Educators' approaches to physics practical work

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Dedicated
to my late grandfather Eliphus Molefe Motlhabane
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ABSTRACT

Research in physics education has indicated that physics practical work is based heavily on recipe-following, with little attention being paid to the teaching and learning of skills (Johnstone & Letton, 1990:11, Johnstone & Letton, 1991:83, Meester & Maskill, 1995:576). The approach commonly used by educators was a cut-and-dried laboratory procedure, which minimises learner involvement (Olney, 1997:1345).

Recently, new approaches to science laboratory work have been implemented (Hake, 1992). In South Africa a new approach called Outcomes Based Education (OBE) was introduced in 1995. Notwithstanding these changes, learners still do not learn how to do practical work effectively (Meester & Maskill, 1995:576). Educators still prefer the authoritarian style of teaching, the emphasis being on the acquisition of factual knowledge and preparation for examinations.

The aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The empirical study was conducted with 46 educators attending an ACE (Advanced Certificate in Education) upgrading programme at the North-West University, Potchefstroom Campus, South Africa. The educators were divided into six groups. One educator in each group presented a micro-lesson on Ohm's law, while the rest of the group members role-played the learners. The micro-lessons were video-taped, transcribed, analysed and discussed.

Questionnaires (Appendices B, P and Q) were used in this study. The first questionnaire (Appendix B) was given to educators as an assignment to individually prepare a lesson on Ohm's law in order to probe their views on an OBE lesson in physics, its characteristics, practical work and its outcomes. The second questionnaire (Appendix P) was developed and completed by the researcher to record, evaluate and analyse observations in the video-taped micro-lessons. The last questionnaire (Appendix Q) was used to gauge perceptions of educators on video-taped micro-teaching as a tool in modelling educators' approaches to physics practical work.

The results indicate that the educators that participated in this study experienced problems in approaching physics practical work. They lacked skills in facilitating practical work in physics. Instead of outcomes-based approaches, the educators' approaches revolved around the transfer of

factual information through "chalk and talk" and confirmation of taught concepts through routines-guided experiments.

The researcher intervened by engaging educators in viewing the video-tapes, an in-depth discussion of the video-tapes and the preparation and presentation of a "model" lesson. All (100%) (Table 6.17) the educators that participated in this study indicated that the use of video-taped micro-teaching lessons could help in the training of educators.

A CD-ROM containing video-clips of all the micro-lessons was developed. The intention of the researcher is that the video-clips should be used at workshops, seminars, conferences and training institutions. Their merits and the demerits should then be discussed.

OPSOMMING

Navorsing in fisika-onderwys het getoon dat fisika praktiese werk hoofsaaklik op die volg van 'n resep gebaseer is waar min aandag gegee is aan die onderrig en leer van vaardighede (Johnstone & Letton, 1990:11, Johnstone & Letton, 1991:83, Meester & Maskill, 1995:576). Die benadering wat algemeen onder opvoeders gebruik is, was 'n vooraf uitgemaakte laboratoriumprosedure met minimum leerderbetrokkenheid.

'n Nuwe benadering tot laboratoriumwerk in wetenskap word tans geïmplementeer (Hake, 1992). Dié benadering, naamlik Uitkomsgebaseerde Onderwys (UGO), is in 1995 in Suid-Afrika ingevoer. Nieteenstaande die veranderings wat dit meegebring het, leer leerders egter steeds nie hoe om praktiese werk doeltreffend uit te voer nie (Meester & Maskill, 1995:576). Opvoeders verkies steeds die outoritêre onderrigstyl met die klem op die verwerwing van feitekennis en voorbereiding vir eksamens.

Die doel van hierdie studie is om ondersoek in te stel na hoe opvoeders by sekondêre skole praktiese werk in fisika by die FET-vlak in die Noordwes Provinsie, Suid-Afrika, aanpak. Die empiriese studie is gedoen met 46 opvoeders wat die Gevorderde Sertifikaat in Opvoeding se opgraderingsprogram by die Noordwes-Universiteit, Potchefstroom-kampus, Suid-Afrika, bywoon. Die opvoeders is in ses groepe verdeel. Een opvoeder in elke groep het 'n mikroles oor Ohm se wet aangebied, terwyl die res van die groep die rolle van die leerders vertolk het. Die mikrolesse is op videoband opgeneem, getranskribeer, ontleed en bespreek.

Vraelyste (Bylaes B, P en Q), is in die studie gebruik. Die eerste vraelys (Bylae B), is aan opvoeders gegee as 'n opdrag om individueel 'n les oor Ohm se wet voor te berei ten einde vas te stel wat hul uitgangspunte is met betrekking tot 'n uitkomsgebaseerde les in fisika, die eienskappe daarvan, praktiese werk, en die uitkomste. Die tweede vrealys (Bylae P), is ontwikkel en voltooi deur die navorser om die waarnemings van die videoband-mikrolesse aan te teken, te evalueer en te ontleed. Die laaste vraelys (Bylae Q), is gebruik om die persepsies van die opvoeders ten opsigte van videoband-mikrolesse te meet ten einde 'n model daar te stel van opvoeders se benaderings tot fisika praktiese werk

Die resultate dui aan dat die opvoeders wat aan die studie deelgeneem het, probleme in hul benadering tot fisika praktiese werk ondervind vanweë hul gebrek aan vaardighede om dié werk te fasiliteer. Instede van 'n uitkomsgebaseerde benadering, het die opvoeders se benaderings gewentel rondom die oordrag van feitekennis deur middel van "voordrag en swartbord " en die bevestiging van die konsepte wat onderrig is deur middel roetine-eksperimente.

Die navorser het ingegryp deur die opvoeders na die videobande te laat kyk, 'n dieptebespreking van die videobande, en die voorbereiding en aanbieding van 'n "modelles". Al die (100%) opvoeders wat aan die studie deelgeneem het, het aangetoon dat die gebruik van videobande in mikrolesonderrig kan help in die opleiding van opvoeders.

'n CD-Rom wat videosnitte van al die mikrolesse bevat, is ontwikkel. Die navorser se oogmerk is dat die videosnitte gebruik moet word by werkwinkels, seminare, konferensies en opleidingsinstansies. Die voor- en nadele moet dan bespreek word.

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CHAPTER 1

ORIENTATIVE INTRODUCTION

1.1 PROBLEM ANALYSIS AND MOTIVATION FOR THIS STUDY

New approaches to science practical work have recently been implemented (Hake, 1992). In South Africa a new approach called Outcomes Based Education (OBE) was introduced in 1995. Various studies (Johnstone & Letton, 1990:11, Johnstone & Letton, 1991:83, Meester & Maskill, 1995:576) indicate that physics practical work is based heavily on recipe-following, with little attention being paid to the teaching and learning of skills. Olney (1997:1345) refers to this approach as a "cut-and-dried" laboratory procedure, which minimises learner involvement.

Currently, the most important role of practical work is seen as the teaching of practical skills (Cilliers *et al.*, 2000:28). Although learners still learn about physics practical work, they do not learn how to do it effectively (Meester & Maskill, 1995:576). This contributes to a limited understanding of concepts in physics (Johnstone & Letton, 1991:83).

According to Hodson (1992:65), practical work in school science is both over-used and under-used. Over-used means that educators engage in practical work as a matter of course, thus expecting it to assist in the attainment of all the learning goals of the subject. Under-used means that practical work's real potential can rarely be exploited.

Research by Van der Linde *et al.* (1994:48) indicate that schools in developing communities, including the South African context, do not provide sufficient numbers of learners in the fields of technology and other science-related professions. In this regard the efficient teaching of physics at school level should be of the utmost importance. However, Van der Linde *et al.* (1994:48) argue that little or none has come of efforts to introduce a more practical approach in science teaching, mainly on account of the fact that educators cling to lecturing as a major teaching method. Similar problems occur in classrooms all over Africa and in most other developing countries (Hodson, 1992:65). According to Van der Linde *et al.* (1994:50), the curriculum reforms of the previous decades in many developing countries have not been accompanied by an equivalent reform of teaching styles. Educators still prefer the authoritarian style of teaching, the emphasis being on the acquisition of factual knowledge and preparation for examinations. Many fear the organisation of practical work (Van der Linde *et al.*, 1994:50).

Questions have been posed about the cost-effectiveness and purpose of practical work. Evidence about what is achieved when learners engage in practical work may lead to ambiguous conclusions, as there could be both positive and negative indicators regarding the acquisition of knowledge, skills and attitudes. The inactivity is a creeping phenomenon from primary/elementary school to secondary/high school and even to tertiary level (university, educator training college) education. Hence, practical work is under siege in both wealthy developed countries and poor developing countries (Bradley *et al.*, 1998:1406).

The usefulness and effectiveness of the traditional practical work are increasingly coming under fire and criticism (Cilliers *et al.*, 2000:20). Van Rensburg and Bitzer (1995:137) argue that the study methods of learners are not to be blamed for a relatively low pass rate and the problems learners encounter. Most probably, approaches used by science educators are to be blamed. Hence, Domin (1999:547) suggests that additional research is needed to probe into the difficulties and effectiveness of the approaches used in physics practical work.

Currently, there is much interest and concern directed towards helping learners learn actively and effectively, avoiding some of the known pitfalls in conventional teaching patterns or methods (Coleman *et al.*, 1997:137). The latter implies that physics practical work needs to be brought into productive reinforcement. It is thus necessary to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The latter will assist science educators to successfully meet the outcomes and purposes of physics practical work in order to act effectively as facilitators in the realm of physics practical work.

1.2 DESCRIPTION OF TERMS

1.2.1 Educators

For the purpose of this study the term *educators* refers to those educators teaching grades 10, 11 and 12 (secondary school).

1.2.2 Approaches

By approaches, the researcher refers to the teaching methodologies (strategies) used by educators in practical work. A teaching strategy is a broad plan of action for teaching-learning activities with a view to achieve one or more specific outcomes. Within a strategy there are teaching methods, for example inquiry-based approaches such as discovery and problem-solving, demonstration and the practical approach. A teaching method is a particular technique that an educator uses to help learners gain the knowledge that they need to achieve a desired outcome (Mahaye, 2002:210). Literature on the different approaches used in physics practical work is provided in Chapter 3.

1.2.3 Physics

In the secondary phase (grades 10, 11 and 12) physical science is divided into two sections, physics and chemistry. The focus of this study was on educators' approaches to practical work in physics.

1.2.4 Practical work

The term *practical work* has many interpretations. The researcher refers to any activity that requires that learners should be active participants. Paragraph 2.2 provides a detailed explanation of what practical work entails.

1.3 AIM OF THIS STUDY

The aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa.

1.4 SPECIFIC OBJECTIVES OF THIS STUDY

In paragraph 1.3 above it was indicated that the aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The study reveals educators' difficulties and lack of skills in facilitating practical work in physics with the objective to propose intervention strategies and recommendations to improve the situation based on the research results. The question is whether practical work in physics is still based on recipe-following, with little attention being paid to the teaching and learning of skills.

The following objectives have been set to guide the study, namely to:

- Conduct a literature study on the role of practical work in the science curriculum;
- conduct a literature study to reveal contemporary approaches to practical work in physics;
- investigate empirically the teaching strategies (approaches) presently used in physics practical work by secondary school science educators in the North West Province (South Africa);
- suggest intervention strategies to train current and future science educators; and
- make recommendations from the study regarding the execution of physics practical work in South African schools.

1.5 HYPOTHESIS

The hypothesis of this study can be stated as follows: *Secondary school science educators in the North West Province (South Africa) experience difficulties in approaching physics practicals.* As a result of this, practical work in physics is still based on recipe-following, with little attention being paid to skills learning, interactive, inquiry and learner-centred teaching strategies.

1.6 RESEARCH METHODS

1.6.1 Literature study

National as well as international approaches used in physics practical work were surveyed. The focus was on the outcomes of practical work. The role of practical work in the science curriculum was discussed.

1.6.2 Empirical study

The empirical study was conducted with educators attending an upgrading course (Sediba Project) at the North-West University (Potchefstroom Campus). A detailed research methodology on how the empirical study was conducted is provided in Chapter 5.

1.7 PERMISSION TO VIDEO-TAPE

A letter (Appendix C) to ask permission to video-tape and view educators' presentation was written to educators.

1.8 STATISTICAL TECHNIQUES

The Statistical Support Services of the PU for CHE assisted in the statistical analysis of the empirical data.

1.9 CHAPTER DIVISIONS

Chapter divisions of this study are presented in paragraphs 1.9.1 to 1.9.6. The chapters are in line with the aim and objectives of the study given in paragraphs 1.3 and 1.4 respectively.

1.9.1 Chapter 1: Orientative introduction

This chapter presents an orientative introduction. It analyses various studies conducted on the different viewpoints regarding approaches to physics practical work, which prompted this study. A comprehensive problem analysis and motivation for conducting this study is presented, which includes the hypothesis, the objectives and the aim of this study.

1.9.2 Chapter 2: Literature study: The role of practical work in the science curriculum

An overview of the literature study conducted on the position and role of practical work in the science curriculum is provided in Chapter 2. The literature that was surveyed includes the different perspectives on the meaning of practical work. The situation analysis of practical work in developing countries and the role and purpose of practical work, with specific reference to the outcomes of practical work, are presented. The laboratory as a learning environment to attain the outcomes of practical work is discussed.

1.9.3 Chapter 3: Literature study: Approaches to physics practical work

Chapter 3 surveys literature on approaches to physics practical work. The literature study includes the constructivist approach to science teaching, generative science teaching, and inquiry-based approaches. The inquiry-based approaches discussed include: the discovery-based approach, problem-based approach, demonstration-based approach, co-operative learning, cognitive conflict as a teaching approach, practical approach, the use of worksheets in practical work and co-operative learning. The approaches were discussed in accordance with the outcomes of practical work (paragraph 2.4.1).

1.9.4 Chapter 4: Literature study: Electric current and Ohm's law

Chapter 4 presents a literature study on electric current and Ohm's law. Since video-taped micro lessons presented by educators are based on Ohm's law, the aim of this chapter was to give the reader background knowledge on concepts related to electric current and Ohm's law. This chapter looks at the concepts of potential difference, electric current, electrical resistance and the relationship between both electric current and potential difference.

1.9.5 Chapter 5: Research methodology

Chapter 5 sets out the research methodology followed in the execution of this study. The first part (paragraphs 5.2-5.3) of the chapter outlines how both the literature survey and the empirical investigation were carried out. Data collection methods (paragraph 5.4), data analysis (paragraph 5.5) and quantitative and qualitative analysis (paragraph 5.6) were discussed. Paragraph 5.7 dealt with the ethical aspect of data collection.

1.9.6 Chapter 6: Results of the empirical study and discussion

In Chapter 6 the results of the empirical study are presented. Responses of educators to different aspects of the coding scheme are presented in Table 6.1 and discussed in paragraphs 6.2.1 to 6.2.13. The responses of educators to items 2(a), 2(b), 2(c) and 2(d) of the assignment (Appendix B) are outlined in tables 6.2 to 6.5. The discussion of the educators' responses is given in paragraphs 6.3.2, 6.3.4, 6.3.6 and 6.3.8 respectively. In tables 6.6 to 6.14 the analysis of micro-lessons 1, 2, 3, 4, 5 and 6 is given. The analysis was based on the video-taped micro-lessons presented (see transcripts of video-taped micro-lessons, Appendices D, E, F, G, H and I and the micro-lesson plans Appendices J, K, L, M, N and O). A summary of the general findings of the micro-lessons, the discussion of the "model" micro-lesson, the results of the questionnaire on video-taped micro-teaching (Appendix Q) and the conclusion to the results of the questionnaire on video-taped micro-teaching are presented in paragraphs 6.5, 6.6, 6.7 and 6.8 respectively. The implications of this study are indicated in paragraph 6.9.

1.9.7 Chapter 7: Conclusions and recommendations

In Chapter 7 the literature and empirical study are summarised. Conclusions and recommendations are indicated.

In the next chapter (Chapter 2) the role of practical work in the science curriculum will be discussed.

CHAPTER 2
PRACTICAL WORK IN THE SCIENCE CURRICULUM

2.1 INTRODUCTION

The aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. In view of the role that practical work should play in the school science curriculum, a review of literature on practical work in the science curriculum is provided. The current chapter outlines the situation analysis of practical work in developing countries (paragraph 2.3). In order to put the role and purpose of practical work (paragraph 2.4) in perspective, it is necessary to discuss views held on what practical work is (paragraph 2.2). The latter discussions would aid in the interpretation of the outcomes of practical work (paragraph 2.4.1). The laboratory as a learning environment (paragraph 2.6) to attain the outcomes of practical work is also discussed.

2.2 WHAT IS PRACTICAL WORK?

This section looks at viewpoints on the meaning of practical work, since practical work may mean different things to different people. To some, practical work might mean laboratory-work experiments performed as teacher demonstrations, or hands-on experimentation by learners in a laboratory or classroom. According to Bradley and Maake (1998:3), the scope of practical work could be extended to include activities such as project work, library research, field work, site visits, environmental monitoring, or investigating technologies. Practical work could be performed in any number of locations and need not be limited to the classroom. Hodson (1992:67) argues that any learning method that requires the learner to be active, rather than passive, is in accordance with the belief that learners learn best by direct experiences, which is what practical work in fact is. Hodson (1992:66) asserts that practical work need not always comprise activities at the laboratory bench. Legitimate alternatives would include computer-assisted learning (CAL), use of worksheet activities (paragraph 3.11.2) in conjunction with an educator demonstration (paragraph 3.8) or video/film presentation, working with case study materials, interviewing, debating and role-playing, writing tasks, making models, posters and scrapbooks, library work of various kinds and making videos.

Practical work is often described as typical laboratory work where learners encounter ideas and principles at first hand. Yager (1991:22) argues that the typical laboratory may not be a laboratory at all. The term could be used to describe a place where learners can test their own ideas and/or their own explanations for objects and events they have encountered as they explored their curiosity about the universe in which they find themselves. Tamir (1977:311) asserts that the laboratory should be used as a place where science learners engage in hands-on activities such as observations and experiments, that is, not only to verify but to find. While the laboratory may be used to illustrate objects, concepts, processes and experiments, its major uniqueness could lie in providing learners with opportunities to engage themselves in the processes of investigation and enquiry.

In physical science classes practical work may mean hands-on as well as minds-on practical work activities such as laboratory experiments. Learners could engage in distance practical work, in which case learners could observe practical work on video or television without hands-on participation. The educator can perform demonstrations, and learners can observe a practical being demonstrated by the educator in the classroom. Learners may participate by observing, asking and answering questions. Group or individual practical work could be arranged, where learners could perform practical work in the classroom. Learners could participate by making, doing, measuring, observing, asking and answering questions (Bradley & Maake, 1998:4).

Practical work could include all types of investigations or experimentation by learners, on their own or in groups, as well as demonstrations by educators (Van der Linde *et al.*, 1994:49). While there may be a wide variety of definitions of practical work, Bekalo and Welford (2000:187) assert that practical work should always involve learner participation, although people might differ in their understanding of the degree of this participation (Bradley & Maake, 1998:4).

2.3 SITUATION ANALYSIS OF PRACTICAL WORK IN DEVELOPING COUNTRIES

Despite the wide acceptance in industrialised countries of practical activities in school science, the literature surveyed for this study indicates that questions have been raised regarding the effectiveness of the practical-related activities (Bradley *et al.*, 1998:1406) and lack of evidence supporting the supposed benefits. Some researchers have suggested that much of what takes place in school laboratories is of little value, ill-conceived, and unproductive (Treagust & Thair, 1999:358).

Developing countries often use practical activities as a means of confirming theory. This could be seen as a game by learners where intelligent learners discover the right answers. The main feature of most classroom transactions revolve around the transfer of factual information through "chalk and talk" and confirmation of taught concepts through routines-guided experimental approaches. This is because the educators themselves often do not have the necessary expertise to organise, carry out and evaluate practical-oriented courses (Bekalo & Welford, 2000:203). The latter may in part be due to the difficulties in accessing information, lack of access to libraries, computer information networks, journals, and limited textbooks. Many of the education systems in developing countries are descendants of those of the former colonial powers, and in some cases continue to be influenced by outside curriculum experts. In many cases these education systems adopted the latest educational fashions from industrialised countries, where the strategies were based on the premise that learners should do more practical work (Treagust & Thair, 1999:358).

Treagust and Thair (1999:358) assert that the effectiveness of practical activities in developing countries are inconclusive and suggest that as long as science achievement tests neglect to measure the skills developed during practical activities, scepticism would remain concerning their measurable benefits. Other authors (Hodson, 1992:65; Van der Linde *et al.*, 1994:48; Bradley *et al.*, 1998:1406) have commented on the inconclusiveness and lack of research on the effects of practical work in developing countries. They suggest caution against drawing conclusions about the value of practical activities in industrialised countries and applying these to developed countries. According to Treagust and Thair (1999:358), there are differences in context between the two types of cultures (industrialised and developing countries). The function of schooling and outcomes provide an example that for many learners in developing countries their first contact with mains electricity and factory-produced technical artefacts may occur in a school science laboratory. Therefore, practical activities may serve a different function for these learners from those in an industrialised country.

