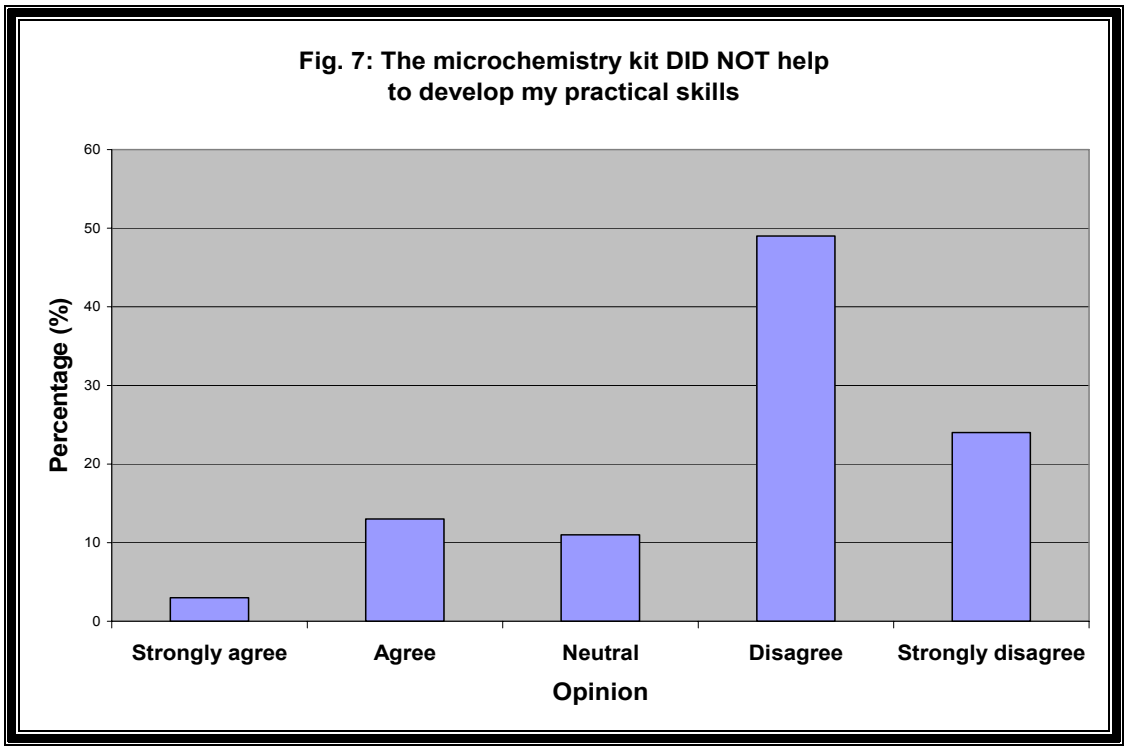
The time factor relating to completion of experiments may be related to psychomotor skills as an educator with poor psychomotor skills will take longer to complete the experiment compared to one that has excellent psychomotor skills. 56% felt that it did not take them lots of time to complete the experiments (Fig.4). Those educators who felt it took them lots of time may have been particularly lacking in experience and without direct supervision and support, it really did take them a lot of time. Of course, the interpretation of "a lot of time" is subjective and only direct observation could clarify the situation.



The cleaning of the small components of the equipment also requires fine motor skills. The easiness in cleaning the equipment is reflected in the very positive (36% strongly agreed and 51% agreed) experience of the educators (Fig. 5). This may be related to the report by Sebuyira (2001) that the use of the comboplate resulted in less contamination compared to the use of traditional test tubes. It is easy (as the results confirm) to clean as most of the parts are made of plastic and therefore there is less chance of breakage while cleaning.



Taking care of the kit would appear to be a related experience to cleaning. However educators were somewhat less positive about taking care of the kit, as indicated in Fig. 6.



About three quarters of the class (Fig. 7) did not agree with the negative statement of experience. Those who agreed with it, may be expressing the point that it did not develop their

practical skills in using conventional equipment. Overall, the views on their experiences related to psychomotor skills, justify their increased support for criterion **b**, after working with the kits.

Observation is one of the basic process skills in science. Thus attitude criterion **c** (Allow learners to learn process skills of science, Table 7) correlates directly with experience **2** (the reactions were difficult to observe, Table 8).

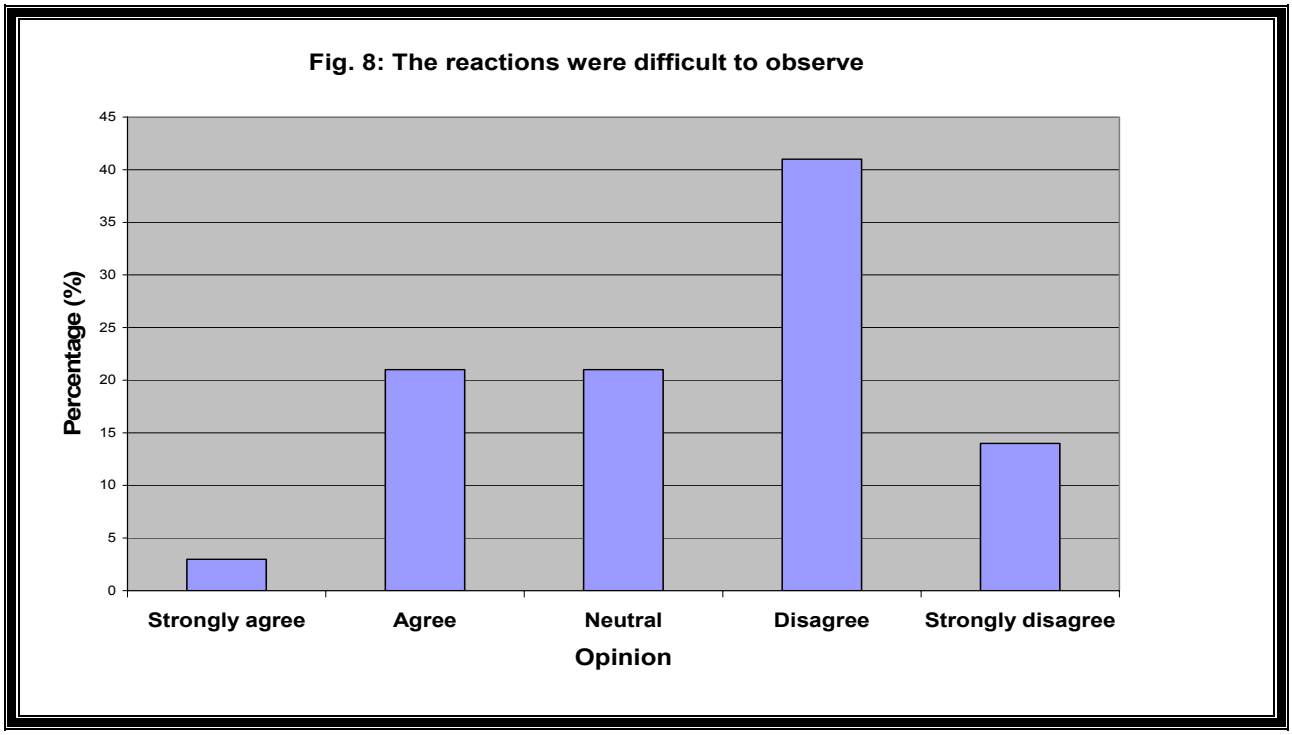
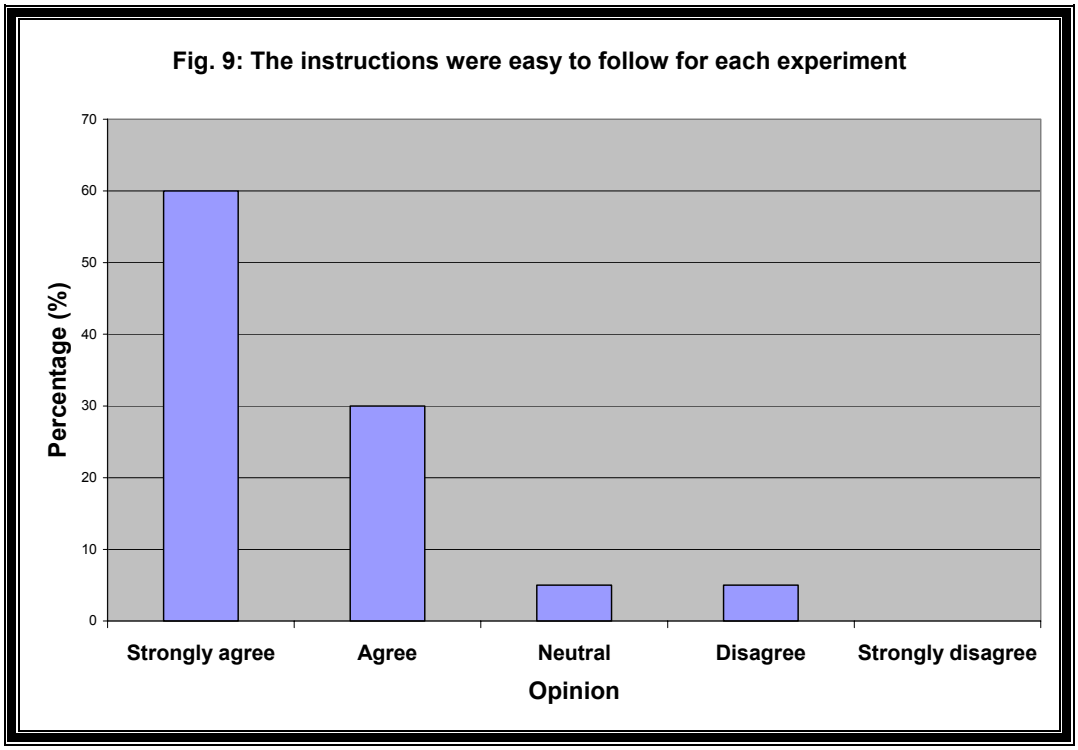


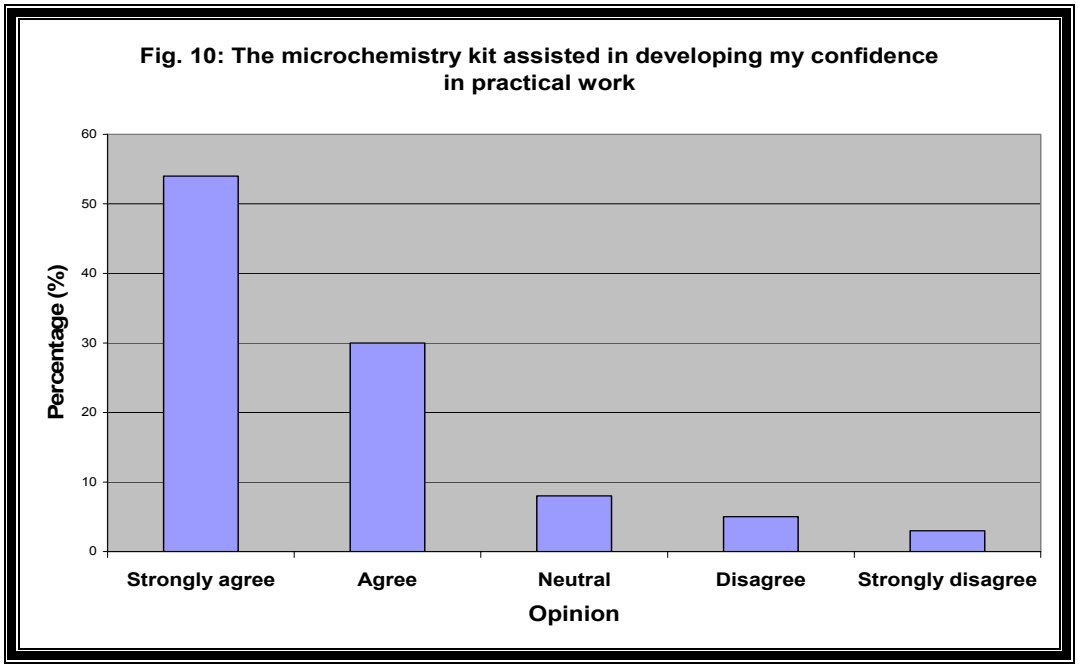
Fig. 8 shows that about half the sample disagreed that the reactions were difficult to observe. This correlates to their positive attitude towards the improvement of process skills. The difficulty that some had in observing the reactions may be due to the microscale nature of the experiments. They may be more used to observing the experiments performed with conventional equipment which is much larger. Sebuyira (2001) also found that some of her sample group found it difficult to observe the reactions. However she pointed out that 'difficult' should not be taken to mean something like 'impossible'! Sebuyira's (2001) results suggest that what is meant is more likely to be 'needed careful observation'; an opinion which is completely reasonable. Like any other equipment it does take time to get used to a particular type of equipment. Perhaps doing more experiments using the microchemistry kit will make one familiar and comfortable with the need for careful observation.

If a student is frustrated by not being able to follow the instructions given for an experiment s/he may lose confidence in performing an experiment. Thus experience **6** (Instructions were easy to follow for each experiment, Table 8) can be linked with attitude criterion **d** (Make the learners more confident, Table 7). Experience 1**3** (It assisted in developing my confidence in practical work, Table 8) is directly linked to criterion **d**.

As indicated in Fig.9, only 5% felt the instructions were not easy to follow. The researcher was involved in developing the experiments and writing the instructions for it. Great care was taken that instructions are unambiguous, easy to understand, follow a coherent order and take into consideration that for most of the users, English may be a second language.



As indicated by Fig 10. the majority of the educators (84%) felt that using the kit developed their confidence in practical work. Once again this presumably reflects a positive experience using the kits. This would explain why an unchanged 76% maintained that practical work makes learners more confident after the use of the microchemistry kit at home.



Attitude criterion **e** (Make learners enjoy the subject matter more, Table 7) may be linked with experiences **10** (It was fun to use the kit), **11** (I am keen to do more experiments using the kit and **15** (I would not like to have to do experiments with other ACE courses) (Table 8).

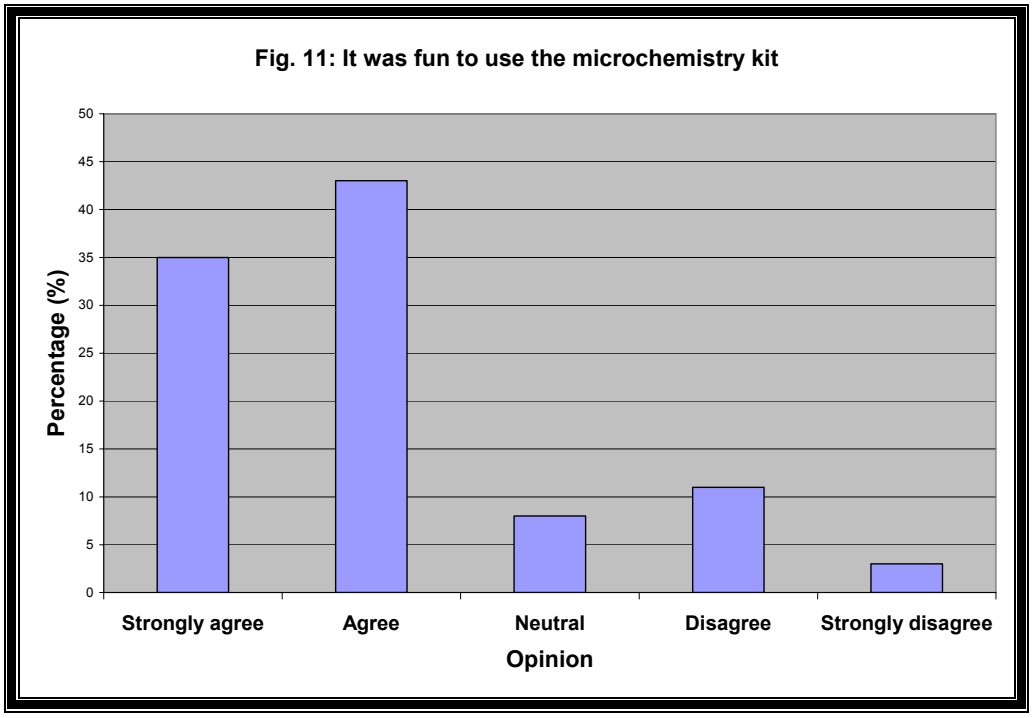
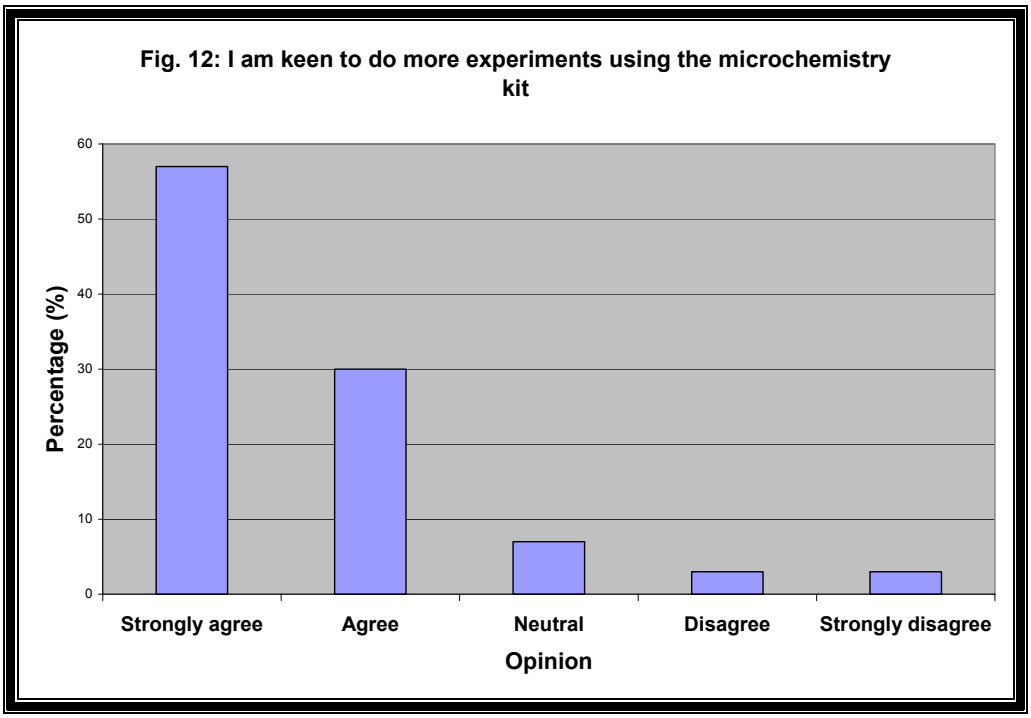
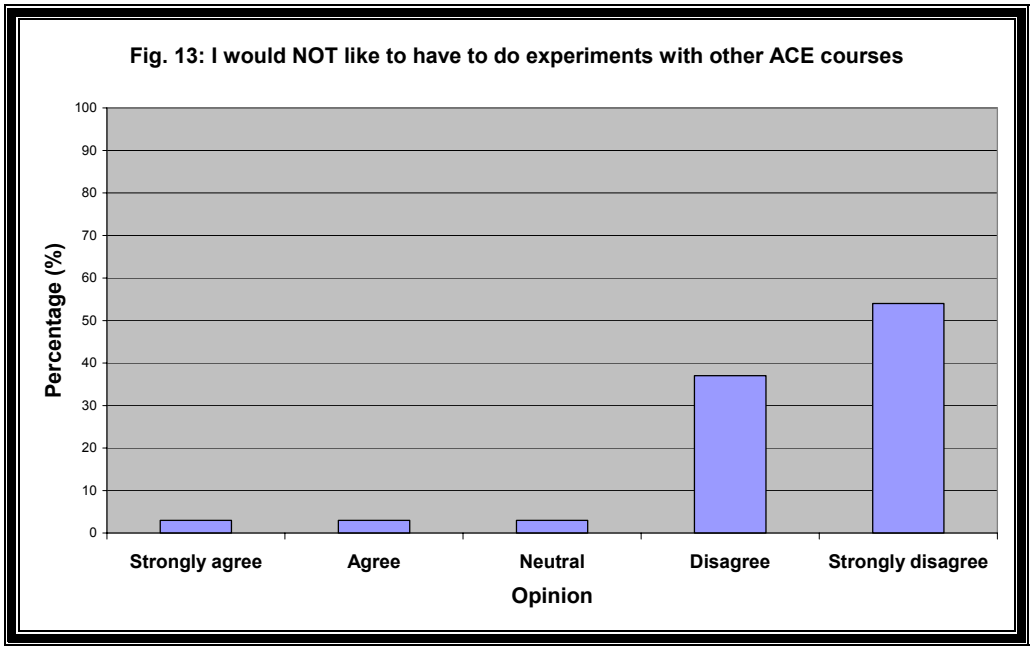


Fig.11 indicates that more than three quarters of the sample agreed that it was fun to use the microchemistry kit.