In developing countries where curricula prescribe the use of practical activities, a number of constraints may prevent the implementation of these activities into classrooms. Commonly reported constraints include a lack of equipment (Waterman & Thompson, 1989:31), large classes (Bradley & Maake, 1998:21), overcrowded syllabi, and an examination system focused on factual recall while ignoring formal assessment of practical outcomes and the application of scientific reasoning to solve problems (White, 1988:107; Treagust & Thair, 1999:358; Bekalo & Welford, 2000:207).

Although the existence of classroom laboratories and equipment may not be used as a criterion for measuring the quality of teaching (Van der Linde, *et al.*, 1994:51), it may be an essential facility if the educators were to use a practical teaching approach. According to research by Van der Linde *et al.* (1994:51) of 30 educators who attended the Research Institute for Education Planning (RIEP) in-service training courses at the University of the Free State (South Africa) in the 1990/1991 period, 38% indicated that they taught in laboratories, whilst 62% used classrooms for the teaching of physical science. At least 25% of the laboratories did not have water and electricity or gas supplies, whilst less than 50% of the educators had mechanical and electrical apparatus at their disposal. The situation regarding facilities and apparatus available in ordinary classrooms used as laboratories for practical work was indicated as even more unsatisfactory (Van der Linde, *et al.*, 1994:51).

According to Van der Linde *et al.* (1994:51), conditions in secondary schools in South Africa are not satisfactory for doing practical work. Researchers of RIEP also indicated that expensive apparatus and equipment that had never been used, was found deteriorating in store rooms and boxes in most of the schools they visited.

Considering the difficulties in implementing meaningful practical activities, the uncertain outcomes and high costs, some authors suggest that practical activities can probably only be recommended for learners in high-income countries and should be limited to those learners destined for post-secondary science studies (Treagust & Thair, 1999:358). However, Jeschofnig (2001) and Bradley *et al.* (1998:1407) argue that the solution to the cost problem should lie with the reduction of scale. They believe, for instance, that the reduction of quantities of chemicals reduces consumables costs, equipment costs, and hazard and waste disposal problems. Such reduction of scale could eliminate the need for specialised and sophisticated laboratories in many cases, reducing storage space requirements. Hence, Waterman and Thompson (1989:28) suggest that small-scale practical work (paragraph 3.14) could provide an economic solution to such problems.

2.4 THE ROLE OF PRACTICAL WORK IN SCIENCE

Practical activities have long played an integral role in secondary school science in industrialised countries, and in particular in secondary school physics (Treagust & Thair, 1999:358; Tamir, 1991:13; Hofstein & Cohen 1996; Van der Linde *et al.*, 1994:50). It has been widely accepted that science curricula at secondary level should contain significant amounts of practical activities and that provision of the necessary resources is entirely justified. Theoretical justification accompanied the inquiry approach. Practical activities were seen as the sole means of providing this learning opportunity.

The role of practical work in this study is viewed in terms of the outcomes thereof (paragraph 2.4.1). The discussion of the outcomes follows in paragraphs 2.4.1.1 to 2.4.1.4. It is important to note that the outcomes of practical work listed in paragraph 2.4.1 will be referred to as outcome 1, outcome 2, outcome 3 and outcome 4 throughout the study. The study reported in this thesis empirically probed the views of educators on "what are the outcomes of a physics practical? (see paragraph 6.3.7). The educators' views are compared to those in the literature study (paragraph 2.4.1)

2.4.1 Outcomes of practical work

The focus of outcomes based teaching and learning in South Africa is on what learners know and can do at the end of their learning experience. The development of an outcomes-based curriculum therefore, will have as starting point the intended results of the learning experience. These results refer to the knowledge (outcome 1 below), skills (outcome 2), teaching of processes of science (outcome 3) attitudes and values (outcome 4) that learners must acquire, and not merely to the prescribed content. The outcomes are stated clearly at the onset and both the educator and the learner know right from the start what the intention of the learning experience is. The outcomes guide the teaching and learning process, as well as the assessment (paragraph 2.4.2) of learner achievement during and after the learning experience. These outcomes provide a means of ensuring the quality of education at the end of the phases and form the basis for assessment (Van Rensburg & Potloane, 1998:27).

The literature abounds with statements and analyses of the aims and outcomes of practical work in science education (Kempa, 1988:148). Listings of such aims and outcomes vary enormously in format of presentation and detail (Kempa, 1988:148). Generally, however, some authors (Van der Linde *et al.*, 1994:50; Allsop, 1991:33; Bradley *et al.*, 1998:1406; Treagust & Thair, 1999:358) argue that the outcomes of practical work focus on the under-mentioned broad outcomes:

Practical work should:

Outcome 1: *Reinforce the understanding of scientific concepts and principles, making abstract concepts more understandable and supporting theoretical learning.*

Outcome 2: *Develop practical skills and techniques.*

Outcome 3: *Teach the processes of science, involvement in problem-solving and a thinking style that exposes learners to the way of working like a scientist.*

Outcome 4: *Stimulate learners' interest and motivate them to realise that science is enjoyable.*

Each of the above outcomes can be elaborated and described further (see paragraphs 2.4.1.1 to 2.4.1.4 for a discussion on each outcome). Such an elaboration is indeed essential if we were to produce goals and objectives of practical work that are meaningful and helpful to both learners and educators (Kempa, 1988:148).

A concentration on these outcomes of practical work is justified because of the adoption of what is essentially a discipline-centred approach to the determination of the aims of science education (Kempa, 1988:148).

- Science is seen as a practical subject, while the mastery of certain practical skills and techniques becomes a prerequisite for its pursuit.

- Science is concerned with the exploration and investigation of natural phenomena. The learning of science should involve a direct practical exposure to such phenomena and to the complexity of scientific situations.

- The generation of scientific knowledge and insights depends on the exercise of systematic scientific enquiry and problem-solving.

2.4.1.1 Discussion of outcome 1

Reinforce the understanding of scientific concepts and principles, making abstract concepts more understandable and supporting theoretical learning.

To accomplish outcome 1, practical work in schools should assist in the exploration, manipulation and development of concepts and make the concepts manifest, comprehensible and useful. The exploration of ideas can constitute the learning process, while bench work can provide the concrete evidence of the outcome of the conceptual exploration. Practical work may provide the conceptual core of learning, thus learners should engage in the conceptual understanding of the theory of science. Practical work in school science was previously seen as a means of obtaining factual information or data. It should rather be a way of exploring and developing conceptual understanding. Learners should be involved in the designing and planning of experimental investigations. A lack of theoretical understanding may cause inappropriate observations, hence learners may look in the wrong place and in the wrong way, and thus make incorrect interpretations (Hodson, 1992:68).

Experiments should be devised by the learner while the educator acts as a facilitator. Such a view is in accordance with theories of motivation that recommend ceding a greater degree of control of learning to the learner. Learners may not engage in practical work without considering conceptual issues. Learners may consider the conceptual relationships relevant to experimental procedures and engage in many of the processes of science without actually doing experiments in the conventional sense. It may be that the concrete situation of the actual experiment serves, on occasions, to distract the learner from the importance of theoretical features of the problem and to inhibit creative thinking (Hodson, 1992:68). Conceptual development should be assisted by encouraging learners to explore, elaborate and test existing ideas against experience, both real experience and the contrived experience of the scientific experiment. Practical laboratory work and experience in the field have a crucial role to play in making abstract concepts more understandable (Hodson, 1992:68).

Learners could develop transfer skills and thus be able to transfer knowledge from one context to another different context. Active learners may have a feeling of ownership of information, data, interpretations and understandings, which means that they may judge the worth of facts and opinions. According to Bentley and Watts (1989:14), ownership can be important because it can be an indication that learning may be intelligible, credible, fruitful and relevant to those learners concerned.

Learners can display their understanding and competence in a number of ways. They could select the most appropriate means of reporting their progress, that is, what they know and understand. During discussions learners may communicate and explain their ideas and understandings so that others may appreciate them (Bentley & Watts, 1989:15).

Learners could engage in self- and peer evaluation, thus evaluating themselves and their peers. Active learning could mean effective learning. Learners may be confident of developing their own criteria to evaluate their own progress regularly and thus recognise their own competences and weaknesses. Learners could also share these criteria and make evaluations of their progress in co-operation with their peers and educators (Bentley & Watts, 1989:15).

According to Tamir (1991:14), practical work could also offer unique opportunities conducive to the identification, diagnosis and remediation of learners' misconceptions and alternative conceptions. This standpoint is further supported by Hofstein and Cohen (1996), who assert that practical work attempts to teach learners central concepts and basic skills. The general methods of presentation could be geared to prevent learners from developing misconceptions and alternative conceptions. Laboratories are designed to help explain the concepts, familiarise learners with the properties of many substances and compounds, and help learners to understand the consecutive steps used to form a specific scientific theory.

2.4.1.2 Discussion of outcome 2

Develop practical skills and techniques

The second outcome attributes the development of practical skills and techniques to practical work. Practical experiences, whether manipulative or intellectual, are qualitatively different from non-practical experiences and essential for the development of skills and strategies with a wide range of effects that could be generalised. These skills may function in concert in the mind of a creative and critical thinker as he or she learns about the world. The skills could be, in essence, learning tools essential for success and even for survival. Hence, if learners could be helped to improve the use of creative and critical thinking skills, they could become more intelligent and thus learn how to learn (Tamir, 1991:14).

An even more extreme view of the desirable role of practical work is presented by Tamir (1991:15), who argues that the imposition of theoretical learning on practical work has a detrimental effect on the development of scientific investigation skills. Educators should not only use practical work as a subservient strategy for teaching scientific concepts and knowledge. There are self-sufficient reasons for doing practical work in science and neither these reasons nor the aims concerning the teaching and understanding of scientific knowledge could be well served by the continual linking of practical work to the content syllabus of science.

Eglen and Kempa (1974:261) further argue that proficiency in manipulative skills has generally been inferred from the quality of experimental results normally communicated by the learner to the assessor in the form of laboratory reports and practical scripts. By implication, this practice presupposes that a high correlation exists between the proficiency with which a practical task is performed and the quality of the results derived from it. They further support the view that the objective of an introductory science course is aimed at the acquisition of the necessary skills and acceptable working habits in the laboratory. Hence they suggest that the acquired skills should be assessed, not the outcomes of sequences of operations (Eglen & Kempa, 1974:261).

Table 2.1 outlines the different categories of practical skills as proposed by Millar (1991:51).

TABLE 2.1 Practical skills

General cognitive processes	**Practical techniques**	**Inquiry tactics**
Observe Classify Hypothesise	Measure temperature with a thermometer, separate a solid and a liquid by filtration, ...	Repeat measurements, draw graph to see trend in data, identify variables to alter, measure, control, ...
← ***may not be taught*** →	← ***may be taught and improved*** →	

Millar (1991:51) differentiates between different categories of practical skills, as in Table 2.1. This table (Table 2.1) indicates the general cognitive processes that may not be taught, and practical techniques and inquiry tactics that may be taught. The practical techniques could be the specific pieces of the know-how about the selection and use of instruments, including measuring instruments and about how to carry out standard procedures. The third category, which is inquiry tactics, could be regarded as a toolkit of strategies and approaches that could be considered in planning an investigation. These would include repeating measurements and taking an average, tabulating or graphing results in order to see trends and patterns more clearly, considering an investigation in terms of variables to be altered, measured, and controlled.

Additional skills can be learnt during science practical sessions. For example, learners could learn organisational skills and such skills may help them organise themselves and others. Learners could learn to work independently and co-operatively within a group. Working closely with others in a small group may involve particular skills and abilities. Such skills could enable them to become co-operative members of the community. Learners could also be aware of the time requirements of different tasks and may be capable of pacing themselves to meet deadlines. In other words, learners may develop the skill of time management (Bentley & Watts, 1989:15).

Eglen and Kempa (1974:263) and Trowbridge *et al.* (2000:223) categorise the manipulative skills into sub-categories. These sub-categories together with generalised performance criteria are listed in Table 2.2.

TABLE 2.2: Sub-categories of manipulative skills

COMPONENT	GENERALISED CRITERIA/PERFORMANCE FEATURES
Methodical working	Correct sequencing of tasks forming part of overall operation Effective and purposeful utilisation of equipment Ability to develop an acceptable working procedure on the basis of limited instruction
Experimental technique	Correct handling of apparatus and chemicals Safe execution of an experimental procedure Taking adequate precautions to ensure reliable observations and results
Manual dexterity	Swift and confident manner of execution of practical tasks Successful completion of an operation or its constituent part-tasks
Orderliness	Tidiness of the working area Good utilisation of available bench space Organisation in the placing of equipment used

2.4.1.3 Discussion of outcome 3

Teaching the processes of science, involvement in problem-solving and a thinking style that exposes learners to the way of working like a scientist.

Outcome 3 is based on the idea that science education should provide learners with a real experience of the whole scientific process that is, identifying a problem, proposing possible explanations and devising tests to determine the validity of a particular explanation.

Tamir (1991:13) asserts that practical work involves two key words, that is, discovery and inquiry. Learners' participation in actual investigations, employing and developing procedural knowledge and skills, may be an essential component in the learning of science as an inquiry. Practical work may give learners an opportunity to appreciate the spirit of science and promote problem-solving, analysing and the ability to generalise.

Bourque and Carlson (1987:232) assert that hands-on practical experience could give learners a more realistic view of the trial and error process that challenges experimentalists in many of the scientific investigations. This practical experience involves them first-hand in the careful observations and manual skills required for gathering accurate data. This hands-on procedure seems to provide the mental activity necessary to assimilate the abstract concepts involved in the chemical interactions taking place in the study of science.

Learners could initiate their own activities and thus learn to take responsibility for their own learning. This could often come from within learners themselves, that is, from their need to know or find a solution. It may be that the impetus or suggestion comes from the educator or from outside the classroom. Nevertheless, they may want to shape it themselves so that it becomes their task and thus become accountable for its outcomes. Hence learners may feel in control and fully involved in their own learning (Bentley & Watts, 1989:14).

Learners can develop decision-making and problem-solving skills. Active learners can recognise the demands of particular tasks, take responsible decisions and seek ways to solve problems. Learners can judge the task for what it is worth, and thus tackle it appropriately even when it derives from outside, from a scheme of work, from the educator or some other source. Decision-making skills may be important when learners have to make decisions with a view to the solution of a problem and take ownership of the problem for themselves (Bentley & Watts, 1989:14).

While some confirmatory practical work that aims at developing self-confidence as well as basic processes and techniques may be necessary, Tamir (1991:19) argues that the majority of practical work should require learners to engage in real problem-solving investigations, under different levels of guidance, according to particular goals and local conditions.

2.4.1.4 Discussion of outcome 4

Stimulate learners' interest and motivate them to realise that science is enjoyable.

Outcome 4 argues that practical work makes science real and stimulates learners' interest. A successful experience in practical-related activities may engender feelings of self-esteem, self-confidence and determination that could be transferable to a wider world outside the laboratory.

It allows learners the opportunity to act like real scientists, and thus develop important attitudes such as honesty, readiness to admit failure and critical assessment of results and of limitations, known as scientific attitudes (Hodson, 1992:76).

One of the purposes of practical work is the development of positive attitudes amongst learners. According to Bradley and Maake (1998:1), this includes making science real to learners, helping learners to appreciate the experimental nature of science, and arousing learners' interest in science. Research done by White (1988:103) indicates that school children begin the study of science with a favourable attitude to it, although they gradually come to regard it less positively. This may suggest that direct experience may be one of the causes of unfavourable attitudes to school. While it is an indication of the way science is taught, this may be a relief because it could mean that educators could do something about it without having to change the views of the whole community.

Tamir (1991:14) asserts that learners usually enjoy activities related to practical work and that when they are offered the opportunity to experience meaningful and non-trivial experiences, they become motivated and interested in science. The primary responsibility for transmitting the context of science should be delegated to the educator and textbook, whereas the primary responsibility for transmitting appreciation of the scientific method should be delegated to the practical activities in school science.

A desirable way of facilitating inquiry could be by assigning individual research projects that learners do on their own under the guidance of the educator. Positive outcomes of the enquiry done by learners could lead to a positive attitude, thus learners could be motivated to perform advanced enquiries (Tamir, 1991:19).

Learners could develop self-esteem, and hence believe in themselves and grow in enthusiasm for what they are doing. They could develop an understanding that learning is an emotional business, which may involve excitement, disappointment, sudden 'eureka' moments and periods of perseverance. Success could mean confidence, and confidence could mean positive feelings and motivation (Bentley & Watts, 1989:15).

The development of a positive attitude towards science and the scientific enterprise (Woolnough, 1991:172) is among the major aims of science teaching. Woolnough (1991:172) further indicates that practical work is an effective environment for enhancing learners' attitudes towards and interest in the learning of science. Learners' attitudes towards practical work activities and towards science as it is practised in the laboratory as a learning environment are important areas to be targeted by educators and researchers in their assessment and monitoring of the science practical experience (Woolnough, 1991:173).

Bradley and Maake (1998:3) indicate that experimental work is a definite characteristic of the natural sciences, and whenever possible practical work should involve learner participation. This could be interpreted to mean that science educators should use practical work in their classes on a regular basis. The type of practical work they use should be individual or group practical work to encourage maximum learner participation. However, a positive attitude is needed for both educators and learners to participate and interact effectively with apparatus and chemicals (Koballa & Crawley, 1985:227).

A positive attitude towards and interest in science have become important concepts for a number of reasons (Koballa & Crawley, 1985:227), among which are:

- A positive attitude towards science is thought to fulfil basic psychological needs, such as the need to know and the need to succeed.

- A positive attitude towards science also influences present and future behaviour, such as interest in working on science projects at home. Hence White (1988:107) emphasises that the quality of learners' learning is affected by their attitudes towards the subject.

2.4.2 The evaluative role of practical work

Traditionally, assessment has been used to rank learners (Bradley & Maake, 1998:22). The assessment was done mostly at the end of the learning process and the aim was to determine how much content the learner had mastered (Van Rensburg & Potloane, 1998:29). Learners were given marks for a piece of work, with the best learner getting the highest mark and the weakest learner getting the lowest mark. Once this ranking has been completed, the educator moves the class to another exercise. The weakest learner was not necessarily given the opportunity to try again (Bradley & Maake, 1998:22).

The new philosophy on learner assessment is completely different. Assessment is seen largely as a diagnostic tool for ascertaining what the learner knows or can do. This information is then used to design further activities for the learner to ensure that every learner progresses. For example, an educator may get a class of thirty learners to perform a titration. The purpose of this exercise could be to see whether learners are able to manipulate the equipment correctly. The educator could assess this by observing the learners at work. Those learners that are able to handle the equipment without the help of the educator would have achieved the outcome and should move on to some new work. Those learners who struggle at first but after assistance from the educator or another learner are able to handle the equipment well, have also achieved the outcome. Those learners that continue to struggle even after they have been assisted have not achieved the outcome. They would need additional opportunities to do this, either by repeating the experiment or by doing another experiment that requires similar competencies (Bradley & Maake, 1998:22).

It is thus important that learners are assessed on an ongoing basis in order to determine whether they are moving towards the achievement of the outcomes. The outcomes are used as the criteria for assessing learners (Van Rensburg & Potloane, 1998:29). Bekalo and Welford (2000:207) argue that the new curriculum objectives in terms of practical work are unlikely to be achieved in the absence of practical elements in the assessments procedures, although educators faced with a content-dominated syllabus and a predominately recall-type examination may be both brave and foolish to change their ways of instruction. If the curriculum were to achieve the desired effect, the current examination procedures would have to be substantially modified and greater emphasis placed than has hitherto been the case when testing practical science capability. This may additionally involve the development of systems of internal assessment carried out by educators, being moderated and standardised by the newly established examination board (Bekalo & Welford, 2000:207).

According to Eglen and Kempa (1974:263), the basis of assessing learners' skills must lie in direct observation of their performances in the laboratory. The assessment of any ability requires *a priori* agreement about the components of ability and the achievement criteria to be used as reference standards in the assessment operation. Table 2.2 lists the components of sub-categories, together with some major operational criteria relevant to the assessment of manipulative skills. Further amplification in relation to particular practical tasks carried out by a learner is required and the nature of the task itself will determine which of the component skills are relevant to an assessment operation and which are not.

Eglen and Kempa (1974:263) assert that the most immediate mode of assessing manipulative skills by direct observation is to form a general impression of a learner's performance in the laboratory. This may be done through noting good and weak performance points and translating the impression gained into a point on the 1-to-5 rating scale. Assessments made in this way could be subjective, as they may vary as the result of inaccuracies and personal biases that are usually associated with subjective judgements. Objective assessments of manipulative abilities may be fairly difficult to accomplish in that they require specific performance criteria to be available against which a particular practical task can be judged. For example, when assessing a learner's competence in the use of a pipette, specific marks that may be assessed might include:

- Whether or not the pipette was emptied by flow under gravity only;
- whether an adequate draining time was allowed; and
- whether the last drop was transferred from the pipette by touching the inside of the receiver flask.

Marks of this nature could be compiled in the form of a check-list of performance criteria to be used in assessing a learner's overall practical performance (Eglen & Kempa, 1974:263). A rubric can be used as a checklist. The use of rubrics to assess practical work will be discussed in the next paragraph (paragraph 2.4.2.1).