Similarly, Fig. 12. shows that the great majority (88%) of the educators were keen to do more experiments using the microchemistry kit. This could be a result of successful use of the kit either by themselves at home or in group work during contact sessions. Fig. 13 probably implies the home experiments are included in the enjoyable experiences. It shows that three quarters of the educators would like to do experiments with other ACE courses. In fact Figs 12 and 13 are mirror images of each other, with Fig. 12 reflecting upon a positive statement and Fig. 13 reflecting upon a negative statement.





Attitude criterion **f** (Provide learners with life skills related to safe handling of chemicals, Table 7), can be directly linked with experience **3** (It was safe to use) and experience **7** (The disposing of chemicals was a problem)(Table 8).

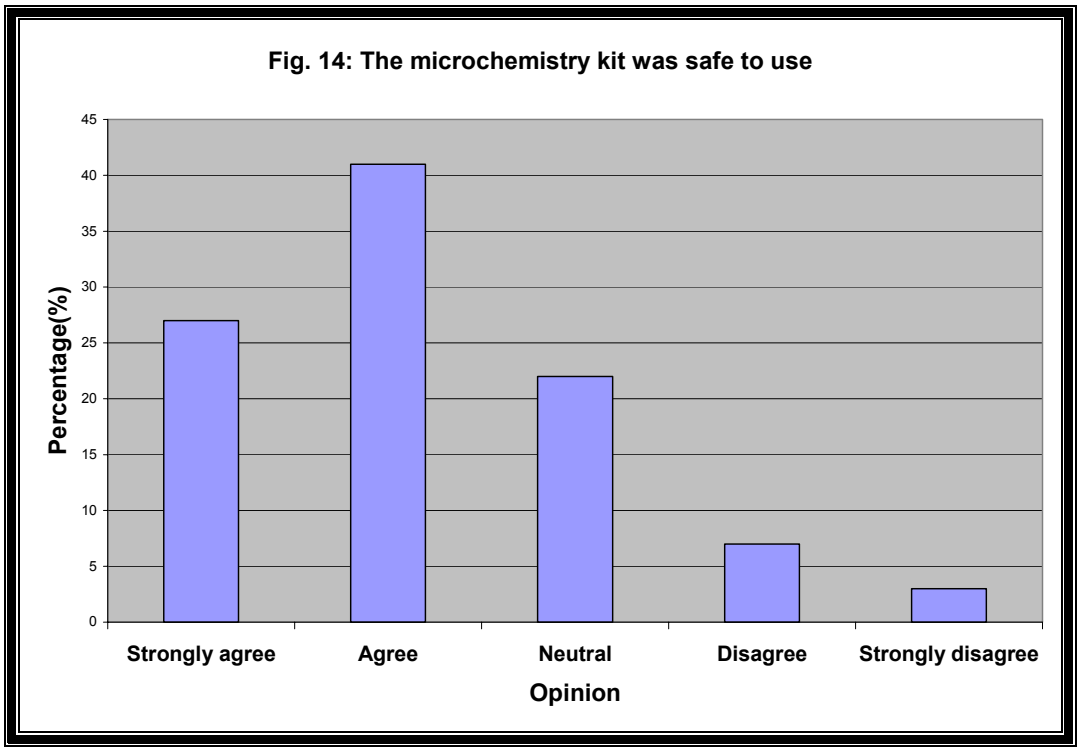
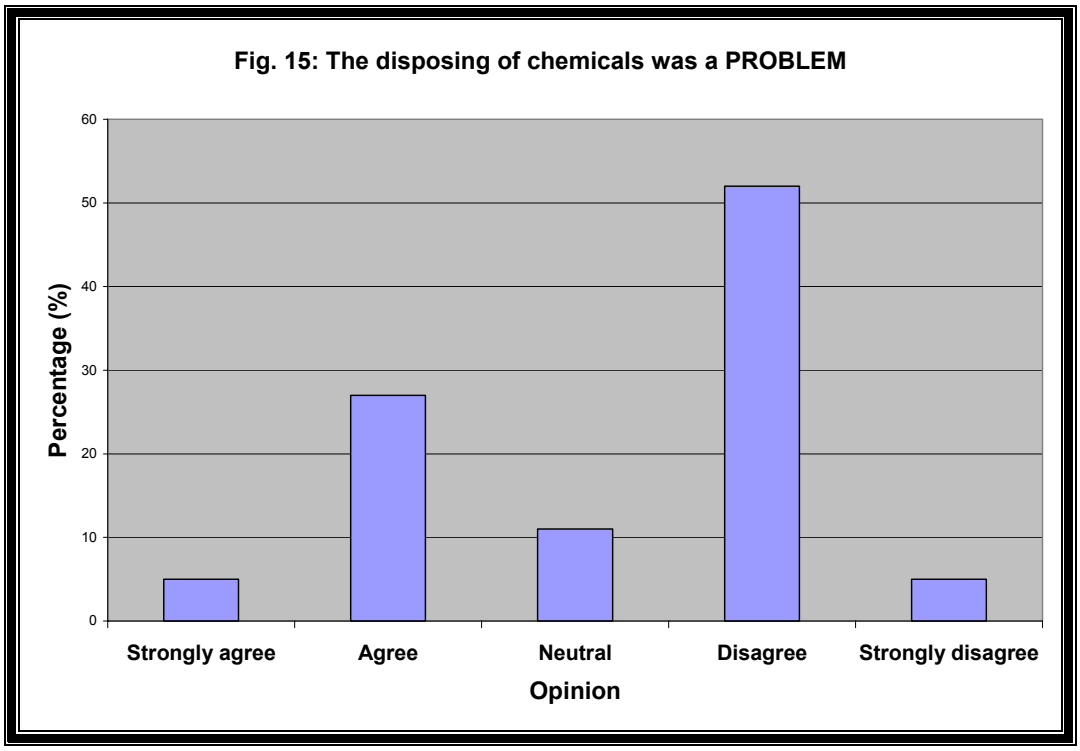
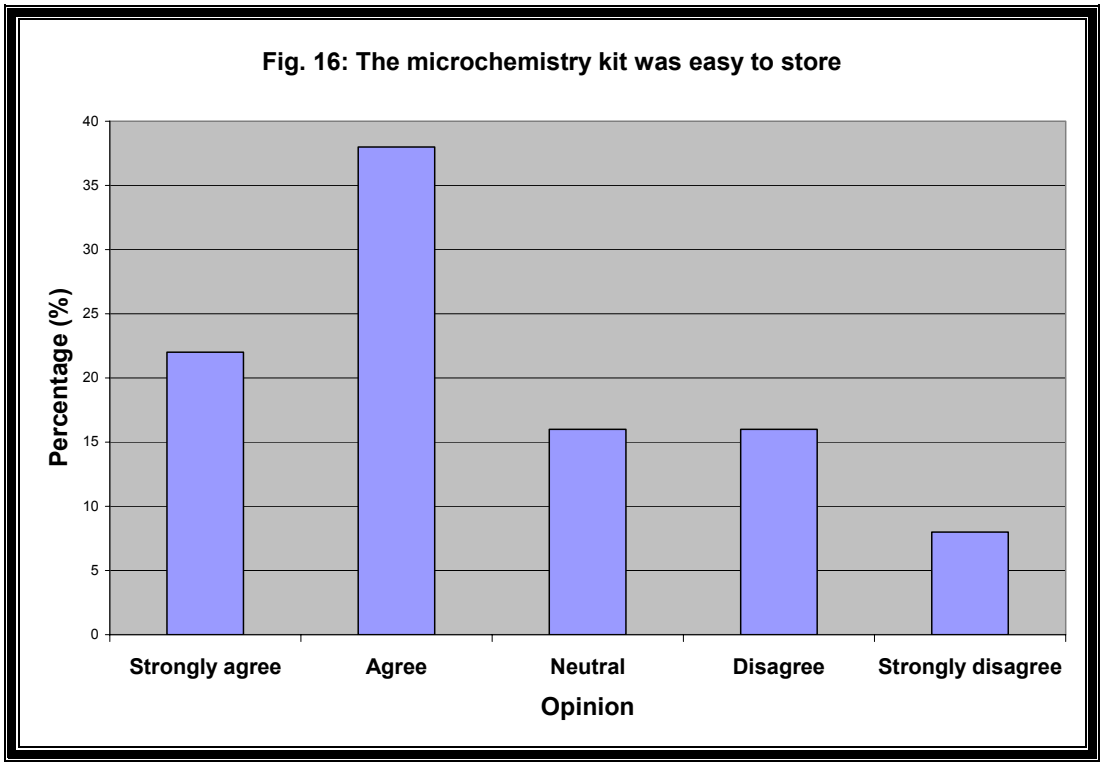


Fig.14 indicates that more than two-thirds agreed that the kit was safe to use. This opinion is of course justified by the small scale of the kit and the use of very small quantities of chemicals. Equally justified is their more neutral opinion overall that disposing of the chemicals was a problem (Fig. 15). The quantities of chemicals that are used to carry out the microscale experiments are so minute that disposing is generally not a problem. Those who reported disposal problems, may simply be stating it was a new problem for them, since it was the first time of doing chemistry experiments at home. Once again personal questioning could clarify this issue. The disposing of chemicals may also be discussed in detail during the contact sessions.



Only experience **8** (It was safe to store the kit) is not linked with any of the attitude criteria. The result obtained for this experience is shown in Fig. 16.



Overall 60% agreed that the kit was easy to store. Ross and Lewin (1992) state that one of the reasons for promoting microscale equipment is that it is easier to store as it needs much less space then conventional laboratory equipment. This is important for home experiments particularly, affecting both storage at home and transport to and from home. As reported later, the fact that a number of educators took the kits to school to do experiments, underlines the easy transportation.

When comparing the percentage support for the attitudinal criteria with the percentage agreement with the experience statement numerically, it is apparent that the high percentages associated with the former are not comparable with the percentages associated with the latter. Theoretical attitudes would seem to be moderated by experience! This is perhaps not surprising. To see whether the general difference casts doubt on the reliability of the respondents the comparative analysis was taken further. To do this, three things were done:

1) For the theoretical attitudinal criteria the percentages strongly in agreement were used,
2) For the actual experience the percentages agreeing and strongly agreeing were added together (for the negative statements the disagreements were added),
3) Where more than one actual experience was related to one theoretical criterion, an average of the percentages, calculated in (2) were used.

These calculations are summarised in Table 9.

Table 9: Comparative analysis of attitude criteria versus experience statements

Attitude Criterion (Pre%/Post%)	Experience Statement Number	%Strongly Agree + % Agree Experience (% Strongly Disagree + % Disagree Experience)	Average Experience %
a) Improve conceptual understanding (89/89)	14	91	91
b) Improve psychomotor skills (62/70)	1	90	
	4	56	
	5	87	
	9	65	
	12	76	75
c) Allow learners to learn process skills of science (84/86)	2	55	55
d) Make the learners more confident (76/76)	6	90	
	13	84	87
e) Make learners enjoy the subject matter more (78/78)	10	78	
	11	88	
	15	92	86
f) Provide learners with life skills related to safe handling of chemicals (65/70)	3	68	
	7	57	63

Each attitude criterion % (pre and post) was plotted against the average % of the experiences linked to it. Fig.17 reflects this comparison.

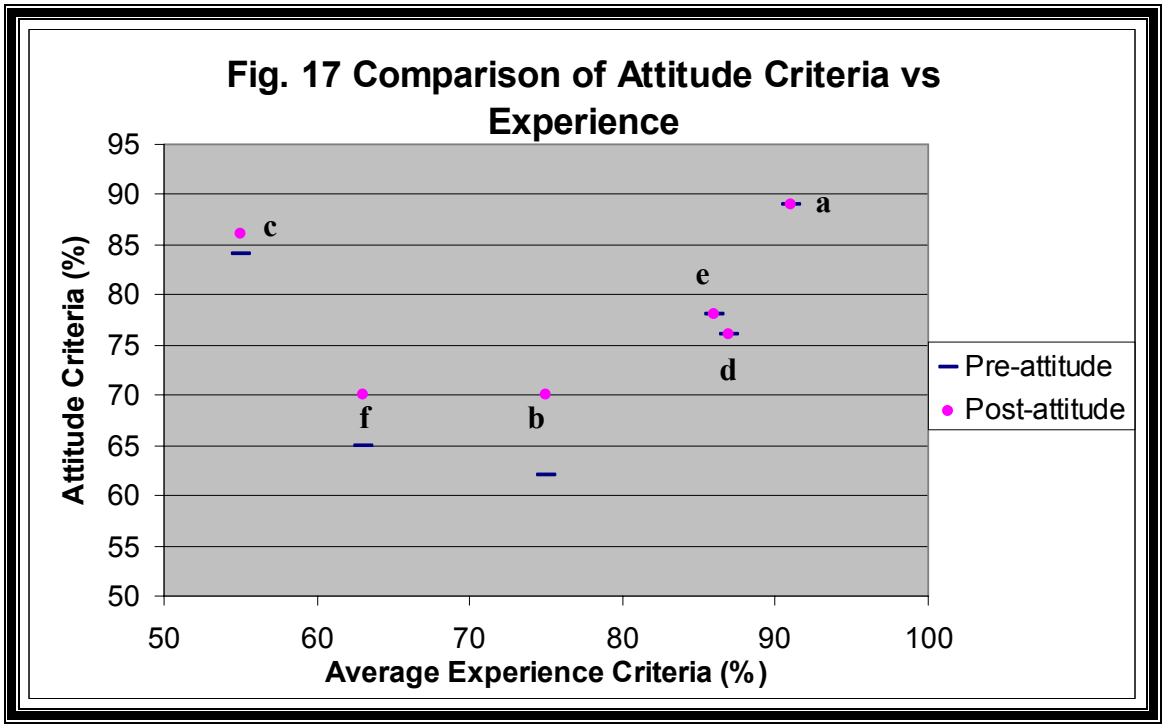


Fig. 17 helps to show that there is a rough relation between the two. As the educators were not made aware of the possible relationship the outcome is interpreted to mean the responses are reliable expressions of opinion.

This interpretation is strengthened by the one point which is an outlier to the others. This point refers to the 'processes of science' attitude criterion. Here it must be remembered that the experimental work required following instructions (Level 1 on level of Inquiry of Laboratory investigations, Woolnough (1991)), not designing experiments (Level 4). Thus the educators' responses honestly and correctly imply weak experience against an outcome they theoretically rate highly. It is also important to note that the theoretical outcome of conceptual understanding is strongly supported by their experience.

4.7.2 Question 2

Question 2 asked the educators to state if they had any other points they would like to add or comment further on the experiences covered in Question 1. Only 40% responded to the question. Of this 70% of the comments were related to the theoretical aspect of the course and not to practical work. 30% commented on the packaging of the chemicals. During the interviews, it was discovered that some of the educators had spilled the chemicals and therefore

improvised by using chemicals from the school, where it was available. The propettes containing the chemicals had split. This is important information for packaging in future as chemicals, are an integral part of performing chemistry experiments. Consideration should be given to the fact that the course is approximately 3 months long and as the experiments are integrated into the theory, it may take that long before the last experiment is performed. This does have implications for how the chemicals are packaged.

4.7.3 Question 3

Question 3 asked the educators to tick the appropriate box with regards to where they performed the experiments. The responses, indicating where they actually performed the experiments, are summarised in Table 10.

Table 10: Where were the experiments performed?

Location	**Percentage (%) (n=37)**
In the kitchen	4
On the dining room table	14
At school	46
Other	38

As indicated in Table 10, about half (46%) the educators, did the experiments at school. In the interview, it was revealed that it was convenient to do them at school, in their class, not necessarily in a laboratory, during a free period or lunch break as much of their time is spent at school and, due to other commitments after school, they preferred to do them there.

The 38% that answered ‘other’, were asked to elaborate. The results are as presented in Table 11.

Table 11: Where were the 'other' experiments performed?

Location	Percentage (%) (n=14)
Outside	**50**
Garage	**22**
Educator Centre	**14**
Bedroom	**14**

The versatility of the microchemistry equipment in terms of where the experiments can be performed can easily be seen from Table 11!

4.3.4 Question 4

Some of the components of the microchemistry kit are small and the researcher wanted to find out if the educators lost any of the components during their use (Question 4). Only two of the educators reported to have lost a microspatula each.

4.3.5 Question 5

To extrapolate on the use of the kit, the educators were asked if they would like their learners to use it in the class and to justify (Question 5). 100% said they would like to use it in the class. The reasons given were varied but these could be placed in 6 categories as shown in Table 12. On close inspection of these reasons the attitude criteria **a-e** (Table 7), are clearly re-iterated by the educators.

Table 12: Why should the microchemistry kits, be used by learners?

Reasons	Percentage (%) (n = 37)	Attitude Criteria
Hazard free, easy to handle, maintain, user-friendly, store and clean. Do not need a laboratory	44	b
Aid the learners in doing practical work/ each learner will be able to do experiments on their own	18	b,c
Promotes hands-on approach/improve skills and conceptual understanding	18	a,b
Promote confidence in learners	9	d
Need very little chemicals	9	f
Make the learners like science more	6	e

The reasons given vary from the actual use of the kit, to increasing the interest of learners in science, to improving conceptual understanding. This can only be attributed to their own positive experiences in using the kit. These are the same reasons given by Bradley et al (1998) amongst others, for using microscience equipment to do practical work.

4.3.6 Question 6

The kit was used at home, so it seemed logical to find out if it had any impact on other people around the home (Question 6). If the kit was used elsewhere they were asked to adapt their answer accordingly. 8% misunderstood the question (they said they had no problem using the kit), 22% responded that there was no impact. Of the 70% who said there was an impact, the various responses were categorized in 6 classes and are given in Table 13.

Table 13: What was the impact of using the microchemistry kit in your home, on your family?

Responses	**Percentage (%) (n = 29)**
At school, learners were interested and wanting to touch it	17
Other educators at school/educator centre were interested	10
Used it for teaching in class	20
Helped in understanding concepts	17
Children at home were curious and wanted to watch	20
Very thrilling experience- realized experiments can be done anywhere, anytime	10
Curious neighbours	6

The responses relate mostly to those that used the kit in the school. Some of the educators (20%) took the initiative of integrating it into their teaching. This shows the great potential of the kit being used in various ways, from educator demonstration, to peer group discussions to eventual use by learners.

4.3.7 Question 7

The kit became part of their learning experience and therefore whether it was discussed with others in their social setting would be interesting to note (Question 7). 27% reported they did not discuss it with anyone. Of the 73% that responded in the affirmative, the various responses (5 categories) are given in Table 14.

Table 14: Comments on discussion with others about the kit

Comments	Percentage (%) (n = 27)
Discussed it with colleagues, want to get for schools to use with learners	52
Friends thought I was very clever, regarded me with high esteem	7
Colleagues also want to do this ACE course	15
Cheaper alternative for accessing practical chemistry for rural schools	22
Uses very little chemicals	4

The comments in Table 14 point to educators wanting to use the kit with learners in the class. According to the survey carried out by Gunter (2005) for the same educators, only 20% of the educators have access to laboratories. From Table 4 it can be seen that only 3% have a laboratory which is fully functional. The microscience kits can be used anywhere, anytime and this includes a normal classroom.

From the results obtained in the questionnaire about experiences of using the microchemistry kit, it can be concluded that the educators had positive experiences in using the kit at home for doing practical work.

4.8 Responses to Interview questions

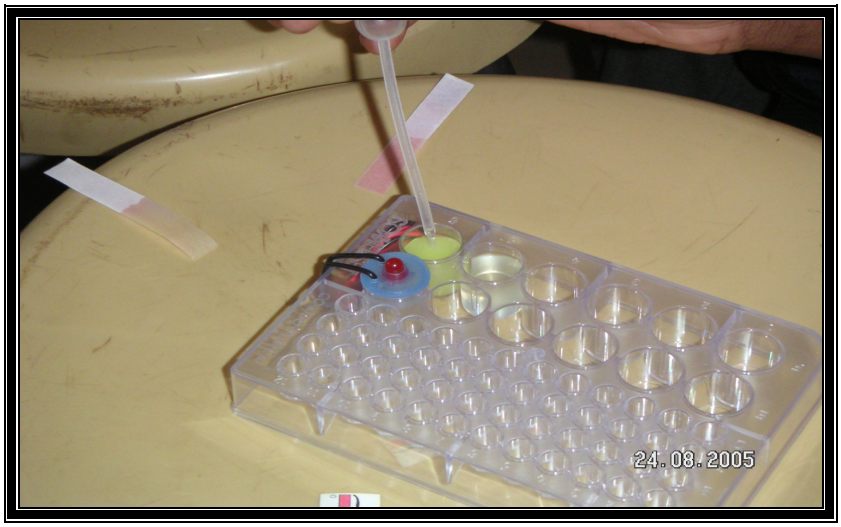
To gain further insight into how the educators coped with the use of the microchemistry kit at home to do experiments, 4 educators were selected at random, from whom permission was granted to visit them at home and interview them while they were performing an experiment. Fig. 18 and 19 show photos of an educator performing an experiment at home. The interview questions are similar to Question 1 of the Questionnaire about experiences in using the microchemistry kit at home. But with the interview the answers could be elaborated upon with prompting from the researcher. Where appropriate, responses from educators during the interviews have been incorporated to support their responses in both the questionnaires.

Question 1: Where did you do the experiments?

One educator did the experiments at school, in an office. He was assisted by another educator. The other educator did the experiment outside her house on a table. Two of them did it in a room in the house. As commented before this shows the versatility of the kit in terms of where the experiments can be performed. It does not require a laboratory at all.

Fig. 18: An educator showing results of an experiment done at home

Fig. 19: An educator performing an experiment at home



Question 2: Were you scared or confident about doing the experiments? How did you feel?

One educator commented that he was nervous as he had not done experiments on his own before. Two of the educators commented that they were fine doing the experiments. The other educator commented that she was nervous when she did the first experiment but after that she was more relaxed. This may relate to building confidence.

Question 3: Did you have any spectators. Any comments from them?

One educator commented she had her younger brother helping her as she is colour blind and therefore, where appropriate, she questioned the brother about the colour of solutions and products after reactions. The other three educators worked by themselves.

Question 4: Were the instructions easy to follow?

All four educators commented that the instructions were easy to follow as they had commented in the questionnaire. This is one of the most important aspects of designing practical experiences. The instructions should be clear, simple and easy to follow. It needs to be trialed by others before it is mass distributed to see how they will cope with it.

Question 5: Were the reactions easy to observe?

Three of the educators stated that the reactions were easy to observe but one commented that she could not see it very easily. On further probing it was discovered that there was not much light in the room where she usually did the experiments. This may be one of the reasons why she could not observe the reactions easily.

Question 6: Was the cleaning of the equipment easy/hard? Where did you clean it?

Three of the educators did not find it difficult to clean the equipment. All of them cleaned it in a sink outside. One educator commented he followed the instructions given for cleaning in the practical manual. One educator did find it difficult to clean the equipment. The reason for this was that he had left the comboplate with the solutions in the wells overnight! This shows how

important it is to follow instructions carefully whether it be for the experiment itself or for cleaning the equipment afterwards.

Question 7: Did the experiments help you in understanding concepts (were you able to relate it to theory?) Elaborate.

All the educators agree that it did help them in understanding the concepts. One educator commented that by doing the experiment you actually see what happens which previously was only read about in a textbook. The colour changes and formation of solids in some experiments, was another interesting aspect that one of the educators pointed out which she had seen for the first time.

One educator was doing a reaction stoichiometry experiment when I visited him, and we discussed it in detail. In the experiment colourless solutions of lead nitrate and sodium iodide react to form a yellow precipitate of lead iodide. This is a statement of facts but, as this educator commented, he was able to look at the formation of the lead iodide in the wells and was able to work out for himself what the stoichiometry of the reaction between lead nitrate and sodium iodide was (previously he had read it in textbooks and accepted it). Now he had done the experiment himself to find that was the case. This proved to be empowering for him and he said he realized what a powerful tool practical work can be in understanding science concepts.

Question 8: Some educators said the experiments took a long time (in the questionnaire). If so, why?

All four educators felt that this was not the case with them. Two of them commented further to say in fact it took less time compared to using conventional equipment.

Question 9: Would you recommend using the microscience equipment in class with learners?

The answer was unanimous that they would certainly like to use it in the class. One educator commented that it was a very attractive alternative for practical work where schools do not have or cannot afford to buy conventional equipment. Another educator commented that it is

user friendly, can be used in groups and thus educators would be able to manage practical work activities effectively.

Question 10: Would you recommend it to your colleagues?

All the educators said they would recommend it to their colleagues. This could be attributed to their positive experiences in using the kits by themselves.

Question 11: Is it better to do an ACE course with/without practical work. Do you feel it is better with/without practical work integrated with the theory?

They all felt that practical work is essential in any ACE course. They also agreed that it is better with the practical work integrated. Two of them commented that with the theory still fresh in mind it is better to do the experiments immediately so that the hands-on experience can consolidate the theory just learnt.

Question 12: Should the packaging of chemicals be done in bottles or propettes?

They all preferred that the liquids be packaged in bottles as two of them had problems with the propettes leaking. This was also picked up in the questionnaires. This point can be considered for future ACE courses.

Question 13: Any other comments?

One educator commented that she was really finding this ACE course very exciting and this novel idea of integrating practical work with the theory looked very positive. Another educator commented on the workload that the ACE course entailed. Time-management is very important. Studying at a distance can be quite lonely and one educator commented that he really appreciated the sms received regularly which reminded him about how to pace his studies.

From the comments received during the interviews it can be concluded that the educators' attitude toward the use of the microchemistry kit at home was very positive. They realized how

important practical work is if integrated in the learning of science concepts. This notion may not have been realized if the practical work component was done in one batch at the end of the course.

4.5 Questionnaire to ascertain what the educators learnt from 'at home' practical activities

This questionnaire was administered at the end of the Chemical Reactions course, after the educators had used the kits at home to do practical work during their independent study. Another group of 25 educators responded to the questionnaire (these educators formed part of the group in the next year the course was run). The questions were aimed to find out what knowledge, skills and attitude they had learned in using the kits at home, thus providing a clue to the third research question. Appendix O provides a sample of the response by one educator to this questionnaire.

For those questions which required the educators to respond with either a YES or NO, and then elaborate on this choice, a two tier approach to analysis was adopted. The first tier corresponds with a YES or NO response. The response with which most educators sided is then further categorized to provide the second tier of the analysis and it is taken as 100% of the sample for this response. For example if in a sample of 25 educators, 20 responded YES and 5 responded with NO, in the second tier analysis the 20 forms the sample size (N= 20). The responses of the educators to all ten questions and the categorization thereof is presented in Appendix P. Table 15 summarises the responses to questions where Y/N or similar type of answer can be quantified.

Table 15: Summary of answers to Questionnaire 3[3]

Q No.	Question statement	% YES	%NO
1	Assists in understanding theory (K)	84	16
2	Compare and contrast contact session vs home experiences	-	-
3	Useful in learning concepts (K)	96	4
4	Assists in learning practical skills (S)	92	8
5	More able to understand and affect environment (A)	84	16
6	Views on doing practical work for learning concepts	-	-
7	Compare home vs contact sessions for usefulness of expts.[1]	68 (H)	28 (CS)
8	Should experiments be done only in a lab (A)	12	80
9	Experiments should be integrated or separate (K)[2]	72 (I)	12 (S)
10	Experience with using kit at home	-	-

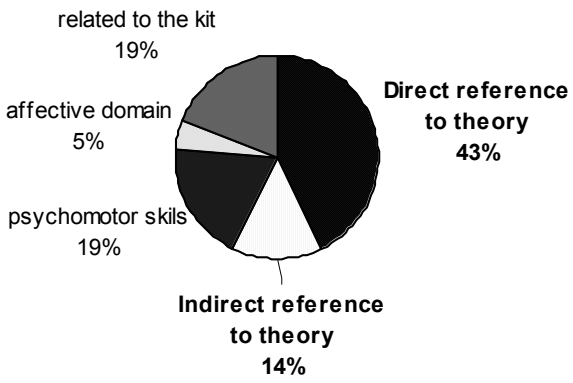
Footnotes: 1) H signifies % finding home more useful; CS signifies % finding contact session more useful.

2) I signifies % following integration, S signifies % separating practical work

3) Open- ended questions have no quantitative results. K = knowledge, S = skills, A = attitudes

The views of the educators on gaining understanding of concepts through using the kit at home can be ascertained by their responses to questions 1, 3, 6 and 9. In response to the question which required educators to respond whether doing the practical activities at home assisted them in understanding the theory better (Question 1), 16% responded with NO and 84% responded with YES. The analysis of those who responded YES is presented in Fig. 20.

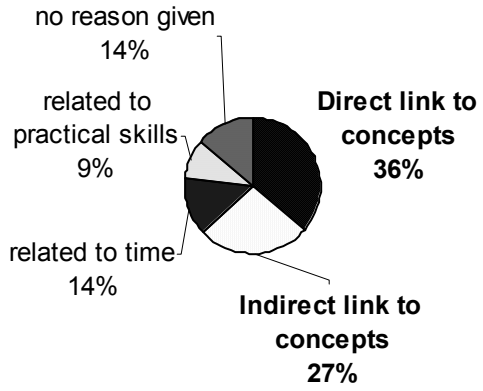
Fig. 20: Did you understand the theory better by doing the practical activities at home?



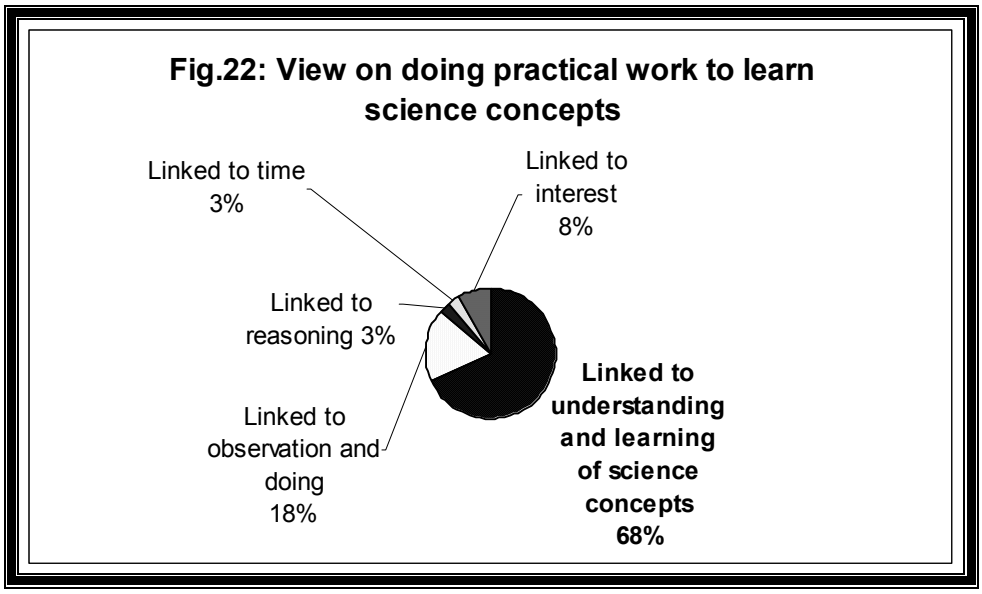
Over half the sample claimed that doing the practical activities at home, did assist them in understanding the theory better. Of note however are the categories related to psychomotor skills and the kit and the affective domain. This either implies misunderstanding or a recognition that concept learning benefits from improvements in skills and attitudes. (For example, convenience of practical work facilitates applying the mind to reflection on concepts).

In response to whether doing the experiments at home aided in understanding the concepts better (Question 3), a resounding 96% responded with a YES! When this was analysed further, 5 categories emerged from the justification of their choice. Fig. 21 shows that more than half the sample confirmed that it aided them in understanding the concepts better. Here the category to note is that related with time, which corresponds to educators having the opportunity to work at their own pace in doing the experiments. This can be reasonably interpreted as saying that by having more time to reflect on their actions, they could better relate them to the concepts involved.

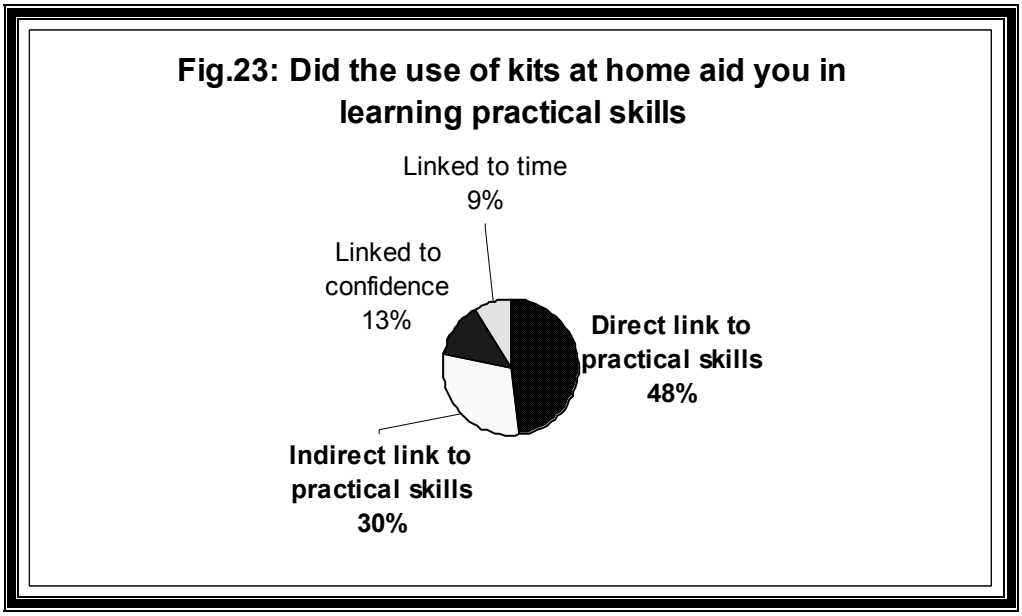
Fig. 21: Did you understand the concepts better by doing the practical activities at home?



Question 6 relates to the educators view on doing practical work for the learning of science concepts (Fig.22). A high number believe that practical work is essential. What is of interest is that on being asked to justify their choice in questions 1, 3 and 6 the number of educators linking it to either theory or understanding concepts is lower than in the first tier where they were asked to state either YES or NO. Given the choice to justify, other categories emerged which still linked to the understanding of concepts indirectly. The figures for their attitude and experience in this regard are, also very high in the previous two questionnaires where they did not have the opportunity to justify their choice. Thus the picture which emerges from Figs. 20, 21 and 22 is that doing practical work at home did make them understand the theory better.

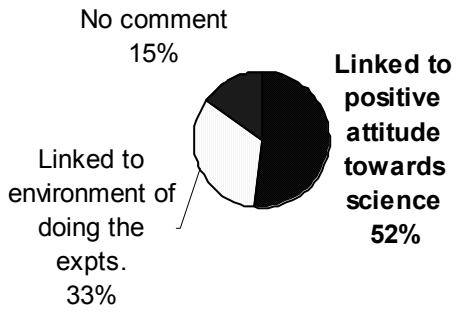


Learning of psychomotor skills is reflected in Question 4, which asked if using the kit at home aided them in learning practical skills. 92% confirmed that it did. Further analysis of their justification (Fig. 23) revealed that three-quarters of that sample responded with either a direct or indirect link to practical skills. This can be related to their experience statements in this regard (Tables 8 and 9) where learning practical skills by doing practical work at home is also rated highly.