2.4.2.1 Using rubrics to assess practical work

A rubric is a scoring tool that lists the criteria according to which a task will be assessed (Department of Education, 2002:25). Examples of rubrics are indicated in Table 2.3 (Department of Education, 2002:25) and Table 2.4 (Pratt, 2003:29).

TABLE 2.3: Rubric for assessing investigative skills

Criteria	**Competency level**		
	Not achieved	Partially achieved	Achieved
	1	2	3
State/identify the problem			
Compile relevant information			
Plan of action			
Execute plan/practical			
Communicate findings/results/interpretation			

TABLE 2.4: Grading rubric for discovery lab activities

Competency level	**Criteria**
10	The learner made different observations each time and had good notes for group sharing. The hypotheses developed are insightful, based on and supported by the observations on paper.
8	The learner made different observations each time and had some notes for group sharing. The hypotheses made some references to the observations.
6	The learner made different observations each time, but lacked notes for group work sharing. The hypotheses were poor and made little reference to observations.
4	The learner made poor or repetitive observations and made no attempt to take notes for sharing. The hypotheses were poor and not based on observations.
2	The learner did not participate in the observation process or lacked important information on paper. The hypotheses were missing or randomly jotted down with no basis in observations.

In assessing learners through rubrics it is recommended that learners should be given a rubric before the exercise or practical is attempted in order to ensure clarity in terms of expectations. Being aware of what is required will focus the mind of the learner and ensure communality between the educator and the learner (Department of Education, 2002:25).

When using a rubric:

- Different scores are added to get a final mark;
- subsequent skills would be assessed similarly; and

- if a total of five skills were to be assessed for example, this would be a maximum of 5x4=20 (Department of Education, 2002:25)

Paragraph 2.5 below looks at how episodes, strings, images, motor skills and cognitive strategies can be used to attain the outcomes of practical work.

2.5 ATTAINING THE OUTCOMES THROUGH EPISODES, IMAGES, STRINGS, MOTOR SKILLS AND COGNITIVE STRATEGIES IN PRACTICAL WORK

White (1991:79) draws attention to images, episodes, strings, motor skills and cognitive strategies as important determinants of the quality of learning. Episodes are considered important in practical activities. These episodes are regarded as the recollection of events during practical activities. They are important as powerful elements in the understanding of concepts or situations. Understanding of the concept or phenomenon could be a function of the extent and mixture of knowledge the person has about it. For example, in the concept of chemical change, a learner might have acquired knowledge of propositions, such as 'mass is conserved in chemical reactions' and 'physical changes are more easily reversed than chemical changes'. The learners' understanding of chemical change may depend on how well the knowledge has been integrated, whether it is a collection of unconnected elements, or whether it is all linked into a coherent whole.

White (1988:106) asserts that strings and images could be important in the social transmission of attitudes. Strings may be inferred from experience, but may be reinforced by repetition. Although images may often be acquired through social transmission, they may also be formed from practical experiences in the laboratory. This could be a single dramatic event or a series of different events during a practical activity in the laboratory. For instance, a succession of science educators may lead the learner to form a composite image in much the same way as recurring episodes lead to scripts. A continued diet of drill exercises may lead to an image of science as slavery, while other experiences may give an image of a laboratory with coloured liquids, interesting smells and flickering lights. These images are virtually indistinguishable from generalised episodes.

Children interpret the things their educators say and the experiences that educators arrange for them in terms of their earlier experiences and beliefs, generally in such a way as to support views already formed. Voluntary activities could drive the interests and attitudes of children apart. According to White (1988:107), educators may not only do what they like, but also have to come to like what they do, hence the more time children spend in different activities the more their beliefs about these activities will diverge.

White (1988:107) indicates that if some activities of learners were given the label science and if these activities were enjoyable, science may be valued and fresh activities that come under the name of practical science are likely to be engaged in. One unfortunate experience could be a failure in an important examination, an inquiry in a science lesson, or an unjustified reproof by a science educator. These may turn a child against science. On the other hand, an unexpected, pleasant experience may reveal joys and beauties to which earlier experiences had closed the eye (White, 1988:107).

If learners are interested in science, they may learn it, and if they are not, they may not learn it. According to White (1988:109), attitudes may encompass more than interest and extend to traits such as curiosity and appreciation. The nature of the person's attitudes may affect not only whether any learning occurs but also the style of learning. Thus attitudes could be influenced by the operation of cognitive strategies and the quality of learners' learning could be affected by their attitudes.

White (1991:79) asserts that practical work could be justified because it could be a prolific source of episodes that learners link to the propositions and intellectual skills that may be acquired in more educator-centred lessons. It may also be very important to take into account how learners process experiences. Information processing and constructivist theories of learning provide insights into the formation of episodes, and practical work should encourage learners to think about what they are learning.

2.6 THE LABORATORY AS A LEARNING ENVIRONMENT TO ATTAIN THE OUTCOMES OF PRACTICAL WORK

Yager (1991:22) indicates that 90% of so-called laboratories in the United States of America were verification activities, hence no real investigations were conducted and the correct answers to the activities were given before practical work began.

Information about learners' perceptions of their classroom learning environment could guide both educators and curriculum developers in searching for instructional techniques and teaching and learning methods that could contribute in their turn to positive aspects of the classroom climate. Laboratory activity may have the potential to enhance constructive social relationship as well as positive attitudes and cognitive growth. The co-operative team effort required for many laboratory activities may promote positive social interactions involving cohesiveness, task orientation, goal direction, democracy, satisfaction and other related factors (Hofstein & Cohen, 1996).

Gathering learners' perceptions of the actual and preferred laboratory learning environment may inform science educators regarding the role of practical work in the learning process. This setting could become more effective in terms of instructional strategies, the cognitive level of instruction and educator-learner and learner-learner interrelationships. Preferred forms of learning environment measures could be used to improve the educational effectiveness of instructional techniques as well as to improve learners' achievement, attitudes and interest in science. The preferred forms are concerned with goals and values orientation and measure perceptions of the laboratory or classroom environment ideally liked or preferred (Hofstein & Cohen, 1996).

According to Hofstein and Cohen (1996), laboratory work could play an important role that may be reflected by the following aspects:

- Many concepts and principles in science could be understood after experiments in the laboratory and prior to the learning of the related subjects in the classroom.
- Inquiry questions could be identified and learners may be asked to suggest ways of solving problems. This may be done by formulating hypotheses, planning experiments, performing them, collecting data, and constructing tables or graphs. Learners are offered the opportunity to analyse and interpret results, leading to conclusions and generalisations.
- Learners could work in pairs or small groups, a fact that may contribute to a positive learning environment in the laboratory.
- Learners are encouraged to participate in their learning activities, and such participation itself could be highly appreciated.
- Learners could perform projects as part of their preparation for matriculation examinations. Such activities could be partially conducted in the laboratory and could provide an

opportunity for informal discussion meetings between educator and learner, and learner and learner.

Hofstein and Cohen (1996) indicate that laboratories are designed partly to:

- Help explain concepts;
- Familiarise learners with the properties of many substances and compounds; and
- Help learners understand the consecutive steps used to form a specific theory.

These tasks in the laboratory are usually clear and are related to the concepts being taught at that time in the classroom.

Research conducted by Wong and Fraser (1996), who investigated the relationship between learners' perceptions of their laboratory classroom environment and their science-related attitudes, indicated that there were statistically significant associations between the nature of the laboratory classroom environment and learners' attitudinal outcomes. Their findings indicated that integration and rule clarity were strong and consistent predictors of the attitudinal outcomes. This implies that learners' attitudes towards science are likely to be enhanced in science laboratory classes where laboratory activities are linked with the theory learned in non-laboratory classes and where clear rules are provided. Another noteworthy finding was the negative association between open-endedness and attitude to scientific inquiry in science as a way that favoured close-ended activities.

According to Tamir (1977:311), the inquiry level of laboratories may be determined by the actual behaviour of the educators and the learners. For example, in a typical verification laboratory, the educator could identify the problem to be investigated, relate the investigation to previous work, conduct demonstrations and give direct instructions, while learners repeat the educator's instructions or read aloud the instructions from the manual. On the other hand, in a typical inquiring laboratory, the educator could ask learners to formulate the problems, to relate the investigation to the previous work or to state the purpose of the investigation. Learners actually identify the problem, state the purpose, predict the results, identify the procedures and perform the investigation.

2.7 CONCLUSION

The literature reviewed indicated that practical work forms a major component of the school science curriculum. Practical work could be essential for the successful learning and teaching of school science. However, practical work should be carried out from a learner's viewpoint as opposed to the viewpoint of educators and/or textbook authors. Practical work is useful and meaningful to learners if they could identify and experience the idea and the activity (Yager, 1991:29).

The rationale for practical work in science involves a number of reasons. It could involve highly complex and abstract subject content for which many learners may fail to comprehend the relevant concepts without the concrete support and opportunities for manipulation afforded in practical work. Practical experiences could be effective in inducing conceptual change (Tamir, 1991:29).

In order to empirically investigate the approaches used by educators in physics practical work, it was necessary to address the following questions: What do researchers view as practical work in science? What is the situation regarding practical work in developing countries as compared to industrialised and developed countries? What are the outcomes of practical work in science? How can the outcomes of practical work be attained? The importance of these questions and answers thereto arise from the aim of this study, that is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa.

The next chapter deals with approaches to practical work. It focuses the nature and history of physics, the constructivist approach to science teaching and different inquiry approaches to science.

CHAPTER 3

APPROACHES TO PHYSICS PRACTICAL WORK

3.1 INTRODUCTION

The aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The aim of this chapter is to give the reader a wider perspective on the different approaches used in practical work. Because of the cardinal importance of practical work in the school science curriculum discussed in Chapter 2, it is important to review the literature on approaches to physics practical work.

To place contemporary approaches to physics practical work in context, paragraph 3.2 outlines the historical overview of the teaching and learning of physics. Paragraph 3.2.1 looks at the learning theories. Paragraph 3.2.2 discusses the educator approaches, while paragraph 3.2.3 looks at the curriculum reforms. The introduction of Outcomes Based Education (OBE) is discussed in paragraph 3.2.4, while paragraph 3.2.5 (Table 3.1) outlines the differences between the old and the new approach (OBE) in South Africa.

3.2 HISTORICAL OVERVIEW OF THE TEACHING AND LEARNING OF PHYSICS

Physics was initially known as "natural philosophy" and appeared as a subject in the early 1800s (Sund & Trowbridge, 1973:233). Content was organised into topics similar to those of our traditional courses today. Mechanics, fluids, heat, light, sound, magnetism, and electricity were the topics taught, mainly by recitation. The Civil War and the event of land-grant colleges in the 1860s placed emphasis on the military and vocational aspects of science and the course became known as physics. Laboratory instruction was emphasised. A list of standard experiments, called "The Descriptive List", was circulated by Harvard in 1886 for use by high schools. Candidates for admission to Harvard were then tested by means of these experiments. The content of high school physics remained nearly constant for more than sixty years, except for the addition of technological information as new advancements occurred. This information was inserted in or appended to the standard course and the textbooks grew thicker. Little was ever removed, although attempts were made to improve the practical nature of the course (Sund & Trowbridge, 1973:233).

Traditionally, science teaching attempted to transmit to learners concepts that are precisely and unambiguously defined, using language capable of transferring ideas from expert to novice (educator to learner) with precision. Sund and Trowbridge (1973:231) further emphasise that science teaching in the secondary school was traditionally concerned mainly with the products of science. Textbooks are sources of facts and theories about the concrete world (Carr *et al.*, 1994:147). According to Sund and Trowbridge (1973:231), textbooks in high school physics were predominantly written by high school educators of physics. These authors were concerned with the accurate communication of scientific knowledge to the high school learner. In the nature of their positions, they were rarely involved in actual scientific research extracting new knowledge from nature. Consequently, the methods of scientific research were given lip service, where learners were not given practice in these methods (Sund & Trowbridge, 1973:231).

As scientific advances were compounded with increasing rapidity in the first half of the twentieth century, textbooks became larger in order to include the newer advances and applications. The science discipline took on the appearance to high school learners of the compendium of knowledge to be memorised or in some way digested. Little attention was paid to the logic of thought development and to the basic cohesiveness of the discipline. Recognition of the burgeoning knowledge in each of the sciences led curriculum planners to try new arrangements in sequence. The real problems caused by excessive attention to applications of science knowledge and an encyclopaedic approach to the subject were not solved (Sund & Trowbridge, 1973:231).

Educators that are themselves insecure in their knowledge of science could find the uncomplicated transmission of knowledge attractive. Transmission teaching avoids discussion (since learners lack knowledge worthy of consideration) and interactions that might reveal educators' uncertain knowledge and so alter power relationships in the classroom. The view of science as a body of unambiguous right answers for transmission into learners' heads could then trap educators into a teaching style inimical to their own and their learning, or into avoidance of the subject entirely (Carr *et al.*, 1994:147).

A further concern about the consequences of this image of science and good learning is that learners who commit the facts to memory are seen to possess a natural ability in science. Other learners are given messages that they are not expected to perform as well. Although having a good memory is an undeniably valuable attribute, there is a good deal of evidence that the memorised knowledge is not well understood. Teaching that values a skill that may not be strongly linked to ability in science could alienate the bulk of learners from the discipline before they have properly experienced it (Carr *et al.*, 1994:147).

The history, nature and philosophy of science have influenced our perception of the world to be subjective. Observations are enmeshed with previous experience of, and existing theories about, the world. We construct meaning for the world around us from our prior attempts to make sense of it (Carr *et al.*, 1994:149). These ideas are attained in the contemporary learning theory, constructivism (paragraph 3.2.1) that initiated changes in educators' approaches (paragraph 3.2.2) and curriculum reforms (paragraph 3.2.3). A consequence is the introduction of OBE in South Africa (paragraph 3.2.4).

3.2.1 Learning theories

Newer theories such as constructivism (paragraph 3.4) see learning as interaction with previously-existing concepts and as the building of new mental constructs from prior understanding. In these theories of learning there is increasing recognition of the importance of the affective dimension in learning, even in the apparently abstract and objective disciplines of science and mathematics. How we feel about the ideas being presented in our learning experiences affects our learning about them (Carr *et al.*, 1994:149). The constructivist approach is discussed in paragraph 3.4.

3.2.2 Educator approaches

For educators the examination-orientated educational system produced time constraints in terms of completing science syllabi and the safest and most timely option was to fulfil learner expectations and adopt educator centred approaches in the classroom. This resulted in educators rushing through syllabi in their attempts to cover all topics, with experiments and demonstrations often being verbally performed by educators and results dictated to learners (Treagust & Thair, 1999:361). Different inquiry-oriented (paragraph 3.5) approaches, discovery, problem-based approaches, the demonstration-based approach, co-operative learning approach, cognitive conflict as a teaching approach, and practical approach, are discussed in paragraphs 3.6, 3.7, 3.8, 3.9, 3.10 and 3.11 respectively.

3.2.3 Curriculum reforms

There is a need for an appropriate curriculum and instructional strategies that allow learners to experience a range of situations that generate the conceptual and procedural knowledge demanded both in and out of the classrooms (Bekalo & Welford, 2000:188). Practical work should form the basis of such a curriculum. However, educators are inadequately prepared to initiate effective learning to fully realise instructional objectives of the new curriculum. Educators therefore generally continue to use traditional educator-centred "chalk and talk" and lecturing methods. While the new curriculum provided instructional outcomes, the problems of identifying and locating appropriate instructional materials and lesson planning were left entirely to the individual classroom educators (Treagust & Thair, 1999:361).

Secondary school science courses have been relatively stable over the years. New courses entered the curriculum from time to time, but only after the character of the school population changed or national emergencies made their existence necessary. Courses that came into being usually found permanent status. Changes were gradual and reflected changing conditions such as industrial advancements, compulsory school laws, or national defence needs (Sund & Trowbridge, 1973:233).

Practical work was guided largely by laboratory workbooks and consisted almost entirely of exercises in verification of physical constants, such as coefficients of expansion, heats of fusion and vaporisation, and acceleration due to gravity. True experimentation was almost entirely absent from high school physics courses. In 1956, a group of university physicists at Cambridge, Massachusetts, took a serious look at the secondary school physics curriculum and found that it did not represent the content or spirit of modern physics. From this group, the Physical Science Study Committee was formed with the objective of producing a modern course for the high school. In the following four years this group developed a textbook, laboratory guide, educator's guide, set of apparatus, monographs, and films. All these aids were correlated closely with one another in order to produce an effective teaching package. In addition, there were a large number of summer institutes for upgrading educators in modern physics and in the philosophy of the new course (Trowbridge *et al.*, 2000:49).

Some of the important differences between the modern course (the course developed by the Physical Science Study Committee) and traditional high school physics were (Trowbridge *et al.*, 2000:49):

- Fewer topics covered at greater depth;
- greater emphasis on laboratory work;
- more emphasis on basic physics;
- developmental approach showing origins of basic ideas of physics; and
- increased difficulty and rigor of the course.

According to Tamir (1991:13), practical work has gradually acquired an increasingly prominent place in the school science curriculum. One of the major changes advocated by the curriculum reform, especially outcomes based education, is that the new conception of the school laboratory is no longer just being an illustrative and confirmatory adjunct to the learning of science concepts but, instead, the centre of the instructional process. Practical work could offer more opportunities for satisfying natural curiosity, individual initiative, independent work, working in one's own time and for obtaining constant feedback regarding the effects of what the learner has been doing.

3.2.4 Introduction of outcomes based education in South Africa

In the period 1991-1997 a new education system for South Africa was designed by nine task teams under the auspices of the National Training Board. In March 1997 the Government announced plans for the introduction of OBE (Outcomes Based Education) at all levels of the country's educational system. One of the most fundamental ways to achieve these purposes was to have a school curriculum in which young people learnt to be active, creative, critical thinkers who would live productive and fulfilling lives when they became adults. This meant that schools should no longer be institutions where learners merely memorised abstract content, but rather places where learners learnt practical and thinking skills that would equip them to obtain and use knowledge that was relevant to their lives or further study (Jacobs & Chalufu, 2002:103).

With the introduction of Curriculum 2005, which is based on the philosophy of outcomes based education (OBE), the new political dispensation in South Africa legislated that active participation of learners in learning should become a reality in all classrooms (Vakalisa, 2002:11).

3.2.5 Differences between the old and new educational approaches in South Africa

The National Department of Education in South Africa sees outcomes based education as a shift from an educator-centred, objective-driven education to a learner-centred, outcomes-oriented education. The outcomes are associated with individuals with certain conceptual knowledge and motor skills (Halloun, 1998). Table 3.1 outlines the differences between the old approach (conventional) and the new approach (OBE).

Table 3.1: Differences between the old and new educational approaches in South Africa

OLD APPROACH	NEW APPROACH (OBE)
Passive learners	Active learners
Exam-driven	Learners are assessed on an ongoing basis
Rote-learning	Encourages critical thinking, reasoning, reflection and action
Syllabus is content-based and broken down into subjects	Integration of knowledge, learning relevant and connected to real-life situations
Textbook/worksheet-bound and educator-centred	Learner-centred, educator acts as a facilitator, educator constantly uses group work and team work to consolidate the new approach
Sees syllabus as rigid and non-negotiable	Learning programmes seen as guides that allow educators to be innovative and creative in designing programmes
Educators are responsible for learners' learning, the motivation of learners is dependent on the educator	Learners take responsibility for their own learning, learners are motivated by constant feedback and affirmation of their worth
Emphasis is put on what the educator hopes to achieve	Emphasis is on outcomes, what the learner becomes and understands
Content is placed into rigid time frames	Flexible time frames allow learners to work at their own pace

It is important to note that Outcomes Based Education (OBE) emerged from and is influenced by constructivism (Halloun, 1998).

The hands-on approach (paragraph 3.3) is dependent on the successful implementation of inquiry-based approaches (paragraph 3.5) such as discovery (paragraph 3.6), problem-based approaches (paragraph 3.7), demonstration-based approach (paragraph 3.8), co-operative learning approach (paragraph 3.9), cognitive conflict as a teaching approach (paragraph 3.10) and the practical approach (paragraph 3.11). It is thus necessary to discuss the hands-on approach in order to place it into context with the latter approaches.

3.3 HANDS-ON APPROACH

Hands-on learning has become a common phrase in science education. Like many other highly used terms and phrases, there are various interpretations of what is meant by hands-on learning (Haury & Rillero, 1994). Rather than an attempt to offer a definitive operational definition, this section presents a variety of viewpoints on what is meant by hands-on learning in science. Issues of whether hands-on learning is a new phenomenon and whether hands-on approaches will continue to have an impact on science teaching and learning in schools will then be addressed.

Hands-on learning means different things to different people. Lowery (1994) emphasises the meaning of the term "hands-on/minds-on", which highlights a biological perspective on human learning. This is the natural way in which humans inquire about the world around them, hence finding the relationship between what they learn in science class and in everyday life. It has become a slogan and is often used to describe any activities in classrooms that use materials. As a slogan, it could easily become a fad. Hands-on learning, however, is not simply manipulating things. It is engaging in in-depth investigations with objects, materials, phenomena and ideas and drawing meaning and understanding from those experiences. Other terms are hands-on and minds-on learning (Haury & Rillero, 1994).