Learning in the affective domain, is reflected in the responses to Question 5. 84% of the educators said that doing the experiments at home did make them feel more able to understand and affect their environment. Further analysis of this sample (Fig. 24) reveals that half justified their answers by linking them with positive attitudes to science. The third of the sample which justified their choice with the physical environment of doing the experiments suggests that the question was taken literally by them. When their affective attitudes were being ascertained with the descriptive words (enjoyment, confidence, etc) related to this domain, in the questionnaires on attitude and experience, their personal experience at home also resulted in very positive feelings.

Fig. 24: Did doing experiments at home make you feel more able to understand and affect your environment

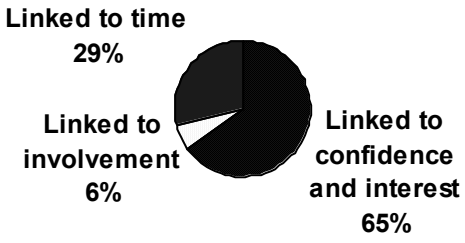


Educators' attitudes are also reflected in Question 8 which tested their views on the suitability of a physical environment for doing practical work. Their responses to Question 8 reveal that 80% feel that it can be done anywhere. This 80% was able to justify their choice as well. In fact some related it to the microscience kit which allows for experiments to be performed anywhere. Those who said it needs to be done in a lab (12%) linked it to either the experience of being a real scientist or storing and safety of equipment and chemicals.

To further investigate the suitability of the environment for doing practical work, the educators were asked if they found the experience of doing practical work at home or contact session more useful in Question 7. 68% found the experience at home was more useful. Within this

sample it is interesting to note that many of them relate it to confidence and interest (Fig. 25)! Another interesting category that emerged is that of time, where it was noted that they could work at their own pace (see also Question 3). Those who preferred their experience at the contact session attributed this to the interaction with other colleagues (Appendix P).

Fig. 25: Why was doing the experiments at home useful?



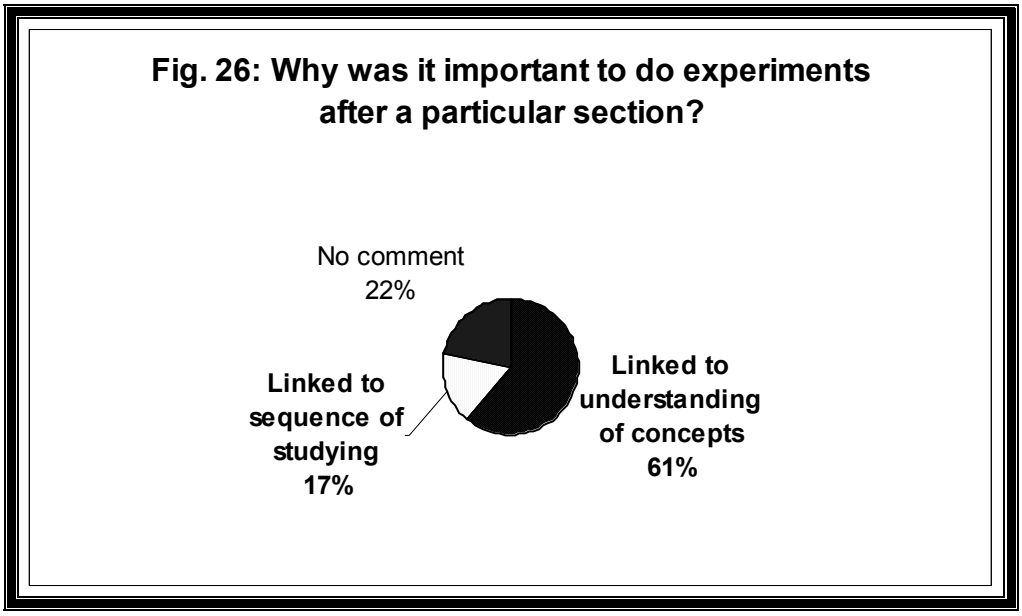
Question 2 also allowed educators to compare and contrast their experience in performing experiments at the contact session and at home. Table 16 attempts to summarise the responses to this question.

Table 16: Doing experiment at the contact session vs at home

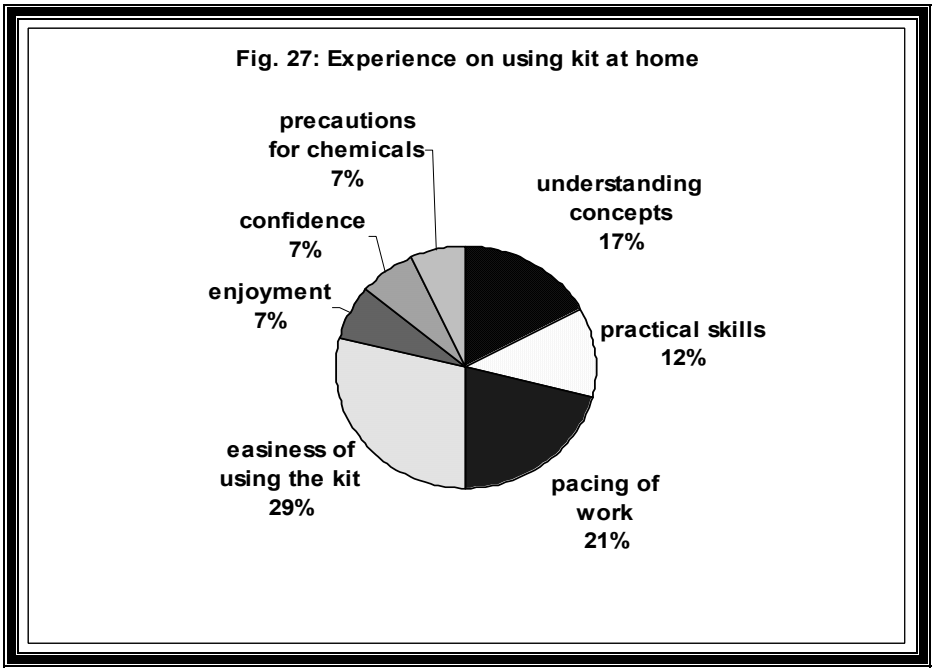
Contact session	Home
Easy-we can help each other(3)	I am now able to do it at home
Work in group so other can assist you	If you make a mistake, nobody to assist you (3)
We can share ideas(3)	Have time to interact with the material (4)
	Can gain experience in using the kit
I could watch someone else doing the experiment	I had to do the experiments on my own
Share ideas, better understanding but not enough time (3)	Gain experience
Easy as we shared ideas	I was on my own had to figure out things on my own (4)
	It is good but time consuming (2)
If you stuck, fellow students can help you (2)	Nobody to help you (2)
You get extra information	Struggle to find information
Tutor came to the rescue if I did not understand	I get confused(3)
Students who are intelligent do things fast and leave the slow learners behind	There was no tutor to ask questions

The interactions and sharing of ideas with colleagues again feature as important aspects of the contact session. The feeling of isolation and lack of supervision being a feature of distance education, comes out strongly in their response to their experience at home.

Apart from the physical environment and the process of performing an experiment, what is also of importance is when an experiment is performed during the course of study. According to Ramsey and Howie (1969), practical work should be integrated within the theoretical framework, for it to be meaningful. 72% of the respondents to Question 9, did indeed do a particular experiment after a particular section as, instructed in the Workbook. 61% of this sample linked it to understanding of concepts (Fig. 26), suggesting that the aims of the Course Workbook authors were being achieved for these educators.



Question 10 allowed the educators to write about their experience in general of using the kit at home. The responses (Fig. 27) were varied. Half the responses corresponded to the cognitive, psychomotor and affective domain, whilst the other half linked it to the easiness of using the kit and pacing of work. The factor of time once again featured for the educators as being important.



It can be concluded that the educators claimed gains in knowledge, skills and attitude from doing practical work at home in conjunction with their Course Workbook. Furthermore they reported several advantages they experienced as compared to the practical work in the contact sessions

4.6 Report of the completed experiment worksheets (Appendix H)

The completed worksheets relating to the experiment were collected as part of a portfolio activity. The observations (change in colour, formation of precipitate, gas formation, etc.) were as expected. The results and deductions drawn after doing an experiment as appears on the worksheets is an indication that the educators were able to follow instructions, perform the experiments and make deductions from the results obtained.

4.7 Conclusion

This chapter presented, analysed and discussed the findings of the three questionnaires and interview responses which will be used to answer the research questions posed for the current study. The results were presented using tables and graphs. In the next chapter the three research questions will be answered. Reflections will also be included and where possible, recommendations will be given.

CHAPTER 5

CONCLUSIONS, REFLECTIONS AND RECOMMENDATIONS

5.1 Conclusions

In this chapter the main findings of the research will be summarized to ascertain whether the research questions set for the current study can be answered. It also attempts to see to what extent was the research able to achieve the aims set out at the beginning.

Based on the findings, reflections and recommendations will be offered where possible so that it may provide a basis for a major study in which the findings may be generalized for the whole population. The conclusion for each question follows.

First Question: ***Can microchemistry kits enable science educators (those studying ACE through distance education) to experience practical chemistry at home?***

The responses to the 14 items relating to experiences of doing practical work with the microchemistry kit at home indicate that the educators' experiences were positive and they were able to experience practical chemistry at home using the kit. Their positive experiences in using the kit indicate that they were able to carry out the experiments unaided and the completed worksheets indicate that they were able to do so correctly. The positive response to confidence, developing practical skills, understanding chemistry concepts and keenness to use the kit in other courses indicate that the three domains (cognitive, psychomotor and affective) identified by Lunetta and Hofstein (1980), can be addressed successfully by using the microchemistry kit at home.

The responses also indicate that the educators believe the aims of practical work, as mentioned by Woolnough and Allsop (1985), i.e: stimulating interest, learning experimental skills and techniques, teaching the processes of science and supporting theoretical learning, can be achieved using the microchemistry kit at home.

It must however be noted that the subjects in this research were science educators. Hence although this first research question can be answered with an unequivocal 'yes' it cannot be concluded that other kinds of distance learners (eg. Learners with no prior experience of practical work) would have equal success.

Second Question: ***How, did the experiences of educators influence their attitude towards practical work?***

The results obtained from the questionnaire indicate that the educators' attitude changed positively or remained unchanged after using the microscience kit at home to do practical work. There was an initial highly positive attitude towards practical work, indicating that the educators were aware of the importance of practical work in learning science. Any negative change in attitude towards practical work, after using the kit at home would be attributed to their experience in using the kit at home. In fact this was not evident. The initial positive attitude towards practical work with regards to improving conceptual understanding, improving psychomotor skills, allowing learners to learn process skills of science, making the learner more confident and enjoying the subject more, etc., can possibly be attributed to the educator's own theoretical beliefs.

Their final attitudes would then presumably reflect upon their personal experiences of practical work conducted at home, alone with their Course Workbook. There are several indications that for some educators this stimulated reflection, in a way that did not happen when experiencing group practical work in the contact sessions. Hence it is a significant outcome that their attitudes either remained very positive or even became more positive.

The significance of the outcome is substantiated by the educators' responses in the questionnaire and interviews about their personal experiences. These responses could have revealed that their personal experiences actually differed from their theoretical attitudes, in some respects at least. This was not the case.

The increase in positive attitude, in improving psychomotor skills and providing learners with life skills related to the safe handling of chemicals when doing practical work, may be due to the special features of the microscience kit. It is easy to handle and uses very little chemicals and these features make it non-threatening for learners yet achieving the goal of learning the safe handling of chemicals.

Third Question: ***What do educators learn from 'at home' practical activities?***

In the responses to the questionnaire to ascertain what they learnt from 'at home' practical activities, several indicators can be found. The educators indicated that experiments can be done anywhere. They do not need to be performed in a laboratory but can be performed anywhere if a convenient, easy to use system with a set of instructions is available. Their microscience kits and Workbook seem to have footed the bill.

The results indicate that the educators felt that their knowledge, skills and attitude had benefited by doing the experiments at home using the microscience kit. In the questions which required general feedback on using the kit at home, the educators cited these three domains and the attributes of the kit in equal measure.

The educators learnt that performing the experiments while doing the theory was important in consolidating their understanding of chemistry concepts.

Having the responsibility of doing the practical work on their own resulted in the educators feeling empowered and more self-confident.

Of note is the time factor which came up in many responses as being an important benefit for doing practical work at home. This raises the question: Is the limited time spent in a conventional laboratory a hindrance to making the connection between theory and practical work? The negative side of doing practical work at home seems to be the isolation and lack of support, two points which are understandable and predictable.

Despite this the educators were able to carry out the experiments on their own. Doing the experiments at home had other benefits: in effect it was able to stimulate interest from other people and raise the esteem of the educator. As a natural consequence it may develop interest in learners to do science. The versatility of the kit in terms of allowing the experiments to be performed just about anywhere, may assist in demystifying science and make it accessible for a larger group of people.

From the findings in this study it can be concluded that the microscience kit can be the right tool for doing practical work at home. In this way they are not constrained in terms of when, where and how they will do the experiments. This is powerful for the way science courses can be studied at a distance. Previous science courses which could not be offered at a distance due to the rural setting of students, who may not be close to a study centre, can now be reorganized thus allowing a greater number of students into the science discipline. The opportunity this affords can go a long way in empowering science students.

5.2 Reflections and Recommendations

In-service educators are good candidates for this ‘at home’ practical work because they may have some background and experience of practical work. Educators doing the GET (General Education and Training) ACE at Wits University also use the microscience kits. For these primary school (Grade 4-9) educators most chemicals required for experiments can be found at

home in everyday substances, so they may not have to be supplied with any chemicals. But what about those students doing science through distance, that have not been exposed to any form of practical work whatsoever? For these candidates a pre-course workshop may be suitable where they are taught not only how to use the microscience equipment, but also about the handling and disposing of chemicals, safety, etc.

In providing practical work at home, the length and level of the science course and the number of experiments that need to be done at home also needs to be considered. With semester courses as provided by the Open University in the UK (Grose, 1999), Colorado Mountain College, America (Jeschognig, 2005) and the ACE course at Wits University, South Africa; with a limited number of rather basic experiments that need to be performed at home per course, the microscale system may be recommended.

The packing of chemicals is important for chemistry courses as they need to be transported. As noted in this study some students experienced spillage of chemicals from the propettes. At Home Science in Colorado, USA also uses propettes for transporting chemicals and has had no problems. The problem may lie with the quality of this batch of propettes as problems were experienced previously where the propettes split.

As discussed in Chapter 2, the social constructivist sees interaction with other learners as being crucial to the learning process. With distance education courses the absence of this interaction is one of the drawbacks. This can be ameliorated by forming study groups, interaction via sms, on-line chat groups and video conferencing. The tutor may provide the scaffolding required via these modes of communication with the learners. This may also provide the encouragement and motivation to carry on with the course. The use of on-line chat groups and video conferencing may be constrained in South Africa currently as very few people have access to a computer and fewer have internet facilities.

The importance of practical work in learning science has been emphasized in this study.

The importance of integrating practical work with the learning of theoretical concepts of science (as done in this study) needs to be researched on larger scale to generalize the findings. If the results are favourable as found in this study, distance education institutions can consider using the microscience kits for their science courses. It is probable that many of the existing experiments done on macroscale can be adapted to be performed on microscale. Distance education institutions which have centers set up where students can go and do practical work, may also use microscience kits for this purpose. This will minimize the cost of equipment and

laboratory facilities at such centres. A study can be done over a longer period of time, involving many more experiments to be done on microscale.

The study does not claim that doing practical work using a microscience kit brings about conceptual understanding. A microscience kit is merely a tool to providing practical experience for distance education students. However it would be interesting to set up a study, using students studying science at a distance, to research if integrating practical work with the learning of theoretical concepts of science does bring about increased understanding. This could be set up by having two sets of equivalent educators, where one set does the practical work separately at the end of the course and the other set does the practical work at home at the same time as a particular theory or concept is studied. Both sets would use the same microscience equipment and carry out the same experiments. A test could be written by both sets after the practical activities have been completed to test their understanding of scientific concepts. This way it can be seen if the integration of practical work improves conceptual understanding or not. If it does then this would encourage further changes in the way practical work is offered within science courses at a distance.

An advantage of using the microscience kit at home to do practical work with educators is that they would have been trained to use the kits. Thus they will be ready to use them in their teaching if the schools are equipped with the kits. With most rural schools in South Africa not having a fully functional laboratory this may be the only way that learners have the opportunity to experience practical science. In fact the Mpumalanga Department of Education has purchased the kits and will first equip those schools in which the science teacher has enrolled for the ACE and formed part of the current study. The practical work experience can also be easily extended to include microscale activities related to physics and biology as well.

An important finding in this study is that the majority of the educators involved felt that although they lacked the help of fellow-students, they gained more by having adequate time. The description of their feelings, convey a strong sense of personal construction of knowledge, skills and attitudes. In keeping with this are expressions of improved self-confidence and this may be important for what happens subsequently in the classroom. This too is a potential focus for future research, namely to determine the longer-term outcomes on educator achievement.

The specific focus of the present study on practical work is an aspect of this broader research theme. Previous experience with primary school educators indicates how difficult it is for educators to integrate practical activities into their curricula (Nakedi, 2002; Roberts et al, 2004). Educators in 400 schools across four provinces in south Africa, although provided with

two days intensive training and expressing great enthusiasm, largely failed to use effectively the microscience kits provided to their schools. The principal reason for this failure was found to be the absence of continuing support by subject advisors. One may postulate that educators completing an ACE program with practical science experiences at home using the microscience kit would be far more likely to implement microscience kits in their classrooms. Their self-confidence derived from self-achievement in using the kits should make the decisive difference.