Hands-on learning is learning by doing. To even imply that it is a fad is to ignore what has been taking place in education, both formal and informal, for years. Vocational education has always understood that if you want someone to learn to repair an automobile, you need an automobile to repair. If you want to teach someone to cook, you put them in a kitchen. Likewise, in order to truly teach science, we must "do" science (Haury & Rillero, 1994).

Hands-on learning involves learners in a total learning experience that enhances learners' ability to think critically. The learner must plan a process to test a hypothesis, put the process into motion by using various hands-on materials, see the process to completion, and then be able to explain the attained results. Hands-on learning is not just a fad because it enables learners to become critical thinkers, able to apply not only what they have learned, but more importantly, the process of learning, to various life situations (Haury & Rillero, 1994).

The importance of learner investigation of basic scientific principles cannot be overstated. Hands-on learning may be the only way learners could directly observe and understand science. As learners develop effective techniques for observing and testing everything around them, they learn the *what*, *how*, *when*, and *why*, of things with which they interact. These experiences are necessary if the youngsters of today were to remain "turned-on" to science and become scientifically literate (Haury & Rillero, 1994).

There is no doubt that there is now more emphasis on hands-on materials than in the recent past. That does not mean, however, that the hands-on science activity ever passed away. Furthermore, good science programmes cannot exist without hands-on (Haury & Rillero, 1994).

A hands-on approach requires learners to become active participants instead of passive learners who listen to lectures or watch films. Laboratory and field activities are traditional methods of giving learners hands-on experiences. With the advent of classroom technology, learners can now participate in a non-traditional form of hands-on education through the use of computers. This technology extends hands-on learning to include minds-on skills. An example of this hands-on/minds-on learning is computer simulations (Haury & Rillero, 1994).

The next paragraph (paragraph 3.3.1) looks at the benefits of the hands-on approach.

3.3.1 Benefits of hands-on approach

Educators that embrace hands-on learning in science seem to recognise certain desirable outcomes and endorse learner-centred instructional approaches. Research has confirmed many of the seemingly intuitive benefits of hands-on learning and has also documented a variety of unanticipated benefits. But what effects of hands-on learning are seen by advocates as most important or valuable?

According to research (Haury & Rillero, 1994; Bradley & Maake, 1998:6; Tamir, 1977:311; McDowell & Waddling, 1985:1037; Lowery, 1994; Hodson, 1992:67; Waterman & Thompson, 1989:29) educators' responses to the benefits of hands on include the following;

- Learners in a hands-on science programme remember the material better, feel a sense of accomplishment when the task is completed, and are able to transfer that experience easier to other learning situations. When more than one method of learning is accessed as in hands-on learning, the information has a better chance of being stored in the memory for useful retrieval. Learners that have difficulty in the learning arena for reasons that include auditory deficiencies or behavioural interference, can be found to be on task more often because they are *part of* the learning process and not just spectators.

- Justifying the use of hands-on science is based on all the current research and methods studies. Current researchers support the notion of multi-faceted bombardment of information and experiences so that the retention level is improved. Learners that are involved in laboratories and activities are empowered in their own learning process.

- The benefits of hands-on-learning in schools revolve around those learners that are either not as academically "talented" or have not shown "interest" in school. This method (hands-on approach) tends to stimulate these types of learners into participating and eventually absorbing information that they would not get from "normal" show-me - tell-me methods.

- The single most important benefit is that although it requires a great deal of preparation time, once a system has been developed, hands-on teaching makes teaching fun.

I hear and I forget
I see and I remember
I do and I understand (Haury & Rillero, 1994)

- Although these words may not be the exact translation, they underscore the need for a hands-on approach to science teaching. Without this approach learners must rely on memory and abstract thought, two methods that restrict learning in most students. By actually doing and experiencing science, students develop their critical thinking skills as well as discover scientific concepts. This self-discovery stays with learners throughout their life, while memory fades.

- If learners are not doing hands-on science, they are not doing science. Science is a process and if learners are not actively engaged in the process, they are not doing science. Most science classes in elementary school teach the vocabulary of science and nothing else (Haury & Rillero, 1994).

- Study after study (Haury & Rillero, 1994; Bradley & Maake, 1998:6; Tamir, 1977:311) has shown the value of hands-on learning. Learners are motivated, they learn more, and even their reading skills improve.

Learning by well-planned activities and experiences in a well-engineered programme is a quality instructional approach (Haury & Rillero, 1994), because it:

- Causes learners to rely on the evidence instead of upon authority (encyclopaedia, minister, doctor, text, teacher, and parent). Most learners live in an authoritarian world with little or no opportunity to practise decision-making because nearly everyone tells learners what to do and when to do it. We continually graduate learners that do not yet have the ability to set up a simple experiment with controlled variables, collect and interpret evidence, or make correct interpretations based upon that evidence;
- provides learners with a similar set of experiences so that everyone can participate in discussions on a level playing field regardless of their socio-economic status. In this way, special benefits are not awarded to those who, by virtue of their wealth or background, have a greater number of experiences;
- fosters learners' thinking by requiring interpretation of the observed events, rather than memorisation of correct responses. When a text or teacher tells learners that plants need light to grow (an untruth) learners simply memorise this without question and are hampered by the falsehood for a lifetime. However, when a learner personally germinates seeds in the dark and finds that they grow taller than seeds grown in the light, he/she has irrefutable evidence from personal experience that plants do not need light to grow. Because he/she now has evidence that light inhibits growth (which it does) he/she now has a chance of figuring out why indoor plants grow toward the light (cell growth of the lighted side of the stem is repressed while the unlighted side grows more, thus causing the stem to grow in such a manner as to aim the upper part of the plant toward the light, which is necessary for growth after the stored food energy has been used up); and

- provides learners with direct experiences with materials, objects, and phenomena and is supported by experience and understanding of how learning takes place. While information can be remembered if taught through books and lectures, true understanding and the ability to use knowledge in new situations requires learning in which learners study concepts in depth and over time, and learning that is founded on direct experience. Therefore, the justification for hands-on learning is that it allows learners to build understanding that is functional and to develop the ability to inquire, in other words, to become independent learners.

The educational implications of a hands-on approach to educators are discussed in paragraph 3.3.2 below.

3.3.2 Educational implications of a hands-on approach to educators

While the majority of educators may be supportive of hands-on learning, many are concerned with their limited backgrounds in science. A lack of adequate preparation becomes an obstacle to educators attempting to implement science programmes. Most educators report a need for help in learning new teaching methods and obtaining information about instructional materials. The question is how can the needed knowledge and experience be obtained? (Haury & Rillero, 1994).

Gaining experience with the hands-on approach is critical to feeling comfortable with this teaching approach. Ideally, this experience would be obtained before exposing learners to hands-on lessons. One way to be introduced to hands-on ideas is by annually attending science conferences. Having funding provided is great, but even if that cannot be secured, it is well worth the expense. A wealth of ideas in the form of workshops and presentations are included and are often presented in such a way that the conference attendee participates in the activities, thereby gaining that valuable experience. Additional avenues for this experience include summer workshops or classes, peer coaching, and just diving in with your learners, using the multitude of resources available that focus on hands-on activities (Haury & Rillero, 1994).

Research reports (Haury & Rillero, 1994; Bradley & Maake, 1998:6; Tamir, 1977:311; McDowell & Waddling, 1985:1037; Lowery, 1994; Hodson, 1992:67; Waterman & Thompson, 1989:29) indicate that there are several ways in which educators could gain experience regarding the hands-on approach:

- Watch other educators in your building who use this method.
- Talk to educators who use activities or teach hands-on science. It is often possible to get ideas on activities, materials, classroom management and resources that could ease one's way into this approach.
- Find activities that correlate with a concept that is currently being taught. Try the activity and observe the learners' reactions and their knowledge of the concept after the activity.
- Attend workshops and in-service activities that promote the use of hands-on. Co-operative learning workshops would also encourage implementation.

Practising educators gain experience with hands-on methods by using hands-on science in their classrooms with their learners. A more difficult question is how educators are prepared to enter into the experience. Educators could prepare themselves to teach hands-on science as individuals - without guidance. Many resources are within the financial reach of educators and they could gather their own materials and plunge in. This avenue might not be the most productive, but could work (Haury & Rillero, 1994).

Educators can prepare themselves to teach hands-on science by participating in courses, institutes, workshops and projects with other teachers under the guidance of experts in the area of science methods, curriculum and resources. Such preparation, accompanied by some practical experience teaching science, is often the most effective way to gain proficiency with hands-on science in the shortest time (Haury & Rillero, 1994).

One of the most effective ways to revolutionise the teaching of science is to involve a complete school staff in the process of curriculum reform so that they have investment in the course of study and support from the other teachers in the school. The staff should make a commitment to hands-on methods and seek the resources and guidance needed to bring the curriculum outcomes to reality. The school should provide the teaching materials and the in-service training necessary to implement the programme. Periodic staff meetings to share successes and troubleshoot problems should be a regular part of the business of science education. Recognition of the fact that a vital science programme requires continual in-service and updating is essential. The job is never done - science education is dynamic (Haury & Rillero, 1994).

One becomes a quality hands-on, material-based, inquiry-approach, learner-centred educator by becoming that kind of learner. Roll up your sleeves, dig in, get your hands on, and allow your childlike curiosity to support your wonder and investigations into things that truly interest you, especially the most common events and things in everyday life. The educator should always be searching, testing, open-minded, and a critical thinker. Educators should not be afraid to invent ideas based on real evidence and have their own unique ways of seeing things. Knowledge should be treated as a tool to continue to grow evermore profound ideas and not as a final answer or as a weapon to squash others' equally profound ideas (Haury & Rillero, 1994).

As an educator, one should strive to value the serious thinking of one's learners and encourage dialogue to discuss different ways of explaining things. The growth of ideas could be encouraged by focusing on new learning opportunities presented by each new idea. Finally, students could be invited to join educators, learning adventures as active and confident colleagues in learning (Haury & Rillero, 1994).

Some of the important implications of the hands-on approach include the following (Gollub & Spital, 2002):

- Effective physics curricula: Curricula should emphasise depth of understanding instead of exhaustive coverage of content. Learners need time to examine and discuss new ideas, using a variety of examples and contexts. Educators need time to assess learners' progress and flexibility to adapt their strategies in response. Clearly, a curriculum that leaves little time for anything but the continual introduction of new material makes the achievement of a depth of understanding impossible.
- Effective instruction: Educators should engage learners in inquiry by providing opportunities to experiment, critically analyse information, make conjectures and argue about their validity, and solve problems both individually and in collaboration. Ideally, instructors should recognise and take advantage of differences among learners by using multiple representations of ideas and posing a variety of tasks.
- Effective in-class assessment: Educators of physics need to assess the depth of understanding of their learners continually and modify instruction accordingly. Consequently, educators must require advanced physics learners to explain their reasoning in everything they do during the course.

- Effective practical work: Effective practical work should be an essential part of any high quality science programme. Although the need for hands-on activities (paragraph 3.3) has been emphasised, what really matters is not hands on but minds on. If we want learners to take their practical work seriously, it should be every bit as intellectually challenging as the conceptual or theoretical discussion that attempts to explain it.

The constructivist approach to science teaching is discussed in paragraph 3.4 below. Paragraph 3.4.1 outlines the central principles of constructivism, while in paragraph 3.4.2 the role of educators and learners in a construction of knowledge is discussed. The role of practical work in the construction of knowledge is discussed in paragraph 3.4.3, while constructivist-based strategies are outlined in paragraph 3.4.4. A model of generative science teaching is discussed in paragraph 3.4.5.

3.4 A CONSTRUCTIVIST APPROACH TO SCIENCE TEACHING

The heart of constructivism is the view that cognition is the result of proactive mental construction. The formation of concepts may arise from the interaction between previously accumulated knowledge and current data (Watts, 1994:52). According to the constructivist view, learners enter science classrooms and laboratories with preconceived personally constructed ideas and beliefs that may be relevant to what they are required to learn, while these ideas and beliefs are often at odds with the concepts of science (Gunstone, 1991:67, Zacharia & Anderson, 2003:618). Practical work could be used to reconstruct and restructure the ideas and beliefs of science in order to show the inconsistency between the contrary conceptions and science (Gunstone, 1991:67).

Concept formation could also be viewed from the constructivist approach, meaning that the starting point is the learners' existing knowledge. Viewed in this way, practical work fits into a constructivist psychology of learning and the current emphasis on affective goals and learners' control of learning. Even though practical work may enhance concept formation, White (1988:73) asserts that it has too many unnecessary barriers to learning (e.g. too much noise). Often this noise may be reduced by better planning, or eliminated altogether by the adoption of alternative action methods (Hodson, 1992:68).

The central principles of constructivism are outlined in paragraph 3.4.1.

3.4.1 Central principles of constructivism

The central principles of constructivism are seen to (Watts 1994:56; Hodson, 1998:34; Gunstone, 1991:67; Rita, 1998:27):

- Provide opportunities to explore and elaborate learners' naïve ideas and develop an understanding of science (outcome 1 paragraph 2.4.1);
- promote active learning and actionable learning, where learners must put their understanding into practice and use their knowledge (outcome 1 paragraph 2.4.1);
- engender shared team work and collaborative group activity within an overall social context (outcome 3 paragraph 2.4.1);
- develop practical-related skills (outcome 2 paragraph 2.4.1);
- work through the use of open-ended investigations where there are few correct answers and approaches to any solution and where pluralism rules (outcome 3 paragraph 2.4.1); and
- make science relevant, enjoyable, fruitful, plausible and highly motivating (outcome 4 paragraph 2.4.1).

White and Gunstone (1992:13) further identify three ways in which construction of meaning occurs:

- There is no immediate stimulus from outside the person, but through reflecting on knowledge the person perceives new links, deduces new propositions or creates new images.
- Construction of meaning occurs through incidental learning, where the person forms new episodes from a situation that was not deliberately designed to promote learning and sees that this episode illuminates some knowledge.
- Meanings are constructed under the guidance of an educator.

In the next paragraph (paragraph 3.4.2) the role of educators and learners in the constructivist approach is discussed.

3.4.2 The role of educators and learners

The constructivist model of teaching looks differently at the roles of the educator and of learners in the science classroom than the traditional model. The educator's role is that of a facilitator of the learning process and not an instructor. Learners are not just passive recipients of what is taught, but are actively involved in interpreting and constructing knowledge. Constructivist learning is always an interpretative process involving individuals' constructions of meaning relating to specific occurrences and phenomena. New constructions are built through their relation to prior knowledge. The challenge for educators is to focus on learners' learning with understanding, rather than the more common (and straightforward) emphasis on covering content. Learning science from a constructivist philosophy implies direct experience with science as a process of knowledge generation in which prior knowledge is elaborated and changed on the basis of fresh meanings (Watts, 1994:51).

Paragraph 3.4.3 looks at the role of practical work in the construction of knowledge. This paragraph should be read with outcome 1 of practical work, that is, *reinforcement of the understanding of scientific concepts and principles, making abstract concepts more understandable and supporting theoretical learning* (paragraph 2.4.1).

3.4.3 The role of practical work in the construction of knowledge

Bradley and Maake (1998:6) assert that practical work, although generally enjoyed by learners, may not automatically lead to improved learning of science concepts. Their research indicate that learners could, for example, learn to perform perfect titrations and associated calculations, yet may be unable to answer questions on similar mole concepts. However, they argue that this may not mean that practical work cannot help learners to construct science concepts, but rather, through poor curriculum design, it often may not. The construction of knowledge in science may depend on practical work being minds-on as well as hands-on. Learners should actively engage in thinking about what they are doing, and why. Hence practical work should connect to teaching that has preceded and to that which will follow, as part of a larger plan to improve science knowledge (outcome 1 paragraph 2.4.1) (Bradley & Maake, 1998:6).

Traditionally, practical work could have features that may inhibit the possibility of learners' restructuring personal theories. In particular, the tasks of assembling apparatus and making required measurements could be the responsibility of the learners. For practical work to have an effect on learners' theoretical knowledge, learners need to reconstruct and link concepts in different ways, and they need to spend more time interacting with ideas and apparatus (Gunstone, 1991:74). Laboratory exercises could be used extensively to allow learners to see, touch and smell chemicals and chemical reactions (Smith & Jones, 1989:8). However Hirsch (2002:31) argues that laboratory exercises are limited to equipment that can be safely used in schools.

Constructivist-based strategies are outlined in the next paragraph (paragraph 3.4.4).

3.4.4 Constructivist-based strategies

According to Rita (1998:25) constructivist-based strategies include:

- Giving learners the autonomy to pursue their own questions;
- using open-ended questions;
- increasing wait-time;
- accepting learners' responses with a neutral "Okay" that neither confirms nor rejects their answers;
- beginning units by asking what learners think about a topic before giving input. By unearthing learners' preconceptions, activities can be tailored in such a way that false ideas are dispelled and learners' inquiry and debate are promoted, and
- occasionally beginning units with a hands-on activity rather than a lecture, giving learners something to refer to mentally during a lecture.

Research conducted by Rita (1998:27) indicates that constructivist teaching in an integrated setting has proven to be the conduit to engage learners in critical thinking, problem-solving (paragraph 3.7), and inquiry-based learning (paragraph 3.5).

A model of generative science teaching which is based on constructivism follows in paragraph 3.4.5.

3.4.5 A model of generative science teaching

The model according to Wittrock (1994:32) consists of four cognitive processes. These processes are discussed below.

3.4.5.1 Knowledge, experience, and conceptions

Learning the critical role of the learners' background knowledge and conceptions in science has been clearly established (BouJaoude, 1991:690; Millar, 1991:48; Barnes & Foley, 1999). These learners' conceptions represent a fundamental component of the model of generative science teaching. They represent the knowledge base for building relations between the concepts to be learned and experience summarised in alternative frameworks. The generation of meaningful, scientific conceptions clearly involves these unscientific concepts. The identification of these learner conceptions implies an advance in the design of science teaching for all learners. Science teaching also involves more than showing learners the incorrectness of their beliefs that work quite well for them everyday in realistic contexts. It involves more than setting up dissonances between learners' models and educator controlled demonstrations. Learners are guided to test and develop their models and thought processes in familiar contexts (Wittrock, 1994:32).

3.4.5.2 Motivation and attrition

Generative science learning involves a distinctive type of motivation. The conscious generation of meaning from experience involves taking responsibility for learning, and believing that one can succeed at understanding complex everyday experiences through actively generating and testing concepts. Although it is not commonly developed in models of science teaching, this distinctive type of motivation offers much promise for increasing generative science learning through active involvement of learners in the construction and testing of concepts in science (Wittrock, 1994:33).

3.4.5.3 Generation

To learn science with understanding, learners generate a model or an explanation that organises information into a coherent structure, and that relates the information to their knowledge and experience. Comprehension of science concepts involves building two types of relations, the first one is among the parts of the new information and the second one is between the new information and the learners' knowledge and experience. Educators can use a variety of procedures to facilitate generative learning. First, familiar materials taken from the learners' everyday experience, familiar words, and familiar believable contexts and problems facilitate generative learning. Educators can use the following devices to facilitate learner generation of relations between their background knowledge and believable, familiar contexts and materials:

analogies, metaphors, images, diagrams, examples, demonstrations, pictures, paraphrases (Wittrock, 1994:34).

A variety of procedures could also be used to facilitate learner generation of relations among the parts or the components of science concepts and science frameworks. These include titles, headings, questions, objectives, summaries, tables, problems and explanation. Educators can also lead learners as they become more proficient, to generate these type of relations. For example, learners can learn to generate their own summaries or explanations as they work on a physics problem involving force and motion. Learners can also be asked to generate their own summaries, metaphors, analogies, explanations, diagrams, concepts maps, pictures, and fortune lines, as ways to facilitate generative learning (Wittrock, 1994:34).

Learners can be given these relations and asked to do something mentally with them. Or, learners can be asked to generate these relations. The choice between these different teaching procedures involves the learners' background knowledge and chances of success at using it. Effectiveness of the relationship between the teaching procedures may be influenced by what the learners are asked to do mentally. Teaching can be direct and still involve generative learning, provided the learner are led to examine, apply, test, or just think about the concepts. However, when the learner have the appropriate background information, teaching other than direct teaching (telling them the concepts and answers) often leads to enhanced interest, motivation, attention, and generation of meaningful relations. This facilitates learning with understanding and a sense of competence that does not come as well with learners learning from educators telling (Wittrock, 1994:34).

3.4.5.4 Metacognition

Learners can also be taught awareness and self control over their own thought processes. They can learn from teaching that different types of problems in science involve different structures, different heuristics, and different strategies for their solutions. These meta-processes of science learning seem especially important in a science for all learners. Learners can also learn to monitor their own use of the generative learning strategies. These individual strategies can be organised into sequences of strategies that facilitate comprehension. Learners need to understand the purpose and utility of learning science. They often profit from learning the utility and everyday value of science. When they learn how to transfer their classroom science learning into a meaningful understanding of their everyday experience, their achievement and interest in science increases, and so may their feeling of competence in ability to learn science. These elements of a generative science teaching model relate directly to the problems of creating a learnable science for all learners (Wittrock, 1994:35).

3.5 Inquiry-based approach

Depending on the emphasis placed in inquiry teaching and learning, a distinction can be made between different approaches, which are discussed as follows:

- Discovery-based approach (paragraph 3.6)
- Problem-based approach (paragraph 3.7)
- Demonstration-based approach (paragraph 3.8)
- Co-operative learning approach (paragraph 3.9)
- Cognitive conflict as a teaching approach (paragraph 3.10)
- Practical approach (paragraph 3.11)

Paragraph 3.5.1 deals with what is inquiry, while paragraph 3.5.2 deals with inquiry teaching and learning.

3.5.1 What is inquiry?

Trowbridge *et al.* (2000:175) defines inquiry as the process by which scientists pose questions about the natural world and seek answers and deeper understanding, rather than knowing by authority or other processes.

The inquiry process includes: defining and investigating problems, formulating hypotheses, designing experiments, gathering of data, and drawing conclusions about problems (Trowbridge *et al.*, 2000:207).

Barnes and Foley (1999) assert that inquiry is a term that is often used with multiple meanings. They state the following general features of inquiry:

- It is central to science learning
- It includes interrelated processes of science such as observation and inference.

- It involves questioning and constructing explanations.
- It involves testing explanations against existing science knowledge via experimentation.
- It incorporates communication of findings.
- It involves critical thinking by looking at alternative possibilities.
- It comprises behaviours such as meeting challenges and acknowledging limitations.

Bekalo and Welford (2000:189) point out that an inquiry-based approach allows learners to experience the concept under study first hand by providing structured experiments designed to lead them to discover the underlying concept. This in turn provides the opportunity to develop limited skills (outcome 2 paragraph 2.4.1), such as following instructions.

The next paragraph (paragraph 3.5.2) looks at inquiry teaching and learning.

3.5.2 Inquiry teaching and learning

There has been much discussion for some years about issues surrounding inquiry teaching and learning, especially with respect to operational definitions of inquiry and perceptions of learners, educators, practising scientists, and science education researchers' perceptions of inquiry processes (Barnes & Foley, 1999).

According to Laws *et al.* (1999:33), an emphasis on inquiry skills is based on the observation that the majority of introductory science learners do not have sufficient experience with everyday phenomena to relate concrete experience to scientific explanation. Although lectures and demonstrations may be useful alternatives to reading for transmitting information and teaching specific skills, they may not help learners how to reason, conduct scientific inquiry, or acquire direct experience with natural phenomena. Peers are often more helpful than educators in facilitating original thinking and problem-solving on the part of learners. The time that is often spent passively listening to lectures would be better spent in direct inquiry in collaboration with peers.

The inquiry mode of teaching, in addition to requiring a different philosophical approach by the educator and learners, also demands higher levels of proficiency in the use of tools of inquiry. These tools consist of the skills (outcome 2 paragraph 2.4.1) needed to inquire into natural events and conditions. For example, one could not learn very much about how forces cause masses to accelerate unless one could make careful measurements of distance, time, force, and mass. To learn the interrelationships between all of these factors requires that the learner refine his measurement skills. It is necessary to know how to use a meter stick or measuring tape, to read the units correctly, and to measure force with a spring scale or some other method. In the classroom the learner must have the opportunity to practise the skills (outcome 2 paragraph 2.4.1) required for a particular inquiry situation, otherwise the experience would probably be frustrating and the learning minimal (Trowbridge & Bybee, 1990:238).

Barnes and Foley (1999) hold that educators would find it difficult to use inquiry based methodologies if they themselves have never experienced them. A review of the literature stresses the need for reform in science teaching by using an inquiry approach. This would enable learners to learn science in a more authentic manner and obtain efficient strategies for acquiring, transforming, organising, storing, and using information that is useful in problem-solving (Barnes & Foley, 1999).

The inquiry level of laboratories may be determined by the actual behaviour of the educators and learners. For example, in a typical verification laboratory, the educator could identify the problem to be investigated, relate the investigation to previous work, conduct demonstrations and give direct instructions, while learners repeat the educators' instructions or read the instructions from the manual aloud. On the other hand, in a typical inquiring laboratory, the educator could ask learners to formulate the problems, to relate the investigation to the previous work or to state the purpose of the investigation. Learners actually identify the problem, state the purpose, predict the results, identify the procedures and perform the investigation (Tamir, 1977:311). According to Yager (1991:22), 90% of the so-called laboratories in the United States of America were verification activities, hence no real investigations were conducted and the correct answers to the activities were given before the practical work began.

Although inquiry teaching should receive major emphasis in science teaching, not everything can or should be taught by inquiry. For example, for learners to learn the names of chemical compounds, they must memorise them. If an educator wants learners to learn how to handle a microscope, an educator may have to show them (Trowbridge *et al.*, 2000:213).

The discovery-based approach to practical work is discussed in paragraph 3.6 below.

3.6 Discovery-based approach

The term *discovery* is a mental process of assimilating concepts and principles (Trowbridge *et al.*, 2000:207). White (1988:195) argues that these mental processes should involve deep processing and construction of meaning. However, for a learner to make some discoveries he must perform certain mental processes such as observing, classifying, measuring, predicting, describing and inferring. Inquiry teaching is built on and includes discovery, because a learner must use his discovery capabilities.

Tamir (1977:311) asserts that the laboratory should be used as a place where science learners engage in hands-on activities (paragraph 3.3) such as observations and experiments, that is, not only to verify, but to find. While the laboratory may be used to illustrate objects, concepts, processes and experiments, its major uniqueness could lie in providing learners with opportunities to engage themselves in the processes of investigation and inquiry (Tamir, 1977:311).

In the physical sciences, learners can make observations and measurements and perform experiments. Yet, they often use instruments which translate the actual phenomena into data without being able to observe the actual phenomena directly. In a chemistry laboratory, learners could observe changes in colour or in appearance, hear explosions, notice different smells, and feel changes in temperature. Based on their perceptions, they have to infer what is happening. Atoms and molecules, electrovalent and covalent bonds can neither be seen nor touched, nevertheless experiments could constitute the conceptual basis for understanding what is happening (Tamir, 1991:19).

Hodson (1998:48) argues that without an appreciation of the relationship among theory, observation and experiment, learners have no incentive to progress beyond common-sense everyday levels of conceptual understanding.

Practical work in schools should be used more often to assist in the exploration, manipulation and development of concepts, and to make the concept manifest, comprehensible and useful. According to Hodson (1992:68, the exploration of ideas could constitute the learning process, while bench work could simply provide the concrete evidence of the outcome of the conceptual exploration. Practical work may provide the conceptual core of learning, thus learners should engage in the conceptual understanding of the theory of science. Practical work in school science has been seen as a means of obtaining factual information or data. It should be a way of exploring and developing conceptual understanding. Learners should be involved in the designing and planning of experimental investigations. A lack of theoretical understanding may cause inappropriate observations and hence learners may look in the wrong place and in the wrong way, and thus make incorrect interpretations (Hodson, 1992:68).

White (1988:29) argues that it is important to make accurate observations during experimentation. This would basically help learners learn skills (paragraph 2.4.1) related to classifying, measuring, predicting, describing and inferring during practical activities in science. Learners could thus form mental images that are stored and constructed as learnt elements of memory. Millar (1991:47) emphasises that the quality of observations in the new domain could be influenced by the concepts. Included are the theoretical ideas about the domain that they bring to bear on the task of observation and by the extent to which they are interested. Observation could also be a way of ascertaining the conceptual understanding that learners have, and the understanding they choose to bring to bear when faced with the task. Learners' responses to the observation task may give insight into the knowledge each one brings to the task. Learners should be taught to become better scientific observers, thus the relevant theoretical framework they bring to a specific observation task should be extended. The task should therefore be presented in a way that engages learners' active attention (Millar, 1991:48).

The literature indicates that experimental observations are very important in making correct and accurate interpretations. According to Du Toit *et al.* (1992:265), prescribed textbooks must enable learners to make their own observations, interpretations and deductions. Practical work should provide one such opportunity, where learners are asked to provide written predictions, giving reasons for what happens in certain situations. During educator-facilitated practical sessions, learners should record what they observe and any discrepancies between observations and predictions should be confronted. Scientific knowledge and scientific methodology should develop together. Learners need to be given the opportunity to classify, measure, compare and contrast. This may help them internalise concepts (Hodson, 1992:71).

The problem-based approach follows in paragraph 3.7 below.

3.7 Problem-based approach

Paragraph 3.7.1 looks at what problem-solving is, while in paragraph 3.7.2 problem-solving as a teaching strategy is discussed. The role of the educator and the role of learners in problem-solving are discussed in paragraphs 3.7.3 and 3.7.4 respectively. In paragraph 3.7.5 the key elements of problem-solving are discussed.

3.7.1 What is problem-solving?

The term *problem-solving* has several connotations. Lally (1994:219) describes problem-solving as a set of mental and physical strategies used to reach the goal or aim or to complete the project. It is a central element of human endeavour, and an essential component of much scientific activity. It would seem, then, that problem-solving may include a wide variety of activities in all sorts of contexts. The definitions of the term problem-solving are fine in general terms but far too vague and all embracing for the purposes of busy science educators. Yet, without too much in the way of guidance or help, science educators have been vaguely exhorted to use problem-solving in their teaching (Lally, 1994:219).

3.7.2 Problem-solving as a teaching strategy

Many learners emerge from basic physics courses with significant misconceptions, poor problem-solving abilities, and an inability to apply the scientific concepts or principles that they had ostensibly learned. The scientific knowledge acquired by these learners is thus more superficial than functionally useful. Science instruction where learners acquire a memorised collection of scientific facts and formulas does little to prepare them for their future courses or changing career demands. Instead, instruction should enable learners to apply basic scientific principles flexibly, to explain or predict diverse phenomena, and to become good problem-solvers and independent learners (Scott & Reif, 1999:819).

Problem-solving as a teaching strategy embodies most of the techniques and learning skills that science educators consider important when learning science by investigative methods. This method is also known as the heuristic method. It allows learners to discover things for themselves and to engage in solving problems. They learn through self-activity. Mahaye (2002:235) points out that self-activity always concerns a problem to be solved, a difficulty to be overcome or a confusion to be resolved. It is, however, important that the educator guides the learner towards problems that form part of the prescribed outcomes. Problem-solving is a form of inquiry learning that engages learners in seeking knowledge, processing information and applying ideas to real-world situations. This means that problems have to be real to the learners and fall as much as possible within their field of interest. The problem should challenge the learner and encourage him or her to greater responsibility for his or her own learning. Problem-solving helps in developing learners' thinking (outcome 3 paragraph 2.4.1) and reasoning skills, thus keeping their natural curiosity alive (Mahaye, 2002:235).

Introducing problem-solving as a strategy in educators' repertoire of teaching skills requires some thought and planning. One of the most important points to remember is that learners' expectations should not be overlooked. As with the learning of concepts a constructivist approach may be appropriate. The starting point is the learners' understanding of what a science lesson is. If they (the learners) are used to a particular style of teaching, the educator may create problems if this were altered too quickly. Problems that require the rapid acquisition of a large number of new skills may similarly create overload. The aim should be a balanced mixture of the new and the familiar so that learners perceive the task as challenging and interesting (Lally, 1994:222).

The following are some of the approaches to problem-solving as outlined by Trowbridge *et al.* (2000:212).

- Begin with a task embedded in a familiar setting.
- Introduce problem-solving techniques that might be applicable.
- Allow learners to create their own paths to a solution.
- Emphasise collaborative learning and problem-solving.
- Help develop collaborative working skills.
- Provide different roles for individuals in a group setting.
- Identify, confront, and discuss misconceptions.

3.7.3 The educators' role in problem-solving

The educators' role in problem-solving involves thinking about and presenting everyday situations and experiences that relate to each concept or fundamental law discussed. The educator should be a facilitator and suppress the urge to tell learners what they should try or what they should discover. He or she should encourage sharing of ideas in class and devise a wide range of options for solving the problem. Educators using problem-solving approaches to learning science will inevitably find some element of resistance. There will be reluctance on the part of learners to change their learning styles from what they have been used to in traditional learning. Similarly, learners may express concern about assessment and testing methods because emphasis on factual memorisation will be minimised. Educators themselves may have serious reservations about using problem-solving methods because of the additional time required and a de-emphasis on coverage of textbook materials. There may also be increased expense because of the wide range of resources needed to fully explore solutions to a problem selected (Trowbridge *et al.*, 2000:213).

3.7.4 The learners' role in problem-solving

In problem-solving, learners have implicit theories in action about how things work. They are not always asked to verbalise these, but in order to reach a solution, they must realise and give expression to their theories in some deliberate way. The most powerful impact of problem-solving is in the motivation it gives through tackling real problems, of taking ownership for the issues so that in the full flush of activity, youngsters are barely conscious of the points when they articulate their alternative conceptions (Watts, 1994:53).

3.7.5 The key elements in problem-solving

Different types of activities may combine these elements in a variety of ways. Context may affect ownership, for example, with learners showing reluctance to take responsibility for organising their work if the context is very unfamiliar. Simulations provide another framework for problem-solving activities. A simulation involves planning a clear structure for learners' work so that they may proceed to the creative part of the work without the direct intervention of the educator. The role of the educator changes from that of lesson leader to a lesson co-ordinator and activity facilitator. The degree to which activities are open-ended will vary, depending on factors such as curriculum, time available and equipment limitations. This in turn will affect the planning and preparation required of the educator (Lally, 1994:223).

Key elements in problem-solving activities are summarised by Lally (1994:224) as indicated in Table 3.2.

TABLE 3.2: Elements of problem-solving

Element	Function
Context	The scene or situation in which a problem is set. Context-rich problem-solving adds reality and increases learner involvement. Contexts should be familiar to learners, particularly in early work
Ownership of problem	Learner ownership increases motivation. Ownership is increased by giving learners responsibility for key aspects of the task.
Problem definition	Macro-definition will usually be determined by the educator or curriculum. Macro-definition by learners enhances ownership (and therefore motivation).
Open-endedness	The number of possible solutions to a problem. For practical work this may often be determined by the curriculum, time available and equipment limitations.
Framework	The style of the problem-solving, for example a simulation or an egg race.
Structure	The amount of guidance given to learners for each stage of the problem-solving process.

The next paragraph (paragraph 3.8) looks at the demonstration-based approach.

3.8 Demonstration-based approach

Trowbridge *et al.* (2000:215) define demonstration as a process of showing something to another person or group. A demonstration could be given inductively, by the educator asking several questions but seldom giving answers. An inductive demonstration has the advantage of stressing inquiry, which encourages learners to analyse and make hypotheses based on their knowledge. Their motivation is high because they are like riddles, and in an inductive demonstration they are constantly confronted with riddles. The strength of this motivation becomes apparent if you consider the popularity of puzzles. Inviting learners to enquire why something occurs taxes their minds and requires them to think. Thinking is an active mental process. The only way in which learners learn to think is by having opportunities to do so. An inductive demonstration provides this opportunity because learners' answers to the educators' questions act as feedback. The educator has better understanding of learners' comprehension of the demonstration. The feedback acts as a guide for further questioning until the learners discover the concepts and principles involved in the demonstration, and the educator is sure that they know its meaning and purpose. Demonstrations, in addition to serving as simple observations of material and verification of a process, may also be experimental in nature. A demonstration can become an experiment if it involves a problem for which the solution is not immediately apparent to the class. Learners particularly enjoy experimental demonstrations because such demonstrations usually have more action (Trowbridge *et al.* 2000:216).

A demonstration can be presented in a number of ways (Trowbridge & Bybee, 1990:234), these include:

- *Educator demonstration.* The educator prepares and gives the demonstration on his own. This approach usually has the advantages of better organisation and a more sophisticated presentation.

- *Educator learner demonstration.* This is a team approach where the learner assists the educator. This type of demonstration gives recognition to the learner. The class may be more attentive because they like to watch one of their peers perform.

- *Learner-group demonstration.* This method can be used occasionally and has the advantage that it more actively involves learners in the presentation. The group approach can be used to advantage if learners are allowed to select the members of their group. The educator should evaluate the group as a whole and assign the group a grade, which is the same for each of its members. The groups will at first form among friends. However, if some of the members are not productive, they will be rejected the next time groups are selected. The peer pressure to produce and become actively involved replaces the necessity for an educator to work. This group arrangement may also be effective in organising practical work. The only problem is that the educator must be patient until group pressure is brought to bear on the non-productive learners in the class.
- *Individual learner demonstration.* This method can produce very effective demonstrations, especially if the learner has status among his/her peers.
- *Guest demonstration.* A Guest demonstration can do much to relieve a boring pattern of routine class activities. Other science educators in the school may be called in to present a demonstration or activity in which they have some special competence. Professional scientists are often willing to give special demonstrations.

Reasons for using demonstrations include the following (Trowbridge & Bybee, 1990:232).

- *Lower cost.* Less equipment and fewer materials are needed by the educator doing a demonstration. It is, therefore, cheaper than having an entire class conduct experiments. However, cheaper education is not necessarily better education.

- *Availability of equipment.* Certain demonstrations require equipment not available in sufficient numbers for all learners to use. For example, not every learner in a physics class need to have an oscilloscope to study sound waves.

- *Economy of time.* The time required to set up equipment for a laboratory exercise can often not be justified for the educational value received. An educator can set up a demonstration and use the rest of the time for other instruction.

- *Fewer hazards from dangerous materials.* An educator safely handle dangerous chemicals or apparatus requiring sophisticated skills more safely.

- *Direction of thinking process.* In a demonstration, an educator has a better indication of the learners' thinking processes and can do much to stimulate the learners to be more analytical and synthetic in their reasoning.

- *Show the use of equipment.* An educator may want to show the learners how to use and prevent damage to a microscope, balance, or oscilloscope.

Good science instruction requires individual practical work on the part of the learners. This is because the best science instruction is primarily concerned with the development of critical thinking, independent powers of analysis, various attitudes (outcome 4 paragraph 2.4.1), skills (outcome 2 paragraph 2.4.1), and abilities such as critical problem-solving (outcome 3 paragraph 2.4.1). These skills can simply not be developed if the learner were consistently in the passive position of hearing, reading, and observing the activities and thinking of others. One learns by doing; one learns to solve real problems and to do critical thinking by experience. However, there is a place, usually a neglected place, for educator demonstrations. Verbal descriptions of scientific phenomena and statements of scientific principles need to be supported by realistic experiences if the learners were to appreciate them fully. Learners vary in their abilities to learn from words, which are abstractions of reality. All learners should be helped to increase their powers of critical listening and reading. The educator could assist learners by providing opportunities for the learners to observe the realities behind the words. For some learners, the visual approach is almost a necessity if they were to gain much from science instruction (Burnett, 1957:199).

In this respect, the demonstration method has certain advantages over the individual laboratory method. If the purpose were to provide a clean-cut demonstration of a principle or phenomenon, the educator could usually achieve better results than the learner could. The educator has a mature understanding of the principle or phenomenon, whereas the learner is at the learning stage where there are many hazy aspects. The educator is experienced in handling the equipment and in interpreting and explaining it to others, whereas the learners tend to be inept and confused about the best means of clarifying points of difficulty or ambiguity to others. It is for these reasons that every science class should have the opportunity of observing many clean-cut, clear demonstrations by the educator (Burnett, 1957:200).

Du Toit *et al.* (1991:49) conducted a survey of the influence of a demonstration programme on the attitudes of high school learners towards chemistry. The programme that was developed contained interesting and visually catching demonstrations with direct correlation to the experience of learners and the school syllabus. The principal aims of the programme were to increase learners' interest and to measure changes in attitude towards chemistry. According to the researchers, the real effect of the demonstrations on the attitude of the learners towards chemistry was the number of initially negative learners that were influenced to respond in a positive way after the demonstrations. Although these changes may not be permanent, Du Toit *et al.* (1991:51) argue that they indicate a positive reaction to the programme and that good and interesting teaching can influence learners' interest.

According to research by Du Toit and Lachmann (1997:41), demonstrations have an influence on the interest in and attitude towards the learning task, which in turn has an effect on the achievement of the learner. The influence of the educator (provider of instruction/demonstration) on learning could be positive where the educator helps the learner to process information, for example to organise information and pay attention to main ideas. The influence of a demonstration programme on the attitudes (outcome 4 paragraph 2.4.1) of the learners towards chemistry as reported by Du Toit *et al.* (1991:49), indicates that demonstrations to large audiences may be a powerful method to bring about a positive change in attitude towards chemistry.

A number of studies have been undertaken to determine the relative effectiveness of educator demonstrations (Du Toit & Lachmann, 1997:41; Du Toit *et al.*, 1991:49) and individual learner experimentation (Lowery, 1994; Bradley & Maake, 1998:6; Tamir, 1977:311). These studies appear to present conflicting results. However, careful examination of these studies indicates that the conditions under which the courses were taught varied considerably, as did the objectives of the educator. In general, it may be stated that the educator-demonstration method tends to be superior when the objective is to clarify the nature of a phenomenon or principle. The individual laboratory experiment tends to be superior when the objective is to develop critical thinking and the laboratory experiments are problem-centred rather than cookbook procedures (Burnett, 1957:200).