APPENDICES

APPENDIX A

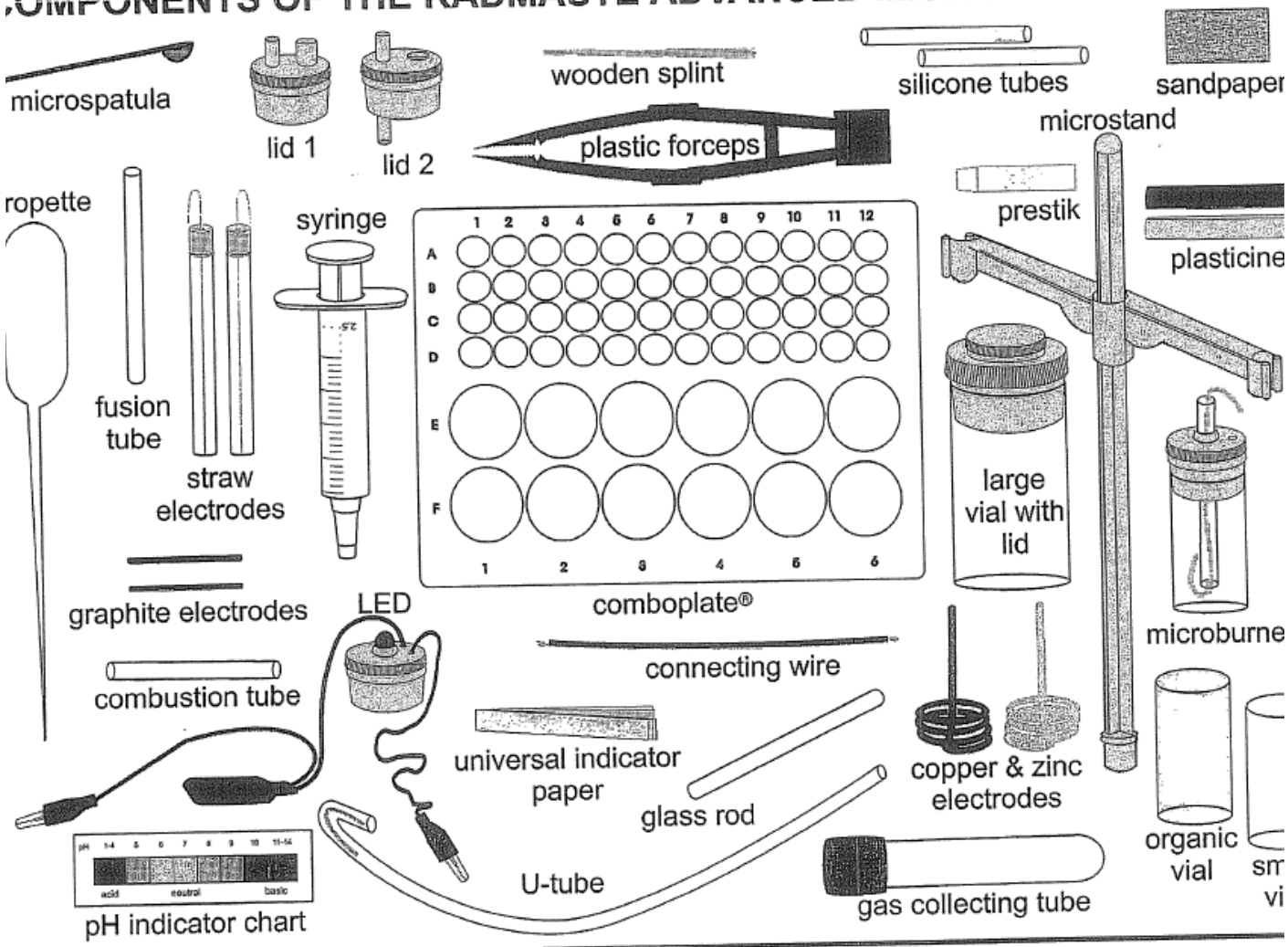
a) Components of the RADMASTE Advanced Microchemistry kit

b) Chemicals used by the students at home

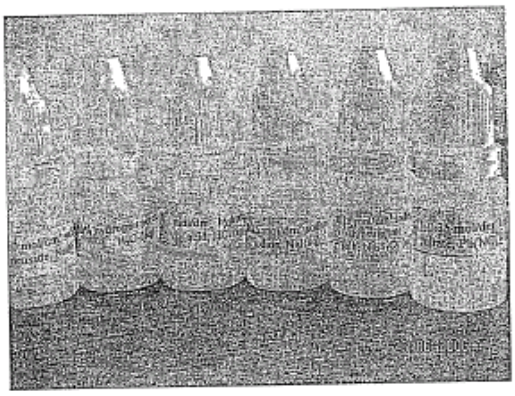
c) An Experimental Set-up using the RADMASTE Advanced Microchemistry Kit

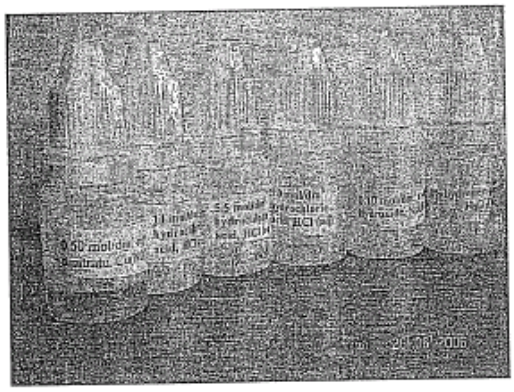
d) Chemistry kit distributed by At Home Science

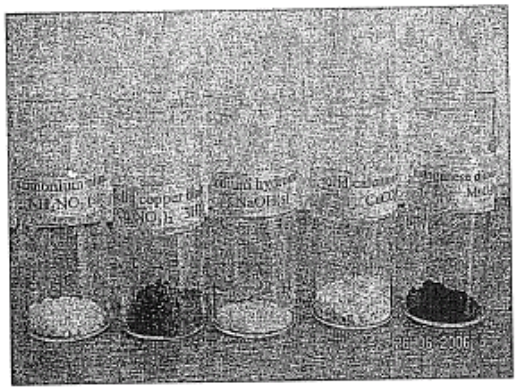
COMPONENTS OF THE RADMASTE ADVANCED MICROCHEMISTRY KIT



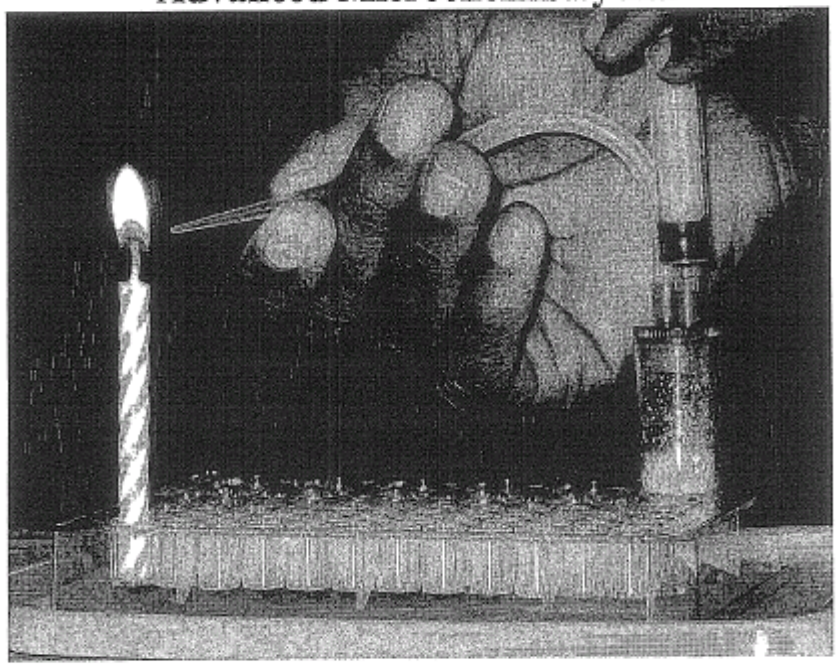
CHEMICALS USED BY THE STUDENTS AT HOME







An Experimental Set-up using the RADMASTE Advanced Microchemistry Kit



Chemistry kit distributed by At home Science

APPENDIX B

Letter to the Mpumalanga Department of Education to obtain Permission to conduct Research

6 April 2005

Attention: Mr Mashaba
Head of Department
Mpumalanga Depart of Education

Re: Application to conduct research using educators from the Mpumalanga area.

My name is Bina Akoobhai. I am currently working at RADMASTE Centre, Wits University, Johannesburg. We are involved in running the ACE program in collaboration with the Mpumalanga Department of Education. I am a tutor for the FET Science educators. I am also studying part-time, for a Masters degree in Science Education.

This letter serves as a request to conduct my research using the Mpumalanga Science FET educators that are attending the ACE course. My research involves looking at the problem of providing practical work experience to students(educators) at home. I would like to use the Microscience system developed at RADMASTE Centre to address the problem and see its effect.

I would really appreciate it if you would grant me the permission to carry out the research. If you require any further information please feel free to contact me.

Thank you

Regards

Bina akoobhai
RADMASTE Centre
Wits University
2050
011 717 6070
0725940955
akoobhaib@radmaste.wits.ac.za

APPENDIX C

Letter from the Mpumalanga Department of Education granting Permission to conduct Research

MPUMALANGA PROVINCIAL GOVERNMENT

Building 5
Government Boulevard
Riverside Park
NELSPRUIT
1200
Republic of South Africa

Private Bag X11341
NELSPRUIT
1200
South Africa

Tel. No.: (013) 766 5552
Fax No.: (013) 766 5581

DEPARTMENT OF EDUCATION

Litiko leTemfundvo Umnyango weFundo Departement van Onderwys Umnyango wezeMfundo

Mr CM Mashaba
Acting Head of Department
Tel: 013-7665299

8 June 2005

Bina Akoobhai
RADMASTE Centre
Wits University
2050

011-7176070 / 0725940955

APPLICATION TO CONDUCT RESEARCH USING TEACHERS FROM THE MPUMALANGA AREA

Application for permission to conduct research is hereby acknowledged.

Please be advised that permission to conduct your research have been approved as advised by Ms DD Mashego, Chief Director: Systems & Planning.

Hoping that you would find this in order, and wishing you well with your research.

MR CM MASHABA
ACTING HEAD OF DEPARTMENT

08/06/2005
DATE

APPENDIX D

Letter attached to the Questionnaires stating its purpose

Dear Student

1. The purpose of the questionnaire is two fold:
   a. It is designed to gather information that will help us to improve the course and teaching strategies. It is designed to ascertain teachers' experiences in using the microchemistry kit at home for experiments.
   b. The information gathered will be used for a Masters research project. We feel that this research will be of great benefit to all of us.
2. The information gathered will in no way affect your marks. We ask that your feedback is frank and honest.
3. All information will be confidential and no name will appear in the report findings.
4. Your participation in answering the questionnaire is truly appreciated.
5. If you have any questions regarding the research please feel free to contact Bina Akoobhai (717 – 6070)

APPENDIX E

Indemnity form signed by the students

ACE Indemnity Form

To : ACE Student doing EDUC 181 (Chemical Reactions)

You will be given chemicals to perform experiments at home. The chemicals are under you care. Please keep them under lock and key at all times. DO KEEP THEM AWAY FROM CHILDREN. Behave responsibly and be careful when performing the experiments. Misuse or poor handling of the chemicals should not be practiced. The University of the Witwatersrand will not be held responsible for any accident or damage to property that may occur once you have been given the chemicals.

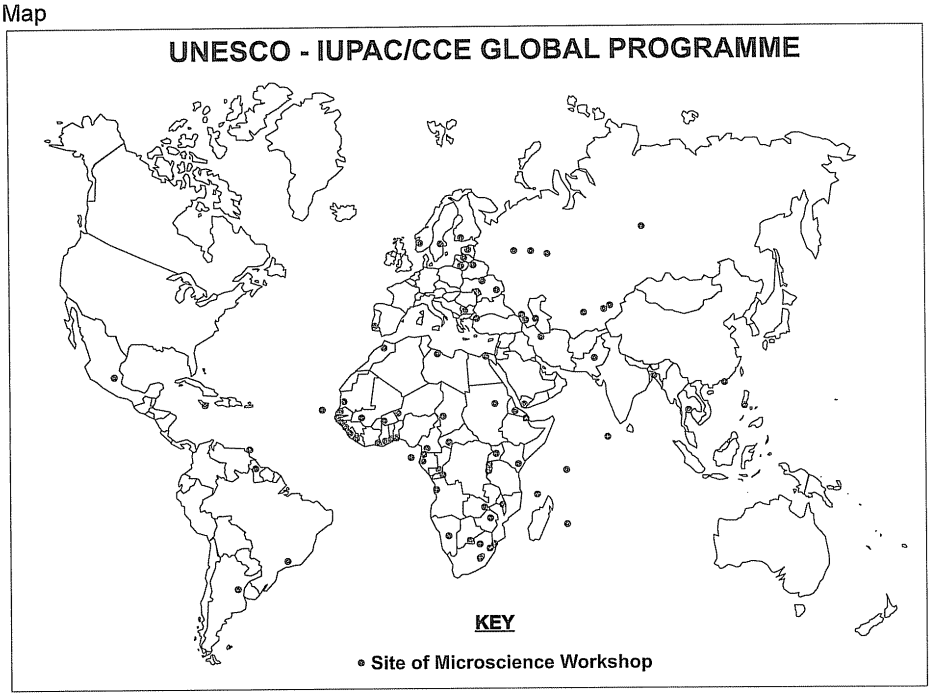
Name: .....
Signature: .....

APPENDIX F

Dissemination of microscience kits worldwide with UNESCO Global Program

GLOBAL USE OF MICROSCIENCE IN SECONDARY SCHOOLS

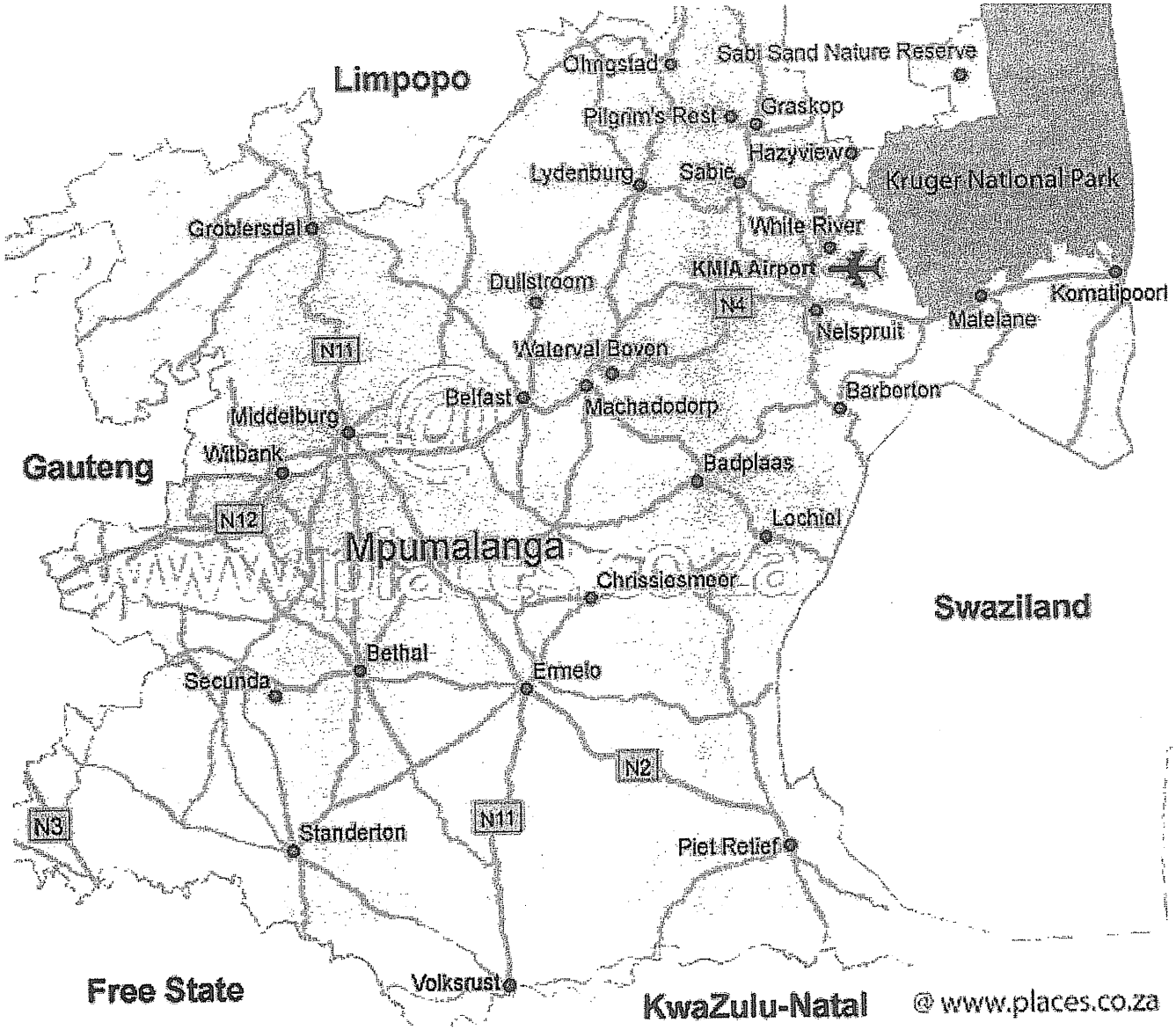
Map



1. **COUNTRIES IN WHICH INTRODUCTORY WORKSHOPS HAVE BEEN HELD**
   Angola, Argentina, Armenia, Azerbaidjan, Bangladesh, Belarus, Benin, Botswana, Brasil, Brunei, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cameroon, Comores, Congo (Brazzaville), Congo (DRC), Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Estonia, Finland, Gabon, Gambia, Georgia, Ghana, Guinea-Bissau, Guinee-Conakry, Guyana, Hong Kong, Iran, Jamaica, Kazakhstan, Kenya, Kyrgyzstan, Latvia, Lesotho, Liberia, Libya, Lithuania, Malawi, Maldives, Mali, Mauritania, Mauritius, Mexico, Moldova, Morocco, Mozambique, Niger, Norway, Pakistan, Philippines, Portugal, Russian Federation (Bashkortostan, Kazan, Russia), Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Sweden, Tadjikistan, Tanzania, Tchad, Thailand, Togo, Trinidad, Turkey, Uganda, Ukraine, Yemen, Zambia, Zimbabwe
   (TOTAL = 77)

APPENDIX G

Map of Mpumalanga Province in South Africa


Limpopo
Ohrigstad
Sabi Sand Nature Reserve
Pilgrim's Rest
Graskop
Hazyview
Lydenburg
Sabie
Kruger National Park
Groblersdal
White River
KMIA Airport
Dullstroom
N4
Komatipoort
Malelane
Nelspruit
N11
Waterval Boven
Belfast
Machadodorp
Barberton
Middelburg
Witbank
Gauteng
Badplaas
N12
Lochiel
Mpumalanga
Chrissiesmeer
Swaziland
Bethal
Secunda
Ermelo
N2
N3
N11
Standerton
Piet Retief
Free State
Volksrust
KwaZulu-Natal
@ www.places.co.za

APPENDIX H

Practical Manual

ADVANCED CERTIFICATE IN EDUCATION (SCIENCE)

Chemical Reactions

[EDUC 181]

Practical Chemistry Manual

2005

RADMASTE & THE SCHOOL OF EDUCATION
UNIVERSITY OF THE WITWATERSRAND,
Johannesburg

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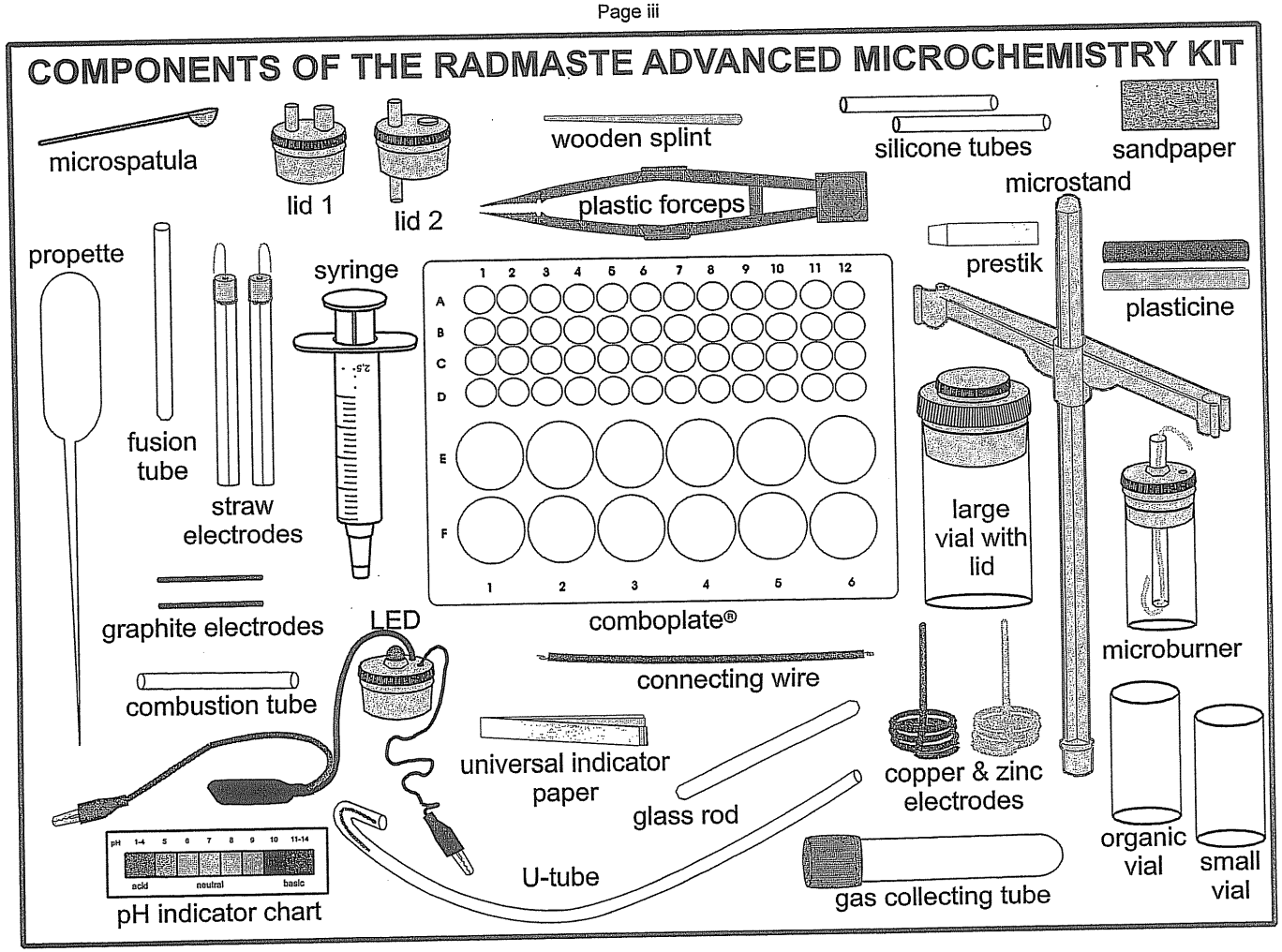
COMPONENTS OF THE RADMASTE ADVANCED MICROCHEMISTRY KIT



CHEMICAL REACTIONS

HINTS AND SAFETY PRECAUTIONS

Welcome to the Practical Chemistry Manual for EDUC 181: CHEMICAL REACTIONS. This document has been prepared to allow you to perform the necessary practical chemistry activities that are related to the topics covered in your course workbook. You will be able to record your observations and results in this book as you carefully carry out the steps for each activity.

You will receive the required chemicals at the same time as this practical manual is made available to you. You must also read the REQUIREMENTS section for each experiment, as some of the chemicals (like methylated spirits) are not provided. You will have to collect the items marked with an asterisk * yourselves.

It is important for you to read the following few pages on HINTS AND SAFETY PRECAUTIONS before you begin the practical work. They will provide you with valuable information to help you look after your microchemistry kit, and to enable you to safely perform practical chemistry activities in the comfort of your home or classroom.

ASSEMBLING THE MICROBURNER

The microburner is needed for Experiment 5, Part 2 of the Practical Chemistry Manual. Once the microburner has been assembled, it is not necessary to take it apart again. However, remember to pour out any methylated spirits (back into the bottle) that may remain inside the microburner, before packing your kit away.

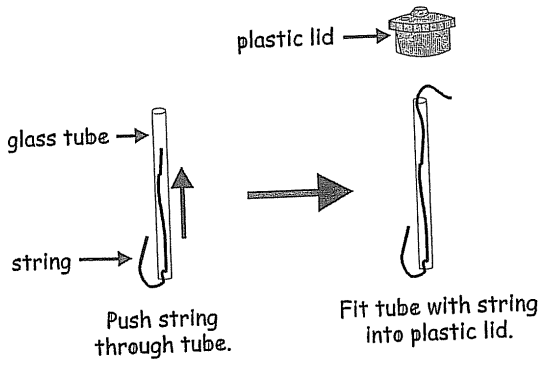
How to Assemble a Microburner:

The items needed to construct the microburner are provided in the kit. They are:

- A plastic sample vial.
- A plastic lid with a large hole in the centre of the lid and a smaller hole at the edge.
- A piece of string (8 - 10 cm long).
- A glass tube (4 mm x 5 cm).
- Methylated spirits (you need to obtain this yourself)

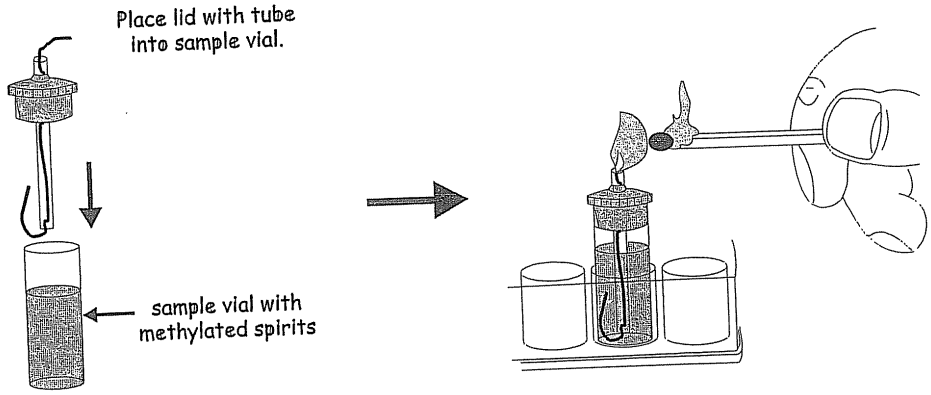
Step 1:
Push the piece of string through the glass tube so that a short length of string projects out of one end of the tube, and a longer piece extends out of the other end.

Step 2:
Remove the plastic lid from the sample vial. Fit the glass tube with string into the large hole in the centre of the plastic lid. The short length of string should protrude at the upper end of the tube.



Step 3:
Half fill the sample vial with methylated spirits.

Step 4:
Replace the lid, being careful to hold the string so that just a small length remains protruding out the top. Wait a few minutes to allow the methylated spirits to soak the string. Light the microburner by placing a lighted match at the exposed bit of string.



Step 5:
Blow the flame out when you have finished using the microburner.

CARE OF THE COMBOPLATE®

Generally, the comboplate® is resistant to dilute acids and bases, aqueous solutions of salts, saturated hydrocarbons, oils, greases, fats and most alcohols. The comboplate® is not resistant to very concentrated inorganic acids (except hydrochloric acid), aromatic and chlorinated hydrocarbons, esters, ketones, tetrahydrofuran (THF), toluene and dimethylformamide. The best general practice is to rinse the comboplate with water as soon as an experiment is finished.

The wells of the comboplate® can be cleaned in a number of ways:

a) Hold the comboplate under running tap water. This rinses the wells free of chemical residue.

b) Place the comboplate in a container with tap water. (The water should be sufficient to cover the wells.) Allow the wells to soak until clean.

c) If a precipitate has settled in a well, roll up a piece of tissue paper, wet it, then push it into the well. Twist the tissue paper around in the well a few times until the precipitate has been wiped off completely.

d) If available, a cotton bud or pipe cleaner can be used to remove a residue from a well. Similarly, a small piece of cotton wool can be twirled around the pointed end of a wooden skewer, moistened with water and used to clean the well. A particularly stubborn residue can be removed by soaking the cotton bud or cotton wool in concentrated hydrochloric acid before wiping.

e) If a precipitate remains lodged in a well, the comboplate can be flushed out with boiling water. (This is particularly helpful for Experiment 1, to remove a lead iodide precipitate that has not been immediately washed out of a well.)

f) If the well is still stained even after following e), use a thin stemmed propette to add a sufficient number of drops of 11 M hydrochloric acid to the affected well to cover the stain. Soak the well until the stain disappears, but avoid prolonged soaking as the acid may also stain the well.

CARE OF THE PROPETTES

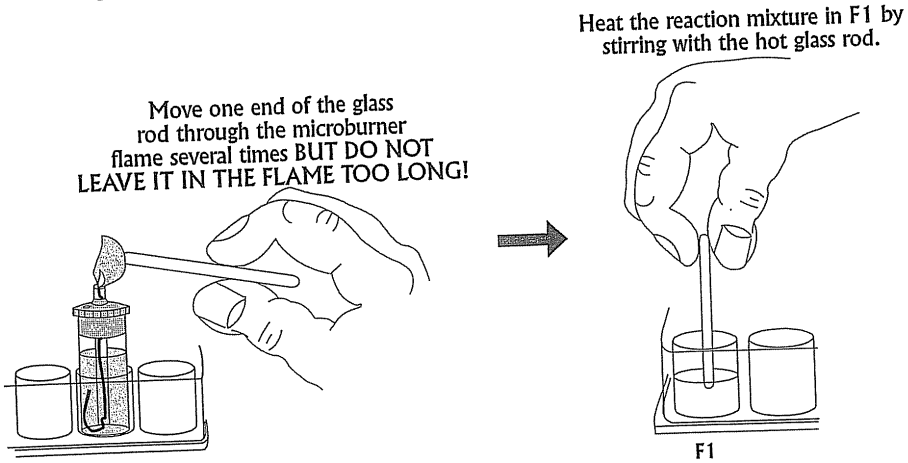
A propette can be mildly heated by immersing the bulb with contents in warm water. *If a propette is heated with a direct flame, it will melt.* Similarly, the propette bulb and contents can be cooled down by immersing in cold or ice water.

Do not use the propette to store organic solvents (such as acetone, hexane, etc.) as it will be dissolved by these. Similarly do not store concentrated sulphuric acid or other corrosive chemicals in the propettes. Propettes are chemically resistant to dilute acids and bases, aqueous solutions of salts, etc. Concentrated hydrochloric acid can safely be used in the propettes.

If a propette becomes excessively hot or begins to collapse inwards as if it is being dissolved, or discolours dramatically when a particular chemical is sucked into it, these are indications that the chemical is destroying the propette. As a precaution, dispose of the relevant chemical and note it so as not to use it in a propette again. Dispose of the propette only if it is not reusable.

USING THE GLASS ROD

A glass rod of PYREX has high thermal resistance and can withstand temperatures of up to 820°C without melting or bending. It can be used for virtually all organic and inorganic chemicals. The rod is used for stirring solutions in the wells of the comboplate®. It can also be passed through the flame of the microburner. The hot rod is then inserted into a well to heat a solution in the well. Similarly, the rod can be cooled using ice or ice water to cool down a solution in a well.



A glass rod usually breaks when dropped onto the floor from a height. Most glass manufacturers supply this kind of rod in various lengths.

USING THE MICROSPATULAS

Each kit contains 8 plastic microspatulas, all of which are connected to a central piece of plastic. To remove a microspatula, break the joining at the narrow end of the microspatula by pulling the spatula away from the piece of plastic. Each microspatula has a spooned end and a narrow end, emulating a conventional spatula. The "spoon" is used to add uniform quantities of solid chemicals to a well in the comboplate®. The narrow end is used when small quantities of solid chemicals are needed, especially when the chemical needs to be inserted into a narrow glass tube. The narrow end can also be used to stir mixtures or solutions in a well.

SAFETY PRECAUTIONS

Please read the following safety precautions and keep them in mind whenever you conduct practical chemistry work, whether on your own or with learners in the classroom. The issue of safety and taking safety precautions does not only apply to practical work carried out with the microchemistry kits. It is something that you must always practise when performing any kind of practical work that involves the use of chemicals, even household chemicals.

Some of the precautions listed here are general in nature, while others are specific for the experiments contained in Parts 1 and 2 of this manual.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. For bases, always have a dilute solution of boric acid close by to apply to the injury. This will help neutralise the base in the eye. The patient should be referred to a doctor.

Never abuse matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

Be careful not to burn yourself when working with the microburner and hot rod. Do not allow the hot rod or flame of the burner to touch the comboplate®, as this will melt the plastic. Ensure that all burners are extinguished when not in use.

Lead solutions and lead salts are poisonous. Avoid contact with these, and dispose of the precipitates in a waste jar.

Hydrogen peroxide is corrosive, and is a bleaching agent. If any solution is spilt on the skin or fabric, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing hydrogen peroxide upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye under running water.

Calcium carbonate may be harmful if ingested or absorbed by the skin. Wash your hands thoroughly with soap and water after handling this chemical.

Hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Methylated spirits is poisonous. Do not inhale the vapour or drink the liquid.

CHEMICAL REACTIONS

EXPERIMENT 1
INVESTIGATING REACTION STOICHIOMETRY

1.1 FOCUS QUESTION

How does the reaction stoichiometry, as shown in a balanced reaction equation, relate to the optimum amounts of reactants to be used in a reaction mixture?

Answer the question once you have completed the experiment.

_____

_____

_____

_____

1.2 REQUIREMENTS

APPARATUS	CHEMICALS
2 x thin stemmed propettes 1 x comboplate® 1 x RADMASTE stencil	0.25 mol dm^{-3} aqueous solution of lead dinitrate, $Pb(NO_3)_2(aq)$ 0.25 mol dm^{-3} aqueous solution of sodium iodide, $NaI(aq)$

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1.3 PROCEDURE AND OBSERVATIONS

1. Answer Questions A and B.

2. Put drops of lead dinitrate solution into the wells of the comboplate, as shown in the table below.

Well	A1	A2	A3	A4	A5	A6	A7	A8
Drops $Pb(N0_3)_2(aq)$	1	2	3	4	5	6	7	8

3. Put drops of sodium iodide solution into the same wells of the comboplate as specified in the table below.

Well	A1	A2	A3	A4	A5	A6	A7	A8
Drops NaI(aq)	8	7	6	5	4	3	2	1

4. Answer questions C to M in the QUESTIONS section.

5. Clean the comboplate out thoroughly with hot water.

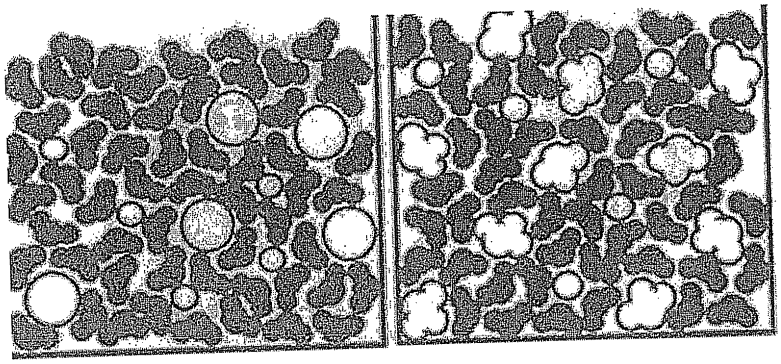
1.4 QUESTIONS

A On the next page are microscopic representations of the two solutions, sodium iodide and lead dinitrate.

Which picture represents the sodium iodide solution? _____

Which picture represents the lead dinitrate solution? _____

Solution (a) **Solution (b)**



The two solutions are at the same concentration. Check that the pictures accurately reflect this.

B The two solutions contain neutral molecules and charged ions. Use your RADMASTE stencil to draw one of each type of ion and molecule in the space below. (The stencil does not have a Pb^{2+} ion. Use the O atom instead, it is approximately the same size.) Name each of these ions and molecules.

_____	_____	_____	_____	_____

Please note that the ions and molecules represented on your stencil are larger than (though in proportion to) those shown in the microscopic representation above. The pictures above were scaled down in order to fit onto the page.

C On the next page is a microscopic representation of a single drop of sodium iodide solution and a single drop of lead dinitrate solution. Look at these pictures, then fill in the table which follows.

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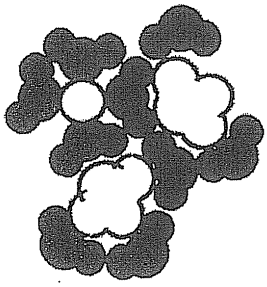
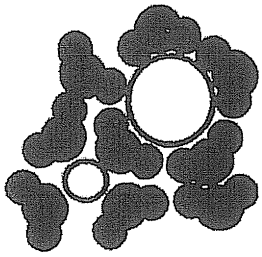
Lead dinitrate



Sodium iodide



Drop of	Number of Molecules / Ions in a Drop				
	Pb^{2+}	$N0_3^-$	Na^+	I^-	H_2O
NaI(aq)					
$Pb(N0_3)_2$(aq)					

D Write down what you see when the sodium iodide solution is added to the lead dinitrate solution.

E Is there a chemical reaction between the lead dinitrate solution and the sodium iodide solution? Explain your answer.

F The word equation for this reaction is:

lead dinitrate(aq) + sodium iodide(aq) → lead diiodide(s) + sodium nitrate(aq)

Write a balanced equation (using chemical formulae) for the reaction.

G Using the information about the composition of a single drop and the balanced reaction equation, fill in the table on the next page. Please note that this is an imaginary exercise, the numbers are not the true numbers.

Well	Number of Ions / Molecules / Formula Units					
	Na^+	I^-	Pb^{2+}	NO_3^-	PbI_2	H_2O
1						
2						
3						
4						
5						
6						
7						
8						

H Look at the comboplate. Which well contains the most solid?