Educators stressed the importance of self-instruction and less reliance on large group or class instruction. Education should prepare learners for life; part of that preparation must be to ensure that the individual continues to learn long after formal education has ended. It is important for the school to reinforce habits and patterns of learning that would prepare the individual to continue his education many years after he/she has left organised instruction. Practical work, because it involves the individual directly in the learning process as well as imparting working skills, is thought to be superior to teaching by demonstration. A person working on a laboratory problem has learnt far more than just the answer to the problem. He may learn to be efficient, self-reliant, and analytical, to observe, manipulate, measure and reason, to use apparatus, and most importantly, to learn on his own. Individual laboratory experimentation helps to attain these goals better than demonstrations do. For this reason, demonstrations should play a lesser role in science instruction, with individual learner investigation receiving priority (Trowbridge & Bybee, 1990:232).

Statements in support of demonstrations as an instructional strategy are probably an attempt to recognise the difficulties educators face in providing classrooms with sets of apparatus needed to carry out class experiments (Bekalo & Welford, 2000:192).

Co-operative learning is discussed in paragraph 3.9 below.

3.9 Co-operative learning

The term *co-operative learning* was the educational buzzword of the early 1990s (Pratt, 2003:25). During this time, co-operative learning conferences, workshops and resources flourished. Unfortunately, co-operative learning was brushed aside during the recent and essential push to rewrite curricula and activities based on standards. Refocusing co-operative learning will help educators to ensure that their learners attain standards. Jacobs and Ward (2000) indicate that co-operative learning can be defined as principles and strategies for enhancing the value of learner-learner interaction. They (Jacobs & Ward, 2000) argue that co-operative learning does not mean that learners must do everything in groups. While group activities play a significant role in learning, whole-class instruction and individual work continue to have an important place in education. A key point is that co-operative learning represents much more than just asking learners to shove their desks together and work as a group. Gawe (2002:190) describes the term co-operative learning as a way of teaching in which learners work together to ensure that all members in their groups have learnt and assimilated the same content. According to Pratt (2003:25), co-operative education is especially suited to developing inquiry-based activities, guiding and facilitating learning, and designing and managing learning environments.

Group work could mean that learners work co-operatively to accomplish a common goal. Participants contribute towards the performance of the task. Nichols and Millar (1994:167) assert that co-operative group learning could be effective in increasing academic achievement when used properly. The latter is further supported by Pratt (2003:29) and Gawe (2002:201), who argue that increased academic achievement together with improved social skills will be evident when co-operative learning contains two essential ingredients. These ingredients are group goals and individual accountability. The continual learner interaction involved in co-operative learning develops a vibrant community in the classroom. Learners gain a better comprehension of concepts and cultivate their capacity for scientific inquiry by asking questions and discussing each member's contributions to arrive at the best answers. When activities revolve around learning groups, learners communicate about science constantly, resulting in much more equity in the classroom learning curve (Pratt, 2003:29).

The success of co-operative learning could include the positive motivational impact of peer support for learning. Co-operative learning could provide to small groups of learners the opportunity to work jointly to accomplish learning objectives. When peers recognise that their team-mates are successful, it could serve as motivation to other members, who may then develop a positive attitude (outcome 4 paragraph 2.4.1) towards science. If they recognise that their rewards depend on the success of their team-mates, they may provide them with emotional and tutorial support for learning (Nichols & Millar, 1994:167).

Working in co-operative groups may direct learners towards improving their knowledge (outcome 1 paragraph 2.4.1) or skills (outcome 2 paragraph 2.4.1) in their pursuit of the team goal of demonstrating achievement. Learners that adopt learning goals could accept tasks of challenging difficulty, while learners with performance goals tend to avoid challenge and could then be less persistent when difficulties are encountered. Such behaviour may account for the achievement benefits associated with co-operative learning and change in attitude towards science (Nichols & Millar, 1994:168). To use this approach requires that educators should stay enthusiastically involved in the activity. When educators sit down at their desk to do their own work during co-operative learning time, learners tend to shut down. Success depends on the educator continually circulating the room in order to listen (educators can quickly pick up on learner's stumbling blocks), to keep learners on task, and where possible, to challenge learners with questions. (Pratt, 2003:29).

Lengthy consecutive seatwork assignments characterised by learners' reading textbook chapters and completing worksheets, have been found to have an unfavourable impact on time spent on the task and do little to enhance positive attitude development. However, the use of models, illustration and practical work by educators to explain concepts could have a positive effect (Koballa & Crawley, 1985:228).

Bonwell and Eison as quoted by Van Rensburg and Bitzer (1995:138) argue that no single teaching strategy or method is always or necessarily better than another. What is extremely important is that learners should share their views on a course with the educator, because the comments and questions of learners reveal what parts of the course they do not understand and what parts they need to review. Collaborative learning or co-operative learning, where the learners are active in class and not merely passive recipients of information, is propagated in literature as an efficient way to enhance learner participation and learning (Van Rensburg & Bitzer, 1995:138).

Van Rensburg and Bitzer (1995:138) advocate that discussion demands intellectual activity and provides learners with the opportunity to learn more than just factual knowledge. This may include ways in which research is done in the field, how people in the field go about explaining events, as well as the implications of the course for personal attitudes, values and skills. According to research by Banerjee and Vidyapati (1997:903), group rewards and individual accountability within the group are essential to the instructional effectiveness of co-operative learning methods, while classroom strategies could deliver dramatic improvements in learning. These authors' research also indicates that learners of a community college had fewer misconceptions in science following co-operative learning in comparison with those following traditional instructional methods (Banerjee & Vidyapati, 1997:903).

According to Gawe (2002:197), outcomes based education is based on the principle of co-operation, critical thinking and social responsibility and should empower learners to participate in all aspects of society. Co-operative learning as an approach that promotes these principles is central to the successful implementation of the outcomes-based approach. Embedded within the principles of co-operative learning are the enhancement of co-operation, development of critical thinking and social skills. Many South African classrooms have been dominated by instructional approaches that were educator-centred (Gawe, 2002:197). These approaches should be replaced by learner-centred co-operative learning.

3.9.1 Co-operative learning methods

Commonly used co-operative learning methods are discussed in paragraphs 3.9.1.1 to 3.9.1.4.

3.9.1.1 Learner teams' achievement division

In a learner teams' achievement division method, the educator presents a lesson followed by study worksheets for a four- or five-member group. Learners in the groups are heterogeneous in terms of ability, sex and ethnicity. Therefore, learners may participate in individual quizzes about the material presented by the educator. Team scores are computed, based on the degree to which each learner improved on his or her own past record. The team with the highest scores are recognised in a class newspaper (Gawe, 2002:202).

3.9.1.2 Team tournament

A team game tournament is similar to the learner teams; achievement division method (paragraph 3.9.1.1) in rationale and method. In team game tournaments instead of quizzes, learners play academic games to show their mastery of the materials. The games are played weekly in a tournament with members of other teams. Teams typically comprise of three learners per team and the highest-scoring teams are recognised in a newsletter (Gawe, 2002:202).

3.9.1.3 Jigsaw I

In Jigsaw I learners are assigned to six-member groups and each group is given a unique set of information on a particular topic. The learners read the information and discuss material in expert groups. The experts return to their group to communicate information to their group mates. Quizzes are given to each learner. The Jigsaw I method does not use a co-operative incentive structure. Hence it is classified as a co-operative task structure that creates interdependence among learners (Gawe, 2002:202).

3.9.1.4 Jigsaw II

Jigsaw II is a modified version of Jigsaw I. It is similar in technique to the methods described in 3.9.1.1 and 3.9.1.2. Learners work in groups of four or five members. Each group member reads a story about a topic given to each group, and each group gets a different topic. Every individual group member should become an expert on the specific topic assigned. Learners discuss their topic in expert groups and then teach what they have learnt to their group-mates. Quizzes are given to each learner and the scores are rearranged into group scores. The highest-scoring groups are recognised in a class newsletter. Unlike Jigsaw I, Jigsaw II utilises co-operative tasks and incentive structures (Gawe, 2002:202).

3.9.2 Facilitation of group work in the science classroom

The challenge in education today is to effectively teach learners of diverse ability and differing rates of learning. This may be achieved through co-operative learning and cross-age tutoring. In co-operative learning, all contribute to the group effort because learners receive group rewards as well as individual grades. High achievers deepen their understanding and lower achievers gain a sense of accomplishment through contributions to the group problem. Cross-age tutoring allows tutees to receive individualised instruction and work with positive role models. Grouping learners in this way eliminates dull, repetitive programmes that, by nature, at best lead to minimum competencies. With reinforced racial and social-economic isolation and racial prejudice in schools and the alienation toward school among lower-achieving learners, group learning may be the only proven effective port in the storm (Haury & Rillero, 1994).

In order to involve all members of a group in a hands-on learning activity (paragraph 3.3), one should assign roles to learners. For example, one learner may be the recorder, another could be in charge of materials, and another may actually perform the activity. The roles should be rotated or reassigned so that each learner can be involved in every part of the process and each learner may have a chance to play their favourite role (Haury & Rillero, 1994).

There are many strategies for implementing a group learning environment. Haury and Rillero (1994) claim to have used the following strategies successfully:

- Decide on the size of the group. Typically use from two to six learners, depending on the nature of the task and the time available.

- Assign learners to groups, preferably by means of heterogeneous grouping rather than by learner ability or learner self-selection. Do not change group assignments with each new task; rather allow time for each group to get to know each other through the work of several tasks. The educator may change the grouping as little as once a month.

- Arrange the room so that groups can work together without disrupting other groups.

- Plan instructional materials to promote interdependence. Give only one copy of the materials to the group.

- Assign roles to ensure interdependence. Give job titles such as summariser, researcher, recorder, motivator, and observer.

- Structure individual accountability as well as group assessment in which individual's rewards are based both on individual scores and on the average for the group as a whole.
- Discuss desired behaviours. Request that learners take turns, use personal names, listen carefully to one another, and encourage everyone to participate.

- Monitor learner behaviour. Circulate around the room to listen and observe groups in action. Note problems in completing assignments and working co-operatively.

- Allow opportunities for groups to orally report their findings to the whole class.

- Give feedback to each group about how well the members worked with one another and accomplished tasks and how they could improve.

Helping learners to work in groups facilitates hands-on learning and directly engages learners in the processes of science (outcome 3 paragraph 2.4.1). Doing science requires learning skills associated with communication and co-operation as well as procedures associated with inquiry. It is also important to communicate explicit expectations for both individuals and groups and to structure activities so that interdependence is essential to successfully complete the assigned tasks. However, care should be taken not to provide too much direct guidance to groups. Collaborative problem-solving is to be encouraged over getting the right answers (Haury & Rillero, 1994).

Various co-operative learning strategies seem particularly useful in science classrooms. Variants of the Jigsaw approach (paragraph 3.9.1.3 and 3.9.1.4) for instance, provide all learners with the opportunity to be experts and contribute to group learning (Haury & Rillero, 1994).

In general, once learners have learnt how to work productively in groups, the educator should resist the temptation to jump in too early and put learners on the right path. An essential part of learning is ascertaining how to identify a path of inquiry and negotiate that path in collaboration with others (Haury & Rillero, 1994).

3.9.3 The role of the educator in co-operative learning

The educator plays a vital role in the implementation of effective co-operative learning. He/she is responsible for the formation of groups and for the way in which those incentives and rewards are used. Implicit in the assignment of a group problem is the educator's responsibility to explain the assignment, the academic expectations for the group, the expected collaboration behaviours, the procedures to follow, and the definition of group success (Artzt & Newman, 1990:19).

The materials and instructions for their use should be structured in such a way that each learner in the group does something to contribute to the group's work. The problem should be set up so that group members depend on one another to complete the task. The need for co-operation should be emphasised where a single group product is required. It should be made clear that group members are responsible for one another. Each person is expected to learn the material and to help others learn the material (Artzt & Newman, 1990:19).

The educator will have to devise ways to hold each learner accountable for learning the material. This can be done by giving frequent quizzes, randomly selecting a group spokesperson to explain the group's solution, and randomly picking papers to grade. The educator, as a class manager, must see to it that the room is organised in such a way that all members of a group are close enough to one another to work comfortably and talk with one another quietly. The groups must be separated so that they do not interfere with one another. Educators should monitor the groups while they are in progress and provide assistance as needed. When a group is functioning poorly, the educator may want to intervene to help learners with the co-operative skills they need. Once these skills have been identified and discussed, the educator may want to see how well the group is practising them and whether the group is functioning more effectively. The educator should provide feedback so that learners know how well they are doing. The educator may ask the groups to monitor their own performance by answering questions about the group's behaviour and functioning. Needless to say, as educators become comfortable with the co-operative learning approach, they may decide how best to facilitate the co-operative learning process (Artzt & Newman, 1990:19).

In paragraph 3.10 cognitive conflict as a teaching approach is used.

3.10 Cognitive conflict as teaching approach

Cognitive conflict is an approach based on problem-solving strategies that learners find relatively convincing. This is based partially on the fact that the cognitive conflict that the child himself engenders in trying to cope with his world motivates his cognitive development. These are his motives for reconstructing his system of cognitive schemes (Niaz, 1995:961).
Teaching strategies used for introducing cognitive conflicts should be based on data that may be contrary to the expectations of at least some learners. After having generated a cognitive conflict (a situation contrary to learners' expectations), it is essential that learners should be provided with an experience that could facilitate the resolution of the conflict (Niaz, 1995:961). This may be one way of approaching practical work in physics.

The cognitive conflict strategy is based on an interactive approach within an intact classroom, providing the educator with an opportunity to facilitate conceptual change as part of normal class activities. It would be extremely difficult to design a strategy that may provide a conflicting situation for all learners in a classroom (Niaz, 1995:961)

The instructor's role in the teaching of experiments is to generate questions or changes in the learners' experiential field that lead the learners into a situation where they experience conflicts or contradictions between their representations and those needed to interpret the situation. Research by Niaz (1995:961) indicates that although the experimental treatment was effective in improving performance on the immediate post-tests, its effect was not sufficient to produce changes in the cognitive structure of the learners (core belief, establishing equivalent relations between different reactants), which could facilitate conceptual change.

The practical approach by Raghubir (1979:14) is discussed in paragraph 3.11 below.

3.11 PRACTICAL APPROACH

According to Raghubir (1979:14), the practical approach is based on the idea that science instruction is composed of laboratory investigations from which science concepts evolve. In all instances learners begin the study of a unit with laboratory investigations rather than a textbook assignment. It may be easier to teach what happens in science than how it happens or even why it happens, while the outcomes of these latter approaches to teaching may outweigh their difficulties.

The approaches occur in three stages, namely pre-lab, lab and post-lab.

3.11.1 Three stages of a practical approach

3.11.1.1 Pre-lab

During the pre-lab stage the educator discusses techniques and equipment that learners use in the investigation. The purpose of the investigation is formulated so that the conclusion is not revealed or implied. References could be given, depending on the nature of the unit under investigation (Raghubir, 1979:14).

3.11.1.2 Lab

During the lab stage learners engage in the process of the investigation to illustrate the concept without any assistance from the educator, who also refrains from giving any direction or outcomes of the investigations. The educator rather chooses or poses, a question and have them answer it. Minimum assistance can be given in setting up the apparatus. A lab report must be written according to the scientific method before the post-lab discussion (Raghubir, 1979:14).

3.11.1.3 Post-lab

During the post-lab, learners discuss the scientific significance of their observations. All, or almost all, discussions must be related to the investigations. Discussions may lead to the development of theory, the setting of hypotheses, the making of assumptions, the design of further investigations, the understanding of variables, careful observation, analysis and interpretation of results, and synthesis of new knowledge (Raghubir, 1979:14).

Practical work has been shown to be a successful teaching methodology for high school science instruction. According to Raghubir (1979:16), learners have shown significantly higher gains for these cognitive factors: formulating hypotheses, making assumptions, designing and executing investigations, understanding variables, observing carefully, recording data, analysing and interpreting results, and synthesising new knowledge (outcome 2 paragraph 2.4.1) and for attitude (outcome 4 paragraph 2.4.1) development: curiosity, openness, responsibility, and satisfaction, compared with a lecture-laboratory approach.

According to Raghubir (1979:16), learners using practical work acquired a greater understanding of science (outcome 1 paragraph 2.4.1), greater information retention, and a better ability to think scientifically (outcome 3 paragraph 2.4.1). A very important aspect of this methodology is that the gains that learners make in the affective domain (outcome 4 paragraph 2.4.1) seem to have a positive effect on their achievement. Research by Raghubir (1979:16) suggests that a science educator should give learners the opportunity to develop intellectual autonomy and to develop the strategies of a scientist. This is because conventionally taught science courses are typically educator-centred in the sense that they provide the learner with very little opportunity for self-initiated and self-directed study (Raghubir, 1979:16).

3.11.2 Worksheets in practical work

McDowell and Waddling (1985:1037) stress the importance of worksheets in practical work and argue that worksheets enable educators to enhance their learners' learning of the factual knowledge (outcome 1 paragraph 2.4.1) through investigations as well as through the manipulative skills being practised. Worksheets help learners to work at their own pace and to be largely independent of the educator. This frees the educator to spend more time with those learners who need extra attention. Worksheets require that learners comprehend instructions, remember what to do, and then execute a task (McDowell & Waddling, 1985:1037).

The use of worksheets is particularly important because it encourages learner participation through hands-on (paragraph 3.3) and minds-on experimentation. Through the use of well-constructed worksheets learners can keep records of their experiments. This will assist learners in constructing and reconstructing their knowledge (outcome 1 paragraph 2.4.1) and thus make links with other areas of knowledge in new situations (McDowell & Waddling, 1985:1037).

According to McDowell and Waddling (1985:1037), the representation of experimental procedures in the dual mode of text and pictorial flow charts can greatly enhance the learners' understanding of the experimental procedures (outcome 2 paragraph 2.4.1). In this way learners are motivated to compare the information presented in both the text and the pictures. This process leads to rehearsal looping, a subconscious search for contradictions between the pictorial and written input. A continual looping of checks and balances is provided, enabling a deeper mental level of information processing.

Lowery (1994) argues that people learn by doing and thinking about what they do. It is imperative that in a thoughtfully designed curriculum, what the mind learns from hands-on experiences (paragraph 3.3) is extended towards abstraction through representational experiences (still and action pictures, drawings, photographs, video and videodiscs). Full abstraction then, should be reached through appropriate narrative and expository writings (Lowery, 1994). However, this depends on the nature of the experiment and the learners' exposure to the outside world.

Practical activities should involve investigations in which learners are encouraged to attempt to solve problems (outcome 3 paragraph 2.4.1). McDowell and Waddling (1985:1038) strongly emphasise the fact that there is little educational value in using practical activities only to confirm the theory that has been taught earlier in the course. Learners should be placed in a problem-solving situation where they can immediately perceive the problem being presented. If worksheets were to meet these requirements, they must be unambiguously able to convey to learners the spirit of the investigation as well as the procedures and the necessary safety precautions (McDowell & Waddling, 1985:1038).

3.12 The approach used in the North-West Province (South Africa)

In the North-West Province, South Africa, different approaches are suggested, depending on the availability of apparatus. Practical work has been categorised (paragraph 3.12.1). The categories are as follows: theoretical practical work (paragraph 3.12.1.1), practical work with improvised apparatus (paragraph 3.12.1.2), and practical work with specialised equipment (paragraph 3.12.1.3).

The intention with these categories is that learners should achieve the following skills (Department of Education, 2002:10):

1. *Group work*: This includes skills such as listening, communicating, co-operating, accountability and tolerance.
2. *Observation/measurement*: This involves the learner's senses and descriptions of change (e.g. the smell of hydrogen sulphide, the colour of the solution). It includes observation, description, matching, classification, recognition, measurement and estimation, and accuracy.
3. *Investigation*: This involves the designing of experiments, which includes planning, selecting apparatus, identifying variables and formulating hypotheses. Other skills could also be part of this procedure.
4. *Recording*: Recording information in an appropriate manner. Utilise the suitable headings where needed (aims, apparatus, diagram when necessary (e.g. circuits), procedure, observations, results, interpretation of results and conclusions).
5. *Interpretation of data*: Use data obtained to identify trends, make deductions, establish relationships, perform calculations, analyse and establish validity.
6. *Manipulative/Procedural*: Identify, select and set up appropriate apparatus. Demonstrate fine motor control in using apparatus and follow scientific procedures.
7. *Drawing conclusions*: use analyses and interpretations to arrive at and discuss conclusions.

3.12.1 Categories of practical work

According to the Department of Education (2002:11), alternative ways to approach practical work for FET schools without equipment and with apparatus can be divided into three categories. The categories are discussed in paragraphs 3.12.1.1 to 3.12.1.3, while an example (worksheet) of each category is indicated in tables 3.3 to 3.5.

3.12.1.1 Theoretical practical work

To adequately deal with theoretical practical work, educators need a set of identical results and a diagram to explain the equipment being used if learners were to perform the experiment to collect their own data. Each individual school could possibly deal with this type of practical without having any resources (Department of Education, 2002:11).