_____

I Is this observation supported by the information you filled in on the table above?

_____

J In the space below is a representation of this well. Use your stencil to draw in the contents of the well. (Hint: Make sure you that you draw the "correct" numbers of ions and molecules. Make sure you represent the phases of the products correctly.)

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K Comment on the ratio of the drops of the two reactant solutions used, when the most solid was produced.

_____

L In the remaining wells, where the maximum solid is not produced, one of the reagents is in excess and the other reagent is limiting. Fill this information in in the table below.

Well	Substance in Excess	Limiting Reagent
1		
2		
3		
4		
5		
6		
7		
8		

M What is the answer to the focus question? Fill this in under the heading 1.1 FOCUS QUESTION at the start of the experiment.

EXPERIMENT 2
CATALYSIS

2.1 FOCUS QUESTION

Which of the following reagents, $NaC\ell(s)$, $Cu(s)$ or $MnO_2(s)$, is a catalyst for the chemical reaction represented below?

$$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$$

Answer the question once you have completed the experiment.

_____

_____

_____

_____

2.2 REQUIREMENTS

APPARATUS	CHEMICALS
1 x thin stemmed propette 1 x comboplate® 3 x plastic microspatulas	Sodium chloride, $NaC\ell(s)$ Copper powder, $Cu(s)$ Fresh 10 % hydrogen peroxide solution, $H_2O_2(aq)$ manganese dioxide powder, $MnO_2(s)$

Note The hydrogen peroxide solution should preferably be fresh, otherwise the desired results will not be obtained.

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2.3 PROCEDURE AND OBSERVATIONS

1. Add 15 drops of the 10% solution of hydrogen peroxide into each of wells F1, F2 and F3.

2. Answer Question A.

3. Use the narrow end of a plastic microspatula to add one spatula of sodium chloride into well F1.

4. Answer Question B.

5. Use the narrow end of another plastic microspatula to add one spatula of copper powder into well F2.

6. Answer Question C.

7. Use the narrow end of another plastic microspatula to add one spatula of manganese dioxide powder into well F3.

8. Answer Question D.

9. Wait till the bubbling in well F3 has stopped. Now add 5 more drops of $H_2O_2(aq)$ to the $NaC\ell(s)$ in well F1.

10. Answer Question E.

11. Use the propette to add 5 more drops of $H_2O_2(aq)$ to the Cu(s) in well F2.

12. Answer Question F.

13. Use the propette to add 5 more drops of $H_2O_2(aq)$ to the $MnO_2(s)$ in well F3.

14. Answer Question G.

15. Clean the comboplate out thoroughly with water.

2.4 QUESTIONS

A Look carefully at the three wells containing the hydrogen peroxide. What do you observe?

_____

B Look carefully at well F1. What do you observe?

_____

_____

C Look carefully at well F2. What do you observe?

_____

_____

D Look carefully at well F3. What do you observe?

_____

_____

E What happens when more $H_2O_2(aq)$ is added to F1?

_____

F What happens when more $H_2O_2(aq)$ is added to F2?

_____

G What happens when more $H_2O_2(aq)$ is added to F3?

_____

H What is the answer to the focus question? Fill this in under the heading 2.1 FOCUS QUESTION at the start of the experiment.

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EXPERIMENT 3
FACTORS AFFECTING THE RATE OF A HETEROGENEOUS REACTION

3.1 FOCUS QUESTION

List three ways in which the rate of the following reaction can be increased,

$$CaCO_3(s) + 2HC\ell(aq) \rightarrow CO_2(g) + H_2O(\ell) + CaC\ell_2(aq)$$

Answer the question once you have completed the experiment.

_____

_____

_____

_____

3.2 REQUIREMENTS

APPARATUS	CHEMICALS
6 x thin stemmed propettes 1 x comboplate® 1 x plastic microspatula	5.5 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ 0.1 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ 1.0 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ 11 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ solid calcium carbonate lumps, $CaCO_3(s)$ solid calcium carbonate powder, $CaCO_3(s)$ room temperature tap water* ice-cold tap water* boiling tap water*

Note The items marked with an asterisk (*) are not supplied in the equipment kit.

3.3 PROCEDURE AND OBSERVATIONS

1. Remove one medium-sized lump of calcium carbonate from the storage bottle with a microspatula. Place the lump into well F1.

2. Add two level spatulas of calcium carbonate powder into well F2, using the spooned end of the plastic microspatula. Spread the powder around so that there are no clumps of powder in one area of the well.

Note

The lumps of calcium carbonate are not always uniform in size. If you use a small calcium carbonate lump in well F1, you may need only one spatula of calcium carbonate powder in well F2 for a proper comparison to be made. Alternatively, if the calcium carbonate lump is large, you may need to increase the amount of powder used in well F2. A large lump may be broken into smaller pieces with a hard object, but do not try to break the lumps in the comboplate® as they are very hard and will crack the plastic.

3. Add 15 drops of water into each of wells F1 and F2 with a clean propette. When adding the water to well F1 do not drop the water directly onto the lump of solid, otherwise the lump may break up. Try to keep it in the lump form too when hydrochloric acid is added in the next step.

4. Use a second propette to add 5 drops of 5.5 mol dm^{-3} hydrochloric acid into wells F1 and F2. Add the 5.5 mol dm^{-3} hydrochloric acid to the water in well F1 and not on top of the lump of solid calcium carbonate.

5. Answer Questions A to C.

6. Use the spooned end of the plastic microspatula to add 1 level spatula of calcium carbonate powder into each of wells F3, F4 and F5. Spread the powder around to break up any clumps.

7. Use a propette to add 15 drops of water into each of wells F3, F4 and F5.

8. Fill a propette with 0.1 mol dm^{-3} hydrochloric acid. Fill another propette with 1.0 mol dm^{-3} hydrochloric acid and a third propette with 11 mol dm^{-3} hydrochloric acid.

9. Line the propettes up in order from lowest concentration to highest concentration

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10. Add 5 drops of 0.1 mol dm^{-3} hydrochloric acid into well F3, 5 drops of 1.0 mol dm^{-3} hydrochloric acid into well F4 and 5 drops of 11 M hydrochloric acid into well F5.

Note: Try to perform this step quickly so that a good comparison of reaction rate can be made from one concentration of hydrochloric acid to the next.

11. Answer Questions D to F.

12. Use the spooned end of the plastic microspatula to add 1 level spatula of calcium carbonate powder into each of wells E1, E2 and E3.

13. Use a propette to dispense 15 drops of ice-cold water into well E1.

14. Use another propette to dispense 15 drops of room temperature water into well E2.

15. Use another propette to dispense 15 drops of boiling-hot water into well E3.

16. Use another propette to dispense 5 drops of 5.5 mol dm^{-3} hydrochloric acid into each of wells E1, E2 and E3.

17. Answer Questions G to J.

18. Clean the comboplate out thoroughly with water.

3.4 QUESTIONS

A What can be observed in wells F1 and F2?

_____

_____

_____

B In which well would you say the reaction is going faster?

_____

_____

C How does the state of subdivision of a solid reactant affect the rate of a heterogeneous chemical reaction?

D What can be observed in wells F3, F4 and F5?

E Arrange the three wells in increasing order of rate of reaction (from slowest to fastest).

F How does the concentration of a reactant affect the rate of a heterogeneous chemical reaction?

G What can be observed in wells E1, E2 and E3?

H Arrange the three wells in increasing order of rate of reaction (from slowest to fastest).

I How does the temperature of the reactants affect the rate of a heterogeneous chemical reaction?

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J What is the answer to the focus question? Fill this in under the heading 3.1 FOCUS QUESTION at the start of the experiment.

EXPERIMENT 4
THE EFFECT OF THE CONCENTRATION OF THE REACTANTS ON THE RATE OF A REACTION

4.1 FOCUS QUESTION

How does increasing the concentration of a reactant affect the rate of a reaction?

Answer the question once you have completed the experiment.

_____

_____

_____

_____

4.2 REQUIREMENTS

APPARATUS	CHEMICALS
3 x thin stemmed propettes 1 x comboplate® 1 x white paper* 1 x watch or stop-watch*	0.15 mol dm^{-3} sodium thiosulphate solution, $NaS_2O_3(aq)$ 11 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ tap water*

Note

1. Any item marked with an asterisk (*) is not supplied in the equipment kit.
2. If any acid is spilt on your skin, then thoroughly wash your skin immediately.

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4.3 PROCEDURE AND OBSERVATIONS

1. Answer Question A.

2. Place the comboplate, with well A1 at the top-left position, on a white piece of paper.

3. Take one propette containing the thiosulphate solution and another propette containing tap water. Use the propettes to dispense the liquids into wells A1 to A8 as specified in the table below.

Drops of Solution	Well							
	A1	A2	A3	A4	A5	A6	A7	A8
$Na_2S_2O_3(aq)$	1	2	3	4	5	6	7	8
$H_2O(\ell)$	7	6	5	4	3	2	1	0

4. Use a pen or pencil to draw a small, dark cross on the white paper. Place well A1 of the comboplate over the cross. You should be able to see the cross beneath well A1 when you look at the comboplate from directly above.

5. Use a clean propette to add 5 drops of 11 mol dm^{-3} $HC\ell(aq)$ to well A1. The moment the last drop is added, start the stop-watch (or note the time on your watch).

6. Stop the stop-watch when the cross on the paper is no longer visible when looking at well A1 from above. It may take a long time for anything to happen, so work on something else while you wait!

7. Answer Question B.

8. Repeat steps 5 to 7 for wells A2 to A8. Watch carefully to see when the cross is no longer visible.

9. Answer Questions C to I.

10. Clean the comboplate out thoroughly with water.

4.4 QUESTIONS

A Sodium thiosulphate reacts with hydrochloric acid according to the following unbalanced reaction equation,

$$Na_2S_2O_3(aq) + HC\ell(aq) \rightarrow NaC\ell(aq) + S_8(s) + SO_2(g) + H_2O(\ell)$$

Balance the reaction equation.

B Fill in the table below.

Well Number	Drops $Na_2S_2O_3(aq)$	Time (s)	1/Time (s^{-1})
1	1		
2	2		
3	3		
4	4		
5	5		
6	6		
7	7		
8	8		

C When sodium thiosulphate and hydrochloric acid are mixed together, the clear colourless liquid turns milky. Why?

D We can measure the rate of a reaction in terms of "the time taken to use up a certain amount of reactant", or "the time taken to form a certain amount of product". Which measurement are we making in this experiment? Explain your answer.

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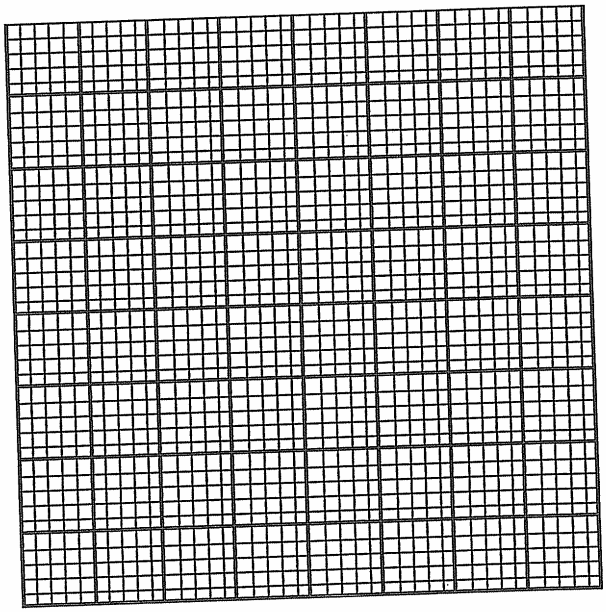
E Arrange the eight wells in increasing order of concentration of sodium thiosulphate in the solution.

_____

F Arrange the eight wells in increasing order of rate of reaction.

_____

G On the graph paper below, plot a graph of rate of reaction (in $seconds^{-1}$) versus concentration of thiosulphate (in drops of sodium thiosulphate).



H Describe the shape of the graph.

_____

_____

I What is the answer to the focus question? Fill this in under the heading 4.1 FOCUS QUESTION at the start of the experiment.

_____

EXPERIMENT 5
LE CHATELIER'S PRINCIPLE: CHANGING THE TEMPERATURE OF THE SYSTEM

5.1 FOCUS QUESTION

How does changing the temperature of a reaction mixture affect a chemical equilibrium?

Answer the question once you have completed the experiment.

_____

_____

_____

_____

5.2 REQUIREMENTS

APPARATUS	CHEMICALS
2 x thin stemmed propettes 1 x comboplate® 1 x plastic microspatula 1 x glass rod 1 x microburner 1 x box of matches	solid copper dinitrate, $Cu(N0_3)_2.3H_2O(s)$ 11 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ room temperature tap water* ice-cold tap water* methylated spirits*

Note

1. The items marked with an asterisk (*) are not supplied in the equipment kit.
2. If any acid is spilt on your skin, then thoroughly wash your skin immediately. Methylated spirits (in the microburner) is poisonous. Do not inhale or drink it.
3. Do not touch the surface of the comboplate with the heated glass rod. It will melt the plastic.

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5.3 PROCEDURE AND OBSERVATIONS

1. Use the narrow end of a plastic microspatula to place 3 spatulas of solid copper dinitrate into each of wells A1 and A2.

2. Use a propette to dispense 11 drops of water into well A1. Use the tip of the spatula to stir until all the solid copper dinitrate has dissolved in the water.

3. Answer Questions A to C.

4. Use the same propette to dispense 6 drops of water into well A2. Use the tip of the spatula to stir until all the solid copper dinitrate has dissolved in the water.

5. Use a second propette to dispense 5 drops of 11 mol dm^{-3} hydrochloric acid into well A2.

6. Answer Questions D to F.

7. Light the microbumer.

8. Pass the glass rod through the flame of the microburner 4 times. Immediately dip the heated end of the glass rod into well A1. Leave the rod in the well for thirty seconds.

9. Answer Question G.

10. Clean the glass rod with a paper towel.

11. Repeat step 8, this time placing the hot glass rod in well A2 for thirty seconds.

12. Answer Question H.

13. Clean the glass rod with a paper towel, then place it in a container of iced water for approximately one minute.

14. Dip the cold glass rod into well A1. Leave for about two minutes.

15. Answer Question I.

16. Repeat steps 13 and 14 , this time placing the cold glass rod in well A2.

17. Answer Questions J to M.

18. Clean the comboplate out thoroughly with water.

5.4 QUESTIONS

A What is the colour of the aqueous copper dinitrate solution, in well Al?

B Write a balanced reaction equation to represent the dissolution of copper dinitrate in water.

C Which ion is responsible for the colour of the solution in well Al?

D What is the colour of the aqueous copper dinitrate solution, after hydrochloric acid has been added to it, in well A2?

E We are investigating the following chemical equilibrium,

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell) \qquad \Delta H > 0$$

Which ion is responsible for the colour of the solution in well A2?

F Is the above reaction exothermic or endothermic?

G What happens to the colour of the solution in well A1 when a hot glass rod is immersed in it?

H What happens to the colour of the solution in well A2 when a hot glass rod is immersed in it?

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I What happens to the colour of the solution in well A1 when a cold glass rod is immersed in it?

J What happens to the colour of the solution in well A2 when a cold glass rod is immersed in it?

K Use Le Chatelier's principle to explain why the solution in well A2 changes colour when it is heated.

L Use Le Chatelier's principle to explain why the solution in well A2 changes colour when it is cooled.

M Why does the solution in well A1 not change colour when it is heated or cooled?

N What is the answer to the focus question? Fill this in under the heading 5.1 FOCUS QUESTION at the start of the experiment.

EXPERIMENT 6
LE CHATELIER'S PRINCIPLE: CHANGING THE REACTANTS CONCENTRATION

6.1 FOCUS QUESTION

How does changing the concentration of the reactants affect a chemical equilibrium?

Answer the question once you have completed the experiment.

_____

_____

_____

_____

6.2 REQUIREMENTS

APPARATUS	CHEMICALS
2 x thin stemmed propettes 1 x comboplate® 1 x plastic microspatula	solid copper dinitrate, $Cu(NO_3)_2.3H_2O(s)$ 11 mol dm^{-3} hydrochloric acid, $HC\ell(aq)$ tap water*

Note

1. The items marked with an asterisk (*) are not supplied in the equipment kit.
2. If any acid is spilt on your skin, then thoroughly wash your skin immediately.

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6.3 PROCEDURE AND OBSERVATIONS

1. Using the narrow end of a plastic microspatula, place 3 spatulas of solid copper dinitrate into each of wells A1 and A2.

2. Use the propette to dispense 6 drops of water into both wells. Use the tip of the spatula to stir until all the solid copper dinitrate has dissolved in the water in both wells.

3. Answer Questions A and B.

4. Dispense a further 5 drops of water into well A1.

5. Use a second propette to dispense 5 drops of 11 mol dm^{-3} hydrochloric acid into well A2.

6. Answer Questions C to F.

7. Using the first propette again, dispense 6 drops of water into each of wells A1 and A2.

8. Answer Questions G to L.

9. Clean the comboplate out thoroughly with water.

6.4 QUESTIONS

A What is the colour of the aqueous copper dinitrate solution?

_____

B The dissolution of copper dinitrate in water can be represented by the following balanced reaction equation,

$$Cu(NO_3)_2(s) + 4H_2O(\ell) \rightarrow Cu(H_2O)_4^{2+}(aq) + 2NO_3^-(aq)$$

Which ion is responsible for the colour of the solution?

_____

_____

C What happens to the solution in well A2 when hydrochloric acid is added to it?

D We are investigating the following chemical reaction,

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

Which ion is responsible for the colour of the solution in well A2 now?

E Use Le Chatelier's principle to explain why the solution in well A2 changes colour when the hydrochloric acid is added to it.

F Write an equilibrium constant expression for this reaction.

G Describe what happens to the solution in well A2 when water is added to it.

H Water is a solvent here. We thus cannot say that "adding water favours the reverse reaction", since water is always present in excess amounts. Instead we need to look at how adding water affects the concentration of the reactant and product molecules. Suppose that the concentration of each species is diluted ten fold. Write a reaction quotient expression (an equilibrium constant expression when a system is not at equilibrium) for the reaction now.

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I If the reaction quotient expression is to equal the equilibrium constant expression, then which substance concentrations should increase?

_____

_____

J If the reaction quotient expression is to equal the equilibrium constant expression, then which substance concentrations should decrease?

_____

_____

K Suppose you are given the following reagents,

- nitric acid, $HNO_3(aq)$
- sodium chloride, $NaC\ell(aq)$
- sodium hydroxide, $NaOH(s)$

Which reagent would you add to well A1 to change the colour from blue to yellow/pale green?

_____

L What is the answer to the focus question? Fill this in under the heading 6.1 FOCUS QUESTION at the start of the experiment.