Ideal results are given to learners and they are involved in the total process, except for the collection of data. An example of this type of practical is given in Table 3.3.

TABLE 3.3: Example of a theoretical practical work

Example: Investigate the relationship between the pressure and volume of an enclosed mass of gas.

Educators' guide:

- ✓ Explain the method and use of the apparatus to learners. This explanation should enable learners to perform the experiment on their own to collect data, if equipment is available.
- ✓ Provide the set of ideal results to learners to record, manipulate, draw graphs, interpret, draw conclusions and discuss findings. Learners must design their own table to record the data.

Results:

VOLUME (add the unit)	PRESSURE (kPa)
35	128,5
32,1	140,2
25	180
20,5	220
15	300
12	375

Since data is provided, the collection and interpretation thereof would probably not be done under these circumstances.

3.12.1.2 Practical with improvised apparatus

To successfully handle practical work with improvised apparatus, educators are required to utilise resources from their immediate working environment and use this exposure for assessment. The North West Department of Education assumes that it is possible for each individual school to deal with this category, despite the presence of very limited resources. An example of this type of practical is given in Table 3.4.

TABLE 3.4: Example of a practical with improvised apparatus

Example: Investigate the factors that influence reaction rate.

Educators' guide:

Use the example of burning wood under different circumstances to investigate the concept. The following factors must receive attention:

- ✓ Surface area - chopping wood into chips.
- ✓ Nature of substance - using different kinds of wood.
- ✓ Temperature - using different types of flames – a candle, stove, or gas burner.
- ✓ Catalyst.
- ✓ Flow of oxygen supply.

The educator can assess various skills during this investigation; the process rather than the final product must be assessed.

Skills such as group work, hypothesising, recording and reporting can be assessed.

Apparatus needed

- ✓ Different kinds of firewood
- ✓ Axe
- ✓ Matches
- ✓ Different types of flames such as a candle, stove, or gas flame.

What to do

- ✓ Let learners discuss the problem making wood burn as quickly as possible.
- ✓ Learners make predictions (hypotheses) as to which factors would have an impact/effect.
- ✓ Learners test their predictions by performing investigations.
- ✓ Learners formulate their findings and use them to confirm or change their predictions.

The educator must guide the learners and not simply provide the possible solutions.

Learners' guide:

- ✓ Discuss with your group the factors that influence your fire.
- ✓ Record your/their investigation findings and report back to the class.
- ✓ Formulate a general hypothesis on the factors influencing reaction rate by using your findings.

3.12.1.3 Practical work with specialised equipment

An example of how practical work with specialised equipment can be approached is given in Table 3.5.

TABLE 3.5: Example of practical with specialised equipment

Example: Investigation based on Ohm's law.

Goals:

- ✓ Determine the unknown resistance.
- ✓ Obtain accurate measurements.
- ✓ Record information obtained in scientific format.
- ✓ Analyse and interpret information.

Instructions:

- ✓ Formulate an action plan to determine the resistance of the unknown resistor.
- ✓ Choose/select appropriate apparatus.
- ✓ Use apparatus and take measurements to obtain data.
- ✓ Manipulate data to determine the required resistance.

Procedures:

I Is it possible to predict the value of a resistor by just looking at it? Explain your answer.

II State your plan of action to determine the resistance and name the apparatus you would need. Also draw an appropriate diagram.

List of apparatus	Circuit diagram

Plan of action (method):

III Put your plan of action to test. Set up the apparatus you have chosen and take the measurements and readings required.

IV Record your results and design/complete a suitable table to record them in a way to depict the relationships involved.

Example of table:

Number of cells	Voltmeter reading (V)	Ammeter reading (I)	V/I
1			
2			
3			

V Interpret the readings, results and calculations and also illustrate the relationship involved (do this in more than one way).

VI Which factors could have been responsible for any deviation in your results? Explain your answer.

VII Formulate your conclusions, including the interpretation of the relationship between the measured physical quantities.

Efforts to successfully reach the outcomes of practical work (paragraph 2.4.1) rely on educators' knowledge of the common weaknesses in learner performances during investigations (paragraph 3.13). Suggested approaches (paragraph 3.13) to eliminate and minimise repetition of such weaknesses could play an important role in reaching the outcomes of practical work.

3.13 Common weaknesses in learners' performance during investigations and suggested approaches

Investigations involve problem-solving with no routine method of arriving at a solution. An interaction of conceptual and procedural understanding is needed to solve investigative problems. While conceptual understanding refers to the facts, laws and principles in science, procedural understanding pertains to the concepts of evidence associated with the design, measurement, data handling, and evaluation of the investigative tasks. For example, concepts associated with design are variable identification, fair test, sample size, and types of relative scale, range and interval, choice of instrument, repeatability, and accuracy. Concepts related to data handing are the appropriate use of tables and graphs. Concepts relevant to the evaluation of the task include the reliability and validity of the ensuing evidence. When performing science investigations, learners face many challenges. However, educators can use classroom strategies to facilitate science investigations and help alleviate common weaknesses associated with learner performance (Chin, 2003:34).

Table 3.5 summarises common weaknesses in learner performance during investigations and suggests the correct approach to be taken as suggested by Chin (2003:35).

TABLE 3.6: Common weaknesses in learner performance during investigations and suggested approaches

Weaknesses	Suggested approach
Planning and design ✓ Not identifying appropriate control, independent, and dependent variables for fair test. ✓ Not planning how to manipulate and measure variables. ✓ Inadequate choice of scale, range and interval of values. ✓ Not planning how to record and organise data to be collected. ✓ Not thinking through the details of the procedure.	✓ Identify which variable need to be kept constant or manipulated and which one is affected as a result. ✓ Decide how to specifically change and measure the variables concerned. ✓ Select adequate range of values to ensure sufficient spread and suitable number of readings. ✓ Plan how to record data using a drawing, table, or graph. ✓ Identify materials to be used and plan what to do at each specific stage.
Carrying out the investigation ✓ Inappropriate handling of equipment leading to inaccurate measurements. ✓ Not controlling relevant variables. ✓ Using a limited range of values. ✓ Not taking repeated measurements.	✓ Use equipment correctly (e.g., hold a thermometer by its upper end, not bulb). ✓ Keep control variables constant. ✓ Use an adequate range to ensure sufficient spread. ✓ Repeat measurements three times to find an average.
Analysis, interpretation, and presentation of results ✓ Using only text to describe or record information may be too scanty or too wordy. ✓ Confusion over use of bar charts and line graphs. ✓ Omitting units of measurements and labels. ✓ Not indicating what lists of numerical data represent. ✓ Making conclusion that does not follow from the findings or that does not address the investigative question.	✓ Use table, if appropriate, to organise data concisely. ✓ Use chart or graph as a visual representation to detect patterns and trends more easily. ✓ Use a bar chart for categorical variables and a line graph for continuos variable. ✓ Include units of measurement for numerical data and labels for diagrams and graph axes. ✓ Order numerical data and use labelled column headings to organise them. ✓ Check that the conclusion is based on and consistent with the data and interpretations, and answer the investigative question.
Post-investigation ✓ Little or no reflection on method, findings and conclusion.	✓ Reflect on the validity and reliability of findings and possible errors. Suggest improvements in design and method.

3.14 CONCLUSION

In this chapter the traditional view of science was scrutinised (Carr *et al.*, 1994:149). This scrutiny has resulted in science being located in a new paradigm (Zacharia & Anderson, 2003:625). The latter is the result of the fact that traditional methods of teaching emphasise static aspects and do not help learners to develop intuition about the dynamics of different phenomena (Hirsch, 2002:31). The literature surveyed for this study indicates that effective physics teaching must encourage the kind of learning that leads to conceptual understanding. Such learning occurs when knowledge is constructed by the individual (Watts 1994:56; Hodson, 1998:34; Gunstone, 1991:67; Rita 1998:27). Therefore, physics teaching should focus on creating interactive classroom learning to facilitate learner self-direction in constructing understandings. Learners can construct scientific conceptions if they experience situations that bring them to question their own alternative conceptions. They are then encouraged to develop more viable replacements built on their own perspectives (Zacharia & Anderson, 2003:625).

A feature from an outcomes-based approach to science teaching is that the outcomes could be different for different learners. Some may want to explore a concept in considerable detail and would develop understandings closer to those of a scientist, while others would be more interested in exploring practical and personal aspects of the topic. This diversity of outcomes poses problems for educators (Carr *et al.*, 1994:150). The outcomes from traditional science lessons are also diverse, although concealed by assessment procedures that rely heavily on recall and rote learning. When understanding is probed at a deeper level, the learning is often found to be superficial, even for learners that have been described as very successful. The problem for learners that are described as successful is that they are often unaware of the partial nature of their development of a particular concept, and find it difficult to contemplate changing their ideas. Procedures in which there is more conversation about learning provide a better base for further learning. The open negotiation of meaning and appreciation of the partial nature of the learning achieved, also model a better image of science (Carr *et al.*, 1994:150).

According to Van Rensburg and Bitzer (1995:138), effective teaching enhances motivation, positively influences learners' attitudes and improves study achievement. Perspectives on the relationship between teaching and learning are forever changing. An increased interest in the learner as a learner results in the conclusion that the independent learning process, and not the quality of instruction, is the major factor influencing academic performance. Lectures, discussions, practical and tutorial sessions, form the framework within which learners learn. The key activity, however, takes place when a learner synthesises and re-evaluates the study content in terms of comprehensibility and previous experience. The role of lecturers and educators can never be denied, though. Science educators have multiple responsibilities. They should help learners learn some of the important accumulated discoveries of humankind as well as to acquire skills for the acquisition and discovery of new information. In addition, they should help learners develop more general problem-solving, communication, and social skills (Lunetta, 1988:164).

Learners should go through the entire lesson with the practical understanding of the purpose, procedure and findings of the experiment. Such an approach may help learners not to acquire or compound misconceptions in physics. Hodson (1992:67) asserts that the approach does not emphasise the retreat to a more traditional approach to practical work that simply aims to illustrate concepts or set out to prove theories that have already been learned. On the contrary, it is an argument in favour of designing a new approach to practical work that is both epistemologically sound (takes into account the contemporary views in the philosophy and sociology of science) and pedagogically sound (takes into account the current views of learners' learning). Both perspectives emphasise prior knowledge and exploration of existing ideas as necessary precursors to practical investigations.

This chapter highlighted approaches used in practical work in the pursuit of effectiveness in teaching practical work in physics. The evaluation of teaching approaches is becoming increasingly important, because a rapidly changing education society is demanding improved teaching performance. The latter involves a process of generating feedback that ought to be used for purposes of self-regulation and improving teaching performance (Van Rensburg & Bitzer, 1995:138). A shift to inquiry-orientated approaches to physics practical work is necessary if we were to reach the outcomes of practical work (paragraph 2.4.1).

The next chapter (Chapter 4) focuses on electric current and Ohm's law.

CHAPTER 4
ELECTRIC CURRENT AND OHM'S LAW

4.1 INTRODUCTION

In this chapter the content of electric current and Ohm's law are presented. Since video-taped micro-lessons presented by educators are based on Ohm's law, the objective of this chapter is to provide the reader with background knowledge on concepts related to electric current and this law. The concepts related to Ohm's law are described.

4.2 ENERGY CONVERSION IN THE ELECTRIC CIRCUIT

In an electric circuit, it is helpful to think of electric energy as being stored in the electric field all around the circuit accompanying the current. Most importantly, the energy is primarily stored in cells and batteries. The function of the electric circuit is to make practical use of the energy stored in cells and batteries. Electric energy can be used to light bulbs, heat stoves and turn motors, in which case it is converted to light, heat and mechanical energy respectively.

4.3 ELECTRIC POTENTIAL

Charges do not flow of themselves. A sustained current requires a suitable pumping device to provide a difference in potential in order to provide a voltage difference. An 'electrical pump' is some sort of voltage source. If we charge one metal sphere positively and another negatively, we can develop a large voltage between the spheres. This voltage sources is not practical. It is not a good electrical pump because when they are connected by a conductor, the potentials equalise in a single brief surge of moving charges. Chemical batteries or generators, on the other hand, are sources of energy in electric circuits and are capable of maintaining a steady flow. Batteries and electric generators do not work to pull negative charges away from positive ones. In chemical batteries, this work is done by the chemical disintegration of, for example zinc or lead in acid, and the energy stored in the chemical bonds is converted to electric potential energy. Generators separate charge by electromagnetic induction. The work done by whatever means in separating the opposite charges is available at the terminals of the battery or generator. This energy per charge provides the difference in potential (voltage) that provides the 'electrical pressure' to move electrons through a circuit joined to these terminals (Hewitt, 1993: 398).

The unit of electric potential (voltage) is the volt. A common automobile battery will provide an electrical pressure of 12 volts to a circuit connected across its terminals. Twelve (12) joules of energy are supplied to each coulomb of charge that is made to flow in the circuit. There is often confusion about charge flowing through a circuit and voltage placed, or impressed, across the circuit. We can distinguish between these ideas by considering a long pipe filled with water. Water will flow through the pipe if there is a difference in pressure across or between its ends. Water flows from the high-pressure end to the low-pressure end. Only the water flows, not the pressure. Similarly, electric charge flows because of the differences in electrical pressure (voltage), while one says that charge flows through a circuit because of an applied voltage across the circuit. One does not say that voltage flows through a circuit. Voltage does not go anywhere, for it is the charges that move. Voltage produces current (if there is a complete circuit) (Hewitt, 1993: 397).

4.4 ELECTRIC CURRENT

When the ends of an electrical conductor are at different electric potentials, charge flows from a higher potential to the lower potential. The flow of charge persists until both ends reach the potential. Without a potential difference, no flow of charge will occur. To attain a sustained flow of charge in a conductor, some arrangement must be provided to maintain a difference in potential while charge flows from one end to the other (Hewitt, 1993: 397).

Electric current is simply the flow of electric charge. In circuits of metal wires, electrons make up the flow of charge. This is because one or more electrons from each metal atom are free to move throughout the atomic lattice. These charge carriers are called conduction electrons. Protons, on the other hand, do not move because they are bound inside the nuclei of atoms that are more or less locked in fixed positions. In fluids, however, positive ions as well as electrons may compose the flow of electric charge. The rate of electrical flow is measured in amperes. An ampere is the rate of flow of 1 coulomb of charge per second. In a wire that carries 5 amperes, for example, 5 coulomb of charge pass any cross section in the wire each second. In a wire that carries 10 amperes, twice as many electrons pass any cross-section each second. It is interesting to note that a current-carrying wire is not electrically charge. Under ordinary conditions, negative conduction electrons swarm through the atomic lattice made up of positively charged atomic nuclei. Thus, there are as many electrons as protons in the wire. Whether a wire carries a current or not, the net charge of the wire is normally zero at every moment (Hewitt, 1993: 397).

4.5 ELECTRICAL RESISTANCE

A battery or generator of some kind is a prime mover and source of voltage in an electric circuit. How much current there is depends not only on the voltage but also on the electrical resistance the conductor offers to the flow of charge. This is similar to the rate of water flow in the pipe, which depends not only on the pressure behind the water but also on the resistance offered by the pipe itself. The resistance of a wire depends on the conductivity of the material and also on its thickness and length. Electrical resistance is less in thick wires. The longer the wire is of course, the greater the resistance. In addition, electrical resistance depends on temperature. The greater the jostling about of atoms within the conductor, the greater resistance the conductor offers to the flow of charge. For most conductors, increased temperature means increased resistance. At temperatures near absolute zero, certain metals acquire infinite conductivity (zero resistance to the flow). Until very recently, it was generally thought that zero electrical resistance could be brought about only in certain metals at these very low temperatures. A big physics breakthrough occurred in 1987 with the discovery that various non-metallic compounds exhibit zero resistance to the flow of charge at much higher temperatures above 100 K. These materials are called superconductors. Once electric current is established in a superconductor, the current will flow indefinitely. At the time of this study, there was an enormous amount of interest in the physics community as to exactly why certain materials acquire superconducting properties. Explanations have generally to do with the wave nature of matter (quantum mechanics) and are being vigorously researched (Hewitt, 1993: 399).

Electrical resistance is measured in units called *ohm. The Greek* letter *omega*, Ω, is commonly used as the symbol for the *ohm*. This unit is named after George Simon Ohm, a German physicist who in 1826 discovered a simple and very important relationship among voltage, current and resistance (Hewitt, 1993: 399).

4.6 OHM'S LAW

The relationship among voltage, current and resistance is summarised by a statement called Ohm's law. Ohm discovered that the amount of current in a circuit is directly proportional to the voltage established across the circuit and is inversely proportional to the resistance of the circuit. Therefore,

$$current = \frac{voltage}{resis\tan ce}$$

Or, in units-form

$$Amperes = \frac{volts}{ohms}$$

So, for a given circuit of constant resistance, current and voltage are proportional to each other. This means we will get twice the current for twice the voltage. The greater the voltage is, the greater the current. However, if the resistance were doubled without change in voltage, the current would be half what it would be otherwise. The greater the resistance is, the smaller the current.

Ohm's law tells us that a potential difference of 1 volt established across a circuit that has a resistance of 1 ohm will produce a current of 1 ampere. If 12 volts are impressed across the same circuit, the current would be 12 amperes. The resistance of a typical lamp cord is much less than 1 ohm, while a typical light bulb has a resistance of about 100 ohms. An iron or electric toaster has a resistance of 15-20 ohms. The low resistance permits a large current, which produces considerable heat. Inside electrical devices such as radio and television receivers, current is regulated by circuit elements called resistors, whose resistance may be a few ohms to millions of ohms (Hewitt, 1993: 400).

The SI unit for resistance is a volt per ampere, which is called *ohm* and is represented by the Greek capital letter omega (Ω). Ohm's law is not a fundamental law of nature like Newton's laws of motion. It is only a statement of the way certain materials behave in electric circuits (Cutnell & Johnson, 2004:581).

4.7 OHM'S LAW AND ELECTRIC SHOCK (APPLICATION)

What causes electric shock in a human body? Is it current or voltage? The damaging effects of shock are the result of current passing through the body. From Ohm's law, we can see that this current depends on the voltage that is applied as well as on the electrical resistance of the human body. The resistance of one's body (e.g. between your hands) depends on its condition and ranges from about 1000 ohms if soaked with salt water to about 500 000 ohms if the skin is very dry. If we touch electrodes of a battery with dry fingers, the resistance our body normally offers to the flow of charge is about 100 000 ohms. We usually cannot feel 12 volts, and 24 volts just barely tingles. If our skin is moist, 24 volts could be quite uncomfortable (Hewitt, 1993: 402).

The human body is a conductor of electricity. The electrical resistance of the human body is fairly large. The resistance between a persons' hands is about 10000 ohms if they are dry and about 1000 ohms if they are wet. There is thus a certain electrical resistance between any two points on a person's body. The magnitude of the resistance depends on the two points on the body between which it is measured. If you touch two objects across which there is an electrical potential difference, this will cause an electric current to flow through your body. The magnitude of the current is determined by the potential difference (Smit, 1992:51).

Many people are killed each year by current from common 120-volt electric circuits. If you touch a120-volt light fixture with your hand while your feet are on the ground, there is a 120-volt 'electrical pressure' between your hand and the ground. Resistance to current flow is usually the greatest between your feet and the ground, so the current is usually not enough to do serious harm. However, if your feet and the ground are wet, there is a low resistance electrical path between your hand and the ground. Your overall resistance is lowered to such an extent that 120-volt potential difference across your body may produce a current greater than your body could withstand. Drops of water that collect around the on-off switch of devices such as a hair-drier could conduct current to the user (Hewitt, 1993: 402).

To receive a shock there must be a difference in electric potential between one part of your body and another part. Most of the current will pass along the path of least electrical resistance connecting these two points. Suppose you fell from a bridge and managed to grab onto a high-voltage power line, halting your fall. As long as you touch nothing else of different potential, you would receive no shock at all. Even if the wire were a few thousand volts above ground potential and even if you hang by it with two hands, no appreciable charge would flow from one hand to the other. This is because there is no appreciable difference in electric potential between your hands. If however, you reach over with one hand and grab onto a wire of different potential ...zap! We have seen birds perched on high-voltage wires. Every part of their bodies is at the same potential as the wire, so they feel no ill effects (Hewitt, 1993: 402).

Most electric plugs and sockets today are wired with three, instead of two, connections. The principal two flat prongs on a plug are for the current-carrying double wire, one part of which is 'live' and the other neutral, while the third round prong is connected directly to the earth. Appliances such as irons, stoves, washing machines, and driers are connected with these three wires. If the live wire accidentally comes into contact with the metal surface of the appliance, the current will be directed to the ground and will not shock anyone who handles it. Electric shock can overheat tissues in the body and disrupt normal nerve functions. It can upset the nerve center that controls breathing. In rescuing shock victims, the first thing to do is clear them from the electric supply with a dry wooden stick or some non-conductor so that you do not get electrocuted yourself. Then apply artificial respiration (Hewitt, 1993: 402).