APPENDIX I

Questionnaire on Experiences in using the microchemistry kit at home

Name: .....

Question 1

The question below refers to your experiences in performing experiments at home using the microchemistry kit for the ACE course, Chemical Reactions. Please tick (✓) the appropriate box to show your opinion.

	Strongly Agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly Disagree (5)
a) It was easy to handle					
b) The reactions were DIFFICULT to observe					
c) It was safe to use					
d) Experiments took LOTS of time to complete					
e) The equipment was easy to clean					
f) Instructions were easy to follow for each experiment					
g) The disposing of chemicals was a PROBLEM					
h) It was easy to store the kit					
i) It was easy to care for the kit					
j) It was fun to use the kit					
k) I am keen to do more experiments using the kit					
l) It did NOT HELP to develop my practical skills					
m) It assisted in developing my confidence in practical work					
n) Doing the experiments DID NOT help me understand the chemistry concepts involved					
o) I would NOT like to have to do experiments with other ACE courses					

Question 2

Are there any other points you would like to make or would you like to comment further on the above points? If so, please respond here and if you need more space write on the back.

.....

.....

.....

.....

Question 3

Where did you perform the experiments? Tick (✓) the appropriate box.

In the kitchen	
On the dining room table	
At school	
Other	

If you have chosen other, please specify.

.....

Question 4

Having completed the three experiments, have you lost any components of the kit? If yes, please specify.

.....

.....

Question 5

Do you feel microchemistry kits will be useful for the learners in your classroom? Please justify.

.....

.....

Question 6

What was the impact of using the microchemistry kit in your home, on your family? (If you did your experiments elsewhere, please adapt your answer accordingly.)

.....

.....

Question 7

Did you discuss your experience in using the kit with your friends, colleagues, etc.? If yes, what were their comments?

.....

.....

APPENDIX J

Questionnaire on Attitude towards Practical Work

Pre-Questionnaire for attitude towards practical work.

Name: .....

1. How many years have you been teaching Science at FET level?

   _____

2. Does the school where you teach have a fully functional laboratory?

   _____

3. If yes, do you use demonstration for teaching or do learners carry out their own practical work?

   _____

   _____

4. During your pre -service teacher training course did you do practical work on your own?

   _____

5. If yes, did you do enough to feel competent or not?

   _____

6. Do you feel confident or do you feel nervous about doing practical work? Please tick (✓) the appropriate box to show your opinion.

	Confident	**Nervous**
Yourself		
Demonstration (in front of a class)		
Supervising (your learners are doing it in the class)		

7. Do you feel practical work is essential in learning science? Please tick (✓) the appropriate box to show your opinion. Does it:

	Strongly Agree	**Agree**	**Disagree**
a) Improve conceptual understanding			
b) Improve psychomotor skills			
c) Allow learners to learn process skills of science			
d) Make the learners more confident			
e) Make learners enjoy the subject matter more			
f) Provide learners with life skills related to safe handling of chemicals			

APPENDIX K

Questions for the Interview with Educators

Questions for the interviews with educators

Question 1: *Where did you do the experiments?*

Question 2: *Were you scared or confident about doing the experiments? How did you feel?*

Question 3: *Did you have any spectators. Any comments from them?*

Question 4: *Were the instructions easy to follow?*

Question 5: *Were the reactions easy to observe?*

Question 6: *Was the cleaning of the equipment easy/hard? Where did you clean it?*

Question 7: *Did the experiments help you in understanding concepts (were you able to relate it to theory?)Elaborate*

Question 8: *Some teachers said the experiments took a long time (in the questionnaire). If so, why?*

Question 9: *Would you recommend using the microscience equipment in class with learners?*

Question 10: *Would you recommend it to your colleagues?*

Question 11: *Is it better to do an ACE course with/without practical work. Do you feel* ***it*** *is better with/without practical work integrated with the theory?*

Question 12: *Should the packaging of chemicals be done in bottles or propettes?*

Question 13: *Any other comments?*

APPENDIX L

Questionnaire on what educators learnt from 'at home' Practical activities

Name: .....

The questions below refer to your view on the knowledge, skills and attitude regarding your experience in using the Microchemistry kit at home.

1. **When you performed the experiments at home using the kit, did it assist you in understanding the theory better? For either YES or NO justify your choice.**

---

2. **Compare and contrast your experience in doing the experiments at home and during the contact session.**

---

3. **Did you find that doing the experiments at home was useful in learning concepts? For either YES or NO justify your choice.**

---

4. **Do you feel that using the kit at home aided you in learning practical skills? For either YES or NO justify your choice.**

---

5. **Did doing the experiments at home make you feel more able to understand and affect your environment? For either YES or NO justify your choice.**

---

6. **What is your view on doing practical work for the learning of science concepts?**

---

7. **You did experiments at home and in the contact session for this course. Which experience was more useful, and why?**

---

8. **Do you feel that science experiments should only be performed in a laboratory? For either Yes or No justify your choice.**

---

9. **Did you do the experiments at home as instructed in the workbook after a particular section OR did you do them separately at a later stage? Justify your choice.**

---

10. **Write a paragraph on your experience of using the kit at home.**

THANK YOU

APPENDIX M

Sample of an answered Questionnaire on Attitude towards Practical Work

Post-Questionnaire for attitude towards practical work.

Name:.....

1. How many years have you been teaching Science at FET level?
   Four.

2. Does the school where you teach have a fully functional laboratory?
   No

3. If yes, do you use demonstration for teaching or do learners carry out their own practical work?

4. During your pre -service teacher training course did you do practical work on your own?
   Yes

5. If yes, did you do enough to feel competent or not?
   Enough

6. Do you feel confident or do you feel nervous about doing practical work:

	Confident	Nervous
Yourself	✓	
Demonstration (in front of a class)	✓	
Supervising (your learners are doing it in the class)	✓	

7. Do you feel practical work is essential in learning science?
Does it:

	Strongly Agree	Agree	Disagree
a) Improve conceptual understanding	✓		
b) Improve psychomotor skills	✓		
c) Allow learners to learn process skills of science	✓		
d) Make the learners more confident	✓		
e) Make learners enjoy the subject matter more	✓		
f) Provide learners with life skills related to safe handling of chemicals	✓		

APPENDIX N

Sample of an answered Questionnaire on Experiences in using the Microchemistry kit at home

Name: R. I. P. KOPE

Question 1

The question below refers to your experiences in performing experiments at home using the microchemistry kit for the ACE course, Chemical Reactions. Please tick (✓) the appropriate box to show your opinion.

	Strongly Agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly Disagree (5)
a) It was easy to handle					✓
b) The reactions were DIFFICULT to observe			✓		
c) It was safe to use		✓			
d) Experiments took LOTS of time to complete	✓				
e) The equipment was easy to clean				✓	
f) Instructions were easy to follow for each experiment				✓	
g) The disposing of chemicals was a PROBLEM		✓			
h) It was easy to store the kit	✓				
i) It was easy to care for the kit	✓				
j) It was fun to use the kit	✓				
k) I am keen to do more experiments using the kit	✓				
l) It did NOT HELP to develop my practical skills				✓	
m) It assisted in developing my confidence in practical work				✓	
n) Doing the experiments DID NOT help me understand the chemistry concepts involved				✓	
o) I would NOT like to have to do experiments with other ACE courses				✓	

Question 2

Are there any other points you would like to make or would you like to comment further on the above points? If so, please respond here and if you need more space write on the back.

The redwater kit is handy to use but too small and fragile. You can't use them without breaking any of them and they are also too small to use by learners

Question 3

Where did you perform the experiments? Tick (✓) the appropriate box.

In the kitchen	✓
On the dining room table	
At school	
Other	

If you have chosen other, please specify.

at the bedroom for from children at home

Question 4

Having completed the three experiments, have you lost any components of the kit?

If yes, please specify.

Spatula

Question 5

Do you feel microchemistry kits will be useful for the learners in your classroom? Please justify. No, too small to be used

Question 6

What was the impact of using the microchemistry kit in your home, on your family?
(If you did your experiments elsewhere, please adapt your answer accordingly.)

Because of too little time at school and too much work.

Question 7

Did you discuss your experience in using the kit with your friends, colleagues, etc.?
If yes, what were their comments?

They complained that they are too small to be used by learners but handy

APPENDIX O

Sample of an answered Questionnaire on what educators learnt from 'at home' practical activities

Name: .....

The questions below refer to your view on the knowledge, skills and attitude regarding your experience in using the Microchemistry kit at home.

1. **When you performed the experiments at home using the kit, did it assist you in understanding the theory better? For either YES or NO justify your choice.**

YES, hands-on experience helped me to become familiar with the kit.

2. **Compare and contrast your experience in doing the experiments at home and during the contact session.**

No contrast, only that the chemicals evaporated and I had to use alternative chemicals which I asked from neighbouring schools

3. **Did you find that doing the experiments at home was useful in learning concepts? For either YES or NO justify your choice.**

Yes, it complemented my knowledge with doing the practicals

4. **Do you feel that using the kit at home aided you in learning practical skills? For either YES or NO justify your choice.**

YES, because I was alone by myself and I succeeded in doing it.

5. **Did doing the experiments at home make you feel more able to understand and affect your environment? For either YES or NO justify your choice.**

YES, because I was able to move from meso to meso.

6. **What is your view on doing practical work for the learning of science concepts?**

It is the most essential part in Science for doing practicals.

7. **You did experiments at home and in the contact session for this course. Which experience was more useful, and why?**

Contact session because we had to share ideas with colleagues.

8. **Do you feel that science experiments should only be performed in a laboratory? For either Yes or No justify your choice.**

No, because not every ~~shoot~~ school has the benefit of a laboratory.

9. **Did you do the experiments at home as instructed in the workbook after a particular section OR did you do them separately at a later stage? Justify your choice.**

I did them at home as instructed in the workbook, because in that case the environment was conducive and I had all the time to myself.

10. **Write a paragraph on your experience of using the kit at home.**

I found it very useful and interesting because I, at home, I have all the time to work and the particular environment and helps me to prepared ~~than~~ perfectly for my lessons at school.

THANK YOU

APPENDIX P

Categorisation of the responses to the Questionnaire on what educators learnt from 'at-home' practical activities

K = knowledge, S = Skills, A = Attitudes

1. **When you performed the experiments at home using the kit, did it assist you in understanding the theory better? For either YES or NO justify your choice. (25)K**

YES:21(84%)

Coding:

1- direct reference to theory (43%)

2 – in-direct reference to theory (14)

3- psychomotor skills(19)

4- affective domain(5)

5 – related to the kit (19)

1) easy to understand the theory and explanation based on observation using the microchemistry kit(2)

1) I could do it when I understood the theory to consolidate my understanding (2)

1) I could repeat the experiment if I did not understand something (2)

1)-observe what exactly happens (as read in theory)(3)

2) I was able to gain knowledge of certain processes (2)

2) enhance learning

3)Its easier to remember if you have done something especially with your hands(4)

4)I gained confidence by doing it on my own

5) helped me to become familiar with the kit(2)

5)The kit is easy to use at home, can be accommodated on a small table (2)

NO:4(16%)

- I have many misconceptions which need to be cleared. It is better at the contact session where the tutor can help to clear misconceptions
- I was not sure if what I was doing was correct (3)

2. **Compare and contrast your experience in doing the experiments at home and during the contact session.(25)**

Contact session	**Home**
Easy-we can help each other(3)	I am now able to do it at home
Work in group so other can assist you	If you make a mistake, nobody to assist you (3)
We can share ideas(3)	Have time to interact with the material (4)
	Can gain experience in using the kit
I could watch someone else doing the experiment	I had to do the experiments on my own
Share ideas, better understanding but not enough time (3)	Gain experience
Easy as we shared ideas	I was on my own had to figure out things on my own (4)
	It is good but time consuming (2)
If you stuck, fellow students can help you (2)	Nobody to help you (2)
You get extra information	Struggle to find information
Tutor came to the rescue if I did not understand	I get confused(3)
Students who are intelligent do things fast and leave the slow learners behind	

3. **Did you find that doing the experiments at home was useful in learning concepts? For either YES or NO justify your choice. (23) K**

Yes: 22(96%)

Coding:

1- direct link to concepts(36%)

2 – indirect link to concepts(27)

3- related to time(14)

4 – related to practical skill(9)

5 – no reason given (14)

1) I studied the concepts before and after doing the experiment, especially after I got the results

1) The concepts can be verified as you are doing the expts at the same time – not at a later stage(3)

1) Better understanding of concepts start with observation(4)

2) Get chance to apply your investigation(3)

2) It complemented my knowledge with doing the practicals (2).

2) I could go between theory and practical

3) I had more time

3) Working at your own pace (2)

4) One gets to learn different skills (2)

5) No reason given(3)

Did not answer yes or No -1(4%)

4. **Do you feel that using the kit at home aided you in learning practical skills? For either YES or NO justify your choice. (25)S**

   YES:23(92%)

   Coding:

   1 – direct link to practical skills(48%)

   2 – in-direct link to practical skills (30)

   3- linked to confidence (13)

   4 – linked to time(9)

1) I had to handle and manipulate all the equipment and materials myself (3)

1) I was able to set up the experiment as per instruction(3)

1) It helps to practice different skills(3)

1) the skills are portable using the kit(2)

2) I had experience of touching the kit and mixing the chemicals(3)

2) Coming from a disadvantaged school I have not done any experiment before but now I can using the kit

2) I was alone and I succeeded in doing it (2)

2) I will be able to demonstrate for my class

3) I worked independently and tried until I got it right. It boosted my self-esteem and confidence.

3) using it in the contact session, I had an idea how to proceed and gained confidence as I did more expts.(2)

4) I had enough time to set up the experiment(2)

NO: 2(8%)

Coding:

1)Linked to no assistance at home (100%)

1)Because sometime I did not know what to do but I tried.

1)when you confused there is nobody to help you

5. **Did doing the experiments at home make you feel more able to understand and affect your environment? For either YES or NO justify your choice. (25)A**

Yes:21(84%)

Coding:

1- link to positive attitude towards science (52%)

2- Linked to direct environment of performing the experiments (33)

3- No comment (15)

1) I felt more confident and wanted to do practical work in my class(2)

1) I was able to move from micro to macro

1) It made me understand the science concepts better

1) Working at home using chemicals encourages interest(2)

1) Before I thought experiments can only be done in a laboratory or open space(3)

1) I have gained knowledge and skills which I can teach my learners(2)

2) I was asked to explain what I was doing by my neighbour

2) I could easily control the conditions when doing the experiment(2)

2) If I had a problem I had to find a solution by myself(2)

2) It was difficult to do some expts. I had to use trial and error

2) I had to wash the kit at home

3) No comment (3)

NO:4(16%)

no comment (4)

6. **What is your view on doing practical work for the learning of science concepts? (28,more than 1 reason given)K**

Coding:

1- Linked to understanding and learning of science concepts (misconceptions)(68%)

2- linked to observation and doing (18)

3- Linked to reasoning(3)

4- Linked to time(3)

5- Linked to interest(8)

1) It can be use to introduce science concepts(3)

1) Makes me understand the science concepts and also understand their effect. Makes my teaching at school simple

1) use it first to enhance learning

1) relate the concepts to practical work(2)

1) It can make you understand concepts clearly(3)

1) It stimulates interest and enhance understanding of science concepts.

1) Can be used to correct misconceptions(3)

1) Makes theory more real. What they are doing practically is common in real life.

1) It is better than just explanation of concepts which is abstract

1) practical is to prove the theory so the learners will understand the theory better(2)

1) should form basis of introducing any concept in science

2) something which you have done practically lasts longer in memory

2) observing something happening- they bound not to forget-It is most essential part in Science(2)

2) It is essential as science is about finding how things happen and why they happen that way(2)

3) It provides an opportunity to apply reasoning

4) It is good though time-consuming

5) increase interest in science (2)

7. **You did experiments at home and in the contact session for this course. Which experience was more useful, and why? (25)**

at CS: 7(28%)

- we shared ideas with colleagues(6)

-assist each other

Home:17(68%)

Coding:

1- Linked to confidence and interest to do practical work (65%)

2- Linked to involvement (6)

3- Linked to time (29)

1) I had to figure it out on my own. I felt confident afterwards(2)

1) Now I can do expts in front of my class as I have more practice(2)

1) I could think independently(3)

1) I had to setup the experiment on my own. I felt happy when I got it right

1) doing on my own aroused my interest

1) I did not have to feel intimidated by my colleagues(2)

1) It aroused interest within my family members. I felt important(2)

2) I was not just a spectator

3) I had more time(3)

Both:1(4%)

The mistake I made at home was discussed at CS

8. Do you feel that science experiments should only be performed in a laboratory? For either Yes or No justify your choice.(25)A

No:20(80%)

Coding:

1- Expts can be done in classroom or anywhere (100%)

1) Can be done in classroom if precautions are taken(2)

1) Can be done anywhere as long as it is safe(2)

1) Even in the classroom or any suitable space where learners can handle apparatus and record observations by themselves

1) Can even be performed outside

!) As long as you have all the equipment it can be done anywhere

1) Microscience kits can be stored in classroom too

1) Micrscience kits allow you to do expts anywhere(2)

1) Learners can make observation in a classroom too

1)A well ventilated area can be used

1) Can be done anywhere where science can be applied

1) As long as there is safe space to keep the equipment

1) The things we do in our lives everyday we are performing experiments, this is either conscious or sub-conscious, it is just that we should be aware of them

1) After performing it at home I feel it can be done anywhere but precautions should be taken(2)

1)Science happens everywhere around us

1) Not all schools have laboratories so experiments can be done anywhere

1)Most schools have no laboratories but it is necessary that they perform experiments. Precaution needs to be taken

Yes: 3(12%)

Give you the real experience of being a scientist

Storage of equipment is safe then, we don't have to carry it around

For dangerous experiments there are fume cupboards

Either: 2(8%)

In the laboratory or anywhere as long as it is safe

Dangerous expts can be done in a laboratory. Others can be done in a classroom

9. Did you do the experiments at home as instructed in the workbook after a particular section OR did you do them separately at a later stage? Justify your choice.(25)K

After a particular section:18(72%)

Coding:

1- Linked to understanding of concepts (61%)

2- Linked to sequence of studying (17)

3- No Comment (22)

1) It made sense to do so, since I could observe what the theory said

1) I could confirm the concepts(2)

1) I could link the theory with the practical

1) I understood what I was studying(2)

1) It will roundup the section and enabled me to have more understanding of the science concepts

1) it assisted in consolidating my understanding of the work(4)

2) To keep the sequence of my studying (3)

3) no comment(4)

At a later stage:3(12%)

-I had problem with my chemicals so I did it at the contact session(2)

-I did not want to clean up after each experiment

No response:4(16%)

10. Write a paragraph on your experience of using the kit at home.(25)

Comments:24(96%)