4.8 ELECTRIC CIRCUITS

Any path along which electrons can flow is a circuit. For the continuous flow of electrons, there must be a complete circuit with no gaps. A gap is usually provided by an electric switch that can be opened or closed to either cut off or allow energy flow. Most circuits have more than one devise that receives electric energy. These devices are commonly connected in a circuit in one of two ways, series or parallel. When connected in series, they form a single pathway for electron flow between the terminals of the battery, generator, or wall socket. When connected in parallel, they form branches, each of which is a separate path for the flow of electrons. Both series and parallel connections have their own distinctive characteristics (Hewitt, 1993: 406).

4.8.1 Series circuits

The following are characteristics of a series circuit (Hewitt, 1993: 407):

- Electric current has only a single pathway through the circuit. This means that the current passing through the resistance of each electrical device is the same.

- The current in the circuit is numerically equal to the voltage supplied by the source, divided by the total resistance of the circuit. This is in accordance with Ohm's law.
- The total voltage impressed across a series circuit divides among individual devices in the circuit so that the sum of the 'voltage drops' across the resistance of each individual device is equal to the total voltage supplied by the source. This follows from the fact that the amount of energy given to the total current is equal to the sum of energies given to each device.
- The voltage drop across each device is proportional to its resistance. This follows from the fact that more energy is dissipated when a current passes through a large resistance than when the same current passes through a small resistance.

However, if the current in one resistor is interrupted, the current in the other is too. This could occur, for example, if two light bulbs were connected in series and the filament of one bulb broke (Cutnell & Johnson, 2004:589).

4.8.2 Parallel circuits

The mayor characteristics of parallel connections are (Hewitt, 1993: 408, Cutnell & Johnson, 2004:590):

- The voltage is the same across each device connected in parallel.
- The total current in the circuit divides among the parallel branches. Since the voltage across each branch is the same, the amount of current in each branch is inversely proportional to the resistance of the branch.
- The total current in the circuit equals the sum of the currents in its parallel branches.
- As the number of parallel branches is increased, the overall resistance of the circuit is decreased. Overall resistance is lowered with each added path. This means the overall resistance of the circuit is less than the resistance of one of the branches.

4.9 CONCLUSION

This chapter addressed questions such as: What constitutes the flow of charge? What is electric current, voltages sources and electrical resistance? It discussed Ohm's law and its applications.

It was important to provide the reader with a background on the latter, since the micro-lessons presented were based on Ohm's law.

The next chapter (Chapter 5) outlines the research methodology followed in this study. It focuses on the literature study as a research method, the methodology followed in the empirical research - that is, target population, coding scheme, video-tapes, direct observation as a method to collect data, recording information, advantages and disadvantages of making video-recordings as a method of collecting data, data analysis and the ethical aspects of the research.

CHAPTER 5
RESEARCH METHODOLOGY

5.1 INTRODUCTION

This chapter outlines the research methodology followed in the study. As mentioned in the first chapter, the aim of this study was to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The study was done through a literature survey and empirical investigation.

Paragraphs 5.2 and 5.3 respectively constitute the research methodology of the literature study and empirical investigation.

5.2 LITERATURE STUDY

The literature review plays a vital role in any research endeavour. It was included in this study because of its value and functions as listed below (Hitchcock & Hughes, 1995:90):

A literature review:

- Broadens and refines existing knowledge.
- Helps to sharpen and clarify research questions.
- Can highlight gaps and under-researched areas.
- Helps clarify theoretical, methodological and analytical issues.
- Will identify current debates and controversies.
- May have its own intrinsic merits.

Study material for the purpose of this survey was obtained by means of an electronic search of publications on the subject in scientific and educational journals and from the Internet. Chapter 2 dealt with the role of practical work in the science curriculum. A review of literature covered different perspectives on the outcomes, meaning, effectiveness and descriptions of the term practical work. This was done to review the different views held by science educators, researchers and scientists in general regarding practical work and the role it plays in the science curriculum. In Chapter 3 a review of literature on the different approaches to practical work in physics was done. The approaches reviewed include the constructivist approach, inquiry-based approach, discovery-based approach, problem-based approach, demonstration-based approach and co-operative learning.

5.3 EMPIRICAL INVESTIGATION

5.3.1 Target population

The target population for this study were educators attending an upgrading programme (Sediba) at the North-West University (Potchefstroom Campus). The group consisted of 46 educators teaching grades 10-12 in the FET (Further Education and Training band). Subjects taught by this group include physical science and mathematics. The highest qualification possessed by these educators was a three-year Diploma in Education, majoring in physics and chemistry.

5.3.2 Empirical research design

Table 5.1 indicates the protocol followed in the empirical investigation. The educators' programme is divided into 4 contact sessions January (first), April (second), July (third) and September (fourth) contact session. The activities were spread throughout the four contact sessions.

Table 5.1: Empirical research design

Activity	Participant	Date
Completion of the coding scheme (Appendix A) Completion of the assignment (Appendix B)	Educators	Between January and March
Analysis of the coding scheme and the assignment.	Researcher	Before the second contact session (April)
Preparation of the micro-lessons (Appendices J to O) in groups.	Educators	April contact session

↓

Presentation of micro-lessons and video-recordings.	Educators Video services of the North-West University, Potchefstroom Campus	April contact session
Viewing of video-taped micro-lessons and discussions.	Educators Researcher facilitates the discussion	April contact session
Repeated viewing of tapes, transcription (Appendices D to I) and analysis (paragraph 6.4).	Researcher	Between April and July contact sessions
Discussion of video-taped micro-lessons.	Educators Researcher facilitates	July contact session
Preparation of the "model" micro-lesson (Appendix R).	Educators Researcher facilitates	September contact session
Presentation and video-recording of the "model" micro-lesson.	Volunteer educator Video services of the North-West University, Potchefstroom Campus	September contact session
Viewing of the video-taped "model" micro-lesson.	Researcher and educators	September contact session
Repeated viewing of the video-taped "model" micro-lesson, transcription (Appendix S) and analysis (paragraph 6.6).	Researcher	September contact session

Discussion of the video-taped "model" micro-lesson.	Educators Researcher facilitates	September contact session
Completion of the questionnaire (Appendix Q).	Educators	September contact session
Analysis of the questionnaire (Appendix Q).	Researcher	After the last contact session (September)

The assignment (Appendix B) was given to educators in the first contact session (January 2004). The educators were given two months to complete the assignments, where after the assignments were returned to the researcher on 1 March 2004. Despite the fact that not all educators who took part in the research posted the assignments in time, the researcher evaluated all the available assignments before the educators came for the second contact session (April 2004). The remaining assignments were submitted at the beginning of the second contact session (April 2004) and were also evaluated.

The experiment used in the video-taped micro-lessons was selected from experiments prescribed by the North-West Department of Education for compilation of the Grade 12 continuous assessment marks (CASS).

The experiments prescribed for physics are as follows:

- Triangle of forces or the parallelogram of forces;
- Newton's second law;
- The charge of an electroscope by contact and induction; and
- The relation between the potential difference across a resistor and the current passing through that resistor (Ohm's law).

For the purpose of this study, educators prepared a micro-lesson on Ohm's law. As specified in the assignment (Appendix B), the lesson had to be prepared according to OBE requirements. As part of the preparation the educators were requested to complete the coding scheme (Appendix A).

During the second contact session (April 2004) individual efforts were combined during the group preparation. The 46 educators that attended the upgrading course were then asked to divide themselves into 6 groups. The first and second group consisted of 7 members each, the third group consisted of 9 members, the fourth group consisted of 7 members and the fifth and sixth group consisted of 8 members each. Each small group had to compile one lesson from their individual efforts. Micro-lesson plans (Appendices J, K, L, M, N and O) were respectively compiled by the first, second, third, fourth, fifth and sixth group of educators. One educator in each group presented the micro-lesson while the others role-played the learners.

Educators presented the micro-lessons and their presentations were video-taped. The video-taped micro-lessons were viewed and discussed with educators during the April and July 2004 contact sessions. The latter resulted in the preparation, presentation, and video-recording of the "model" micro-lesson in September 2004 (last contact session). The educators, together with the researcher, viewed and discussed the "model" micro-lesson. The discussion was facilitated by the researcher. A questionnaire (Appendix Q) was used to gauge perceptions of educators on video-taped micro-teaching as a tool in modelling educators' approaches to physics practical work.

5.4 DATA COLLECTION METHODS

Data for this study was collected from the following:

- Educators' responses to the coding scheme (Appendix A);
- a questionnaire in the form of an assignment (Appendix B);
- micro-lesson plans (Appendix J, K, L, M, N, O and R);
- video-tapes and transcripts of video-taped micro-lessons (Appendices D, E, F, G, H, I and S); and
- a questionnaire (Appendix Q) on video-taped micro-teaching.

The following instruments were used to collect data:

- Coding scheme (discussed in paragraph 5.4.1);

- video-tapes (discussed in paragraph 5.4.2);
- direct observation (discussed in paragraph 5.4.3); and
- questionnaires (discussed in paragraph 5.4.4).

5.4.1 Coding scheme

A coding scheme for effectiveness of practical work as proposed by Millar *et al.* (2002:13) was modified and used for the purpose of this study.

The coding scheme was used because of the following reasons:

- It describes in detail the characteristics of a practical task.
- It can be used to produce a profile of salient features of any practical task.
- Similarities and differences in the kinds of practical work used in school science can be identified, perhaps to compare the types used at different ages or stages, or different science disciplines.
- The coding categories may suggest questions that science educators and researchers might ask about practical work. For example, what is the degree of openness in the task used and how does this compare with our intentions as science educators.
- It provides a basis for addressing questions of effectiveness of practical work.

In this way we may be able, over time, to progress towards a more effective use of practical work in science at all levels (Millar *et al.*, 1999:50). The coding had been used successfully by Millar *et al.* (2002:13).

Sub-scale A of the coding scheme focused on the educators' intended teaching outcomes of the practical. The teaching outcomes were divided into two main groups, namely content and process. The former are concerned with the learning of some aspect of scientific knowledge, the latter with learning some aspects of the process of scientific inquiry.

Sub-scale B dealt with the key elements of a practical task and was divided into three sections: The cognitive structure of the task (section B1), the level and nature of learner involvement (section B2) and the practical context of the task (section B3).

Sub-scale C included the items on the attitudes of educators towards practical work in physics. The items in sub-scales A and B resemble those used by Millar *et al.* (2002:13), while sub-scale C was added by the researcher.

In this study the coding scheme was used as part of educators' individual preparation of the experiment used in this investigation, namely Ohm's law. Their individual efforts were combined in the groups and resulted in the video-taped presentations.

5.4.2 Video-tapes/recordings

At first sight, video-recordings combine the advantages of tape-recording and direct observation as well as providing a record of movements. However, they also combine the disadvantages of both.

The advantages follow in paragraph 5.4.2.1, while the disadvantages are indicated in paragraph 5.4.2.2.

5.4.2.1 Advantages

Video-recordings were used in this study because of the following advantages (Altrichter *et al.*, 1993:100):

- The main advantage is that a relatively holistic record is made of the situation, seen from the perspective of a camera.
- By representing the sequence of events in time, video-recordings can make the context and causal relationships more accessible than other methods of data collection can.
- Behaviour patterns become visible, including the relationship between verbal and non-verbal behaviour.
- Video-tapes are also an excellent way of presenting a situation to others to open up a discussion.

The researchers' observations and important conversations in the video-taped micro-lessons are presented as transcripts in Appendices D, E, F, G, H, I and S.

5.4.2.2 Disadvantages

The advantages of video-recordings must, however, be weighed against several disadvantages (Altrichter *et al.*, 1993:100):

- Video-recordings involve the use of equipment that can be very distracting in a classroom. This could be minimised by using the camera in a static position and using it frequently enough for it to become a routine.
- Video-recordings can be misleading because they give the appearance of being a complete record of events when, in fact, they are highly selective.
- Making good use of video-recordings takes a lot of time.
- A careful analysis concentrating on events that appear to be essential in terms of research questions requires repeated playing of the tape.

Video-recording took place in the studio of the North-West University (Potchefstroom Campus). Intensive preparation was done to organise the studio so that it resembled a classroom situation. However, there were various limitations to the study, namely:

- The researcher confined educators' lessons to exactly 45 minutes.
- Only six (6) micro-lessons and an additional micro-lesson termed "model" micro-lesson were presented and video-taped.

These limitations were due to the costs involved in video-recordings.

In this study video-recordings and direct observations were used with due consideration of both the advantages and disadvantages attached to both methods.

5.4.3 Direct observation as a method to collect data

Direct observation of a situation does not require any technical tools except pencil and paper. It can be thought of as a form of participant observation, a well-known method used by anthropologists and ethnographers. Gay and Airasian (2000:212) argue that the advantages of participant observation include the ability to gain insights and develop relationship with the participants that cannot be obtained in other ways. Normally, participant observers are professional researchers that become part of social situations in order to investigate them. However, for educator-researchers, the prime task is not observation but teaching. When teachers observe lessons systematically, they are taking on a second task that sometimes fits in with their teaching but may sometimes conflict with it (Altrichter *et al.*, 1993:83).

The drawbacks to participant observation are that the researcher may lose objectivity and become emotionally involved with participants. More pragmatically, the researcher may have difficulty participating and taking detailed field notes simultaneously. Non-participant observers are less intrusive and less likely to become emotionally involved with participants. Information such as participants' opinions, attitudes and emotional states are difficult to obtain. Most qualitative research is naturalistic, encompassing holistic inquiry about participants' understanding of their natural setting or environment. The emphasis is on understanding the natural environment as lived by the participants, with no intent on the researchers' part to alter or manipulate the natural environment (Gay & Airasian, 2000:212).

The most important skill in observing is sensitivity to what is observed. Observers have to cope with the dilemma that is normally insoluble. Reality is what is reconstructed from the observers' current understanding. On the other hand, reality has its own stubborn character that resists interpretation and reconstruction. This dilemma can only be solved by double vision, by being aware of one's assumptions and expectations and at the same time approaching each situation as if it were a totally new one. The temptation to make quick and simplistic assumptions about a situation based on one's own prejudices is very strong, particularly for a researcher that is under pressure to take action. In spite of these difficulties, there are particular advantages in using direct observation as a method of data collection, in particular because it relates well to the complex processes of teaching and learning (Altrichter *et al.*, 1993:83).

The researcher took the above-mentioned points into consideration, hence deciding to make observations through monitors in the production room of the video services of the North-West University (Potchefstroom Campus). This enabled all participants to feel free during the presentations. The notes taken by the researcher in the production room during the presentations were later refined when the tapes were viewed.

The following paragraphs looks at the preparation needed to make observations (paragraph 5.4.3.1), recording observations (paragraph 5.4.3.2) and using other people as observers (paragraph 5.4.3.3).

5.4.3.1 Preparing to observe

Observation always involves selecting from a stream of events. The following should be taken into account when preparing to observe (Altrichter *et al.*, 1993:84).

- ***What are you going to observe?*** The more limited the focus of observation, the more precisely it can be observed. However, the more limited the focus of observation, the more likely it is that the outcomes will shed light on only a small, possibly even minor, aspect of the original research question.

The researcher was mainly interested in the approach used by the educators during the lesson. Appendix P indicates the specifics that the researcher looked at when making observations.

- ***Why are you carrying out the observation?*** What are the assumptions and expectations on which it is based? Observing is not a mere registering, but also a theoretical reconstruction of a situation. The observers' assumptions and expectations are theoretical tools for this reconstruction. They are the observers' prejudgements, although striving for objectivity in observing does not mean that these prejudgements can be completely avoided. Instead they should be clarified as far as possible, so that the part they play in producing an understanding can be taken into account at the stage of interpretation.

In this study the reason for carrying out observations are embodied in the aim of this study, which is indicated in paragraph 1.3.

- ***When will the observation be carried out and how long will it take?*** It is particularly important for an educator-researcher to decide beforehand at which times in the lesson it is likely to be possible to devote attention to observation.

In this study the observations were carried out during the presentations (through the monitors in the production room of the video services of the North-West University, Potchefstroom Campus) and after presentations (by viewing the tapes repeatedly). The steps followed are indicated in Table 5.1.

5.4.3.2 Recording observations

Time is a rare commodity for researchers during lessons. It may save time to use an observation schedule with predefined categories. In the lesson each relevant event is then assigned to a category and thereby recorded. It always works better when researchers design their own schedules and match them closely to the purpose and subject of their observation (Altrichter *et al.*, 1993:84). Items indicated in Appendix P were used to record and evaluate observations. It is usually much easier for researchers to make a record of the observation after the event, even though this might mean that some details will be lost. In most cases, the researcher will not be able to write a full record immediately after the observation. However, the most important observation should be recorded as soon as possible, at least in the form of brief notes to enable a fuller reconstruction at a later time (Altrichter *et al.*, 1993:86).

The keen observations and important conversations one has in the field cannot be fully utilised in a rigorous analysis of data unless they are written out in full. In addition to viewing the tapes several times, the researcher transcribed all the video-taped micro-lessons (see transcripts Appendices D, E, F, G, H, I and S). The researcher's transcripts contain what has been seen and heard by the researcher, without interpretation. In other words, the participant observers' primary task is to record what happened without inferring feelings to the participant. The researcher attempts to provide the clearest and most complete narrative of what went on in the field. People's actions and interactions are described (Maykut & Morehouse, 1994:73).

Data obtained requires some selection and interpretation. The researcher becomes adept at weaving descriptions, speakers' words, field note quotations and their own interpretation into a rich and believable descriptive narrative. Although description is the primary aim of data analysis, some of the interpretations found in descriptive research suggest an interest in theory building (Maykut & Morehouse, 1994:122).

In this study the researcher was sitting in the production room of the video services of the North-West University (Potchefstroom Campus). The educators (who role-played the learners) and their presenter were not aware that the researcher was observing their lesson presentations through the monitors in the production room during the recording. Hence the researcher managed to take notes that were later detailed when the researcher viewed the video-taped lessons. This helped to ensure that educators participated fully in the lesson.

5.4.3.3 Using other people as observers

As paradoxical as it may sound, most educators know too much to make good observers in their own classrooms. Observation may require a stranger's view, an ability to see the unexpected and uncommon in daily routines and in what is considered normal. Every situation in the classroom can be seen from different perspectives (Altrichter *et al.*, 1993:91):

- *The educators' perspective.* The educator is responsible for organising what goes on in the classroom and will tend to judge the lesson as more or less successful, according to specific aims.

- *The learners' perspectives.* They may see themselves in a number of roles, for example, as partners (or opponents) of the educator in organising and enacting what goes on.

- *Another person's perspective.* An outsider would want to experience the situation and understand it.

In this study the researcher and supervisor, together with educators, viewed and discussed the video-taped lessons. The researcher put together his perspective and the perspectives of both the educators and the supervisor when analysing the video-taped micro-lessons.

5.4.3.4 Micro-teaching/micro-lessons

It should be noted that though the researcher continually uses the phrase micro-lesson(s), in this study the educators presented a 45 minutes lesson to a small group of educators. This was done in order to obtain a detailed analysis of the lessons presented. In addition, research findings by McIntyre *et al.* (1977:32) indicated that students tend to prefer longer lessons. Hence, the lessons themselves were not micro. In the context of this study the term "micro" is used to refer to a small group of educators who role played the learners. This is contrary to the normal micro-lessons which involve presentations to a small group of learners in a short space of time (Stones & Morris, 1972: 80).

The following are the advantages of micro-lessons:

- It is real teaching (Stones & Morris, 1972: 80).
- It focuses on the accomplishment of specific tasks (Stones & Morris, 1972: 80).
- The student can systematically analyse his own teaching and to make his own evaluations (McIntyre *et al.* 1977:11).
- Feedback is provided immediately (Stones & Morris, 1972: 80).

However, micro-lessons can be expensive in man power, equipment and organisation (McIntyre *et al.* 1977:31).

5.4.4 Questionnaires

Questionnaires (Appendices B, P and Q) were used in this study.

The objectives of the questionnaire (Appendix B) were to:

- Ascertain how educators prepare OBE lessons in physics with specific reference to Ohm's law;
- determine educators' knowledge and characteristics of OBE lessons in physics;
- determine what educators view as practical work in physics; and
- probe the educators' knowledge of the outcomes of practical work.

This questionnaire (Appendix B) was given to educators as an assignment.

The questionnaire (Appendix P) was developed and completed by the researcher according to the following objective:

- To record, evaluate and analysis observations in the video-taped micro-lessons.

The objective of the questionnaire (Appendix Q) was to:

- Gauge perceptions of educators on video-taped micro-teaching as a tool in modelling educators' approaches to physics practical work.

The questionnaires were chosen as a tool because of its advantages (paragraph 5.4.4.1), although it also has its disadvantages (paragraph 5.4.4.2).

5.4.4.1 Advantages

The questionnaire was used as tool of investigation because of the following advantages (Schnetler *et al.*, 1989:50):

- It is economical for both the sender and the respondent in terms of time, effort and cost.
- It facilitates contact with the subjects of the study who could not otherwise be reached.
- It is relatively easy to plan, construct and administer.
- It has great potential when properly used.
- Once it has been constructed skilfully, the investigator may ask anybody to administer it on his behalf.
- It places less pressure on the subject for immediate response; the subject can answer it at leisure; and
- It helps in focusing the respondent's attention on all the significant items.

5.4.4.2 Disadvantages

Apart from the advantages mentioned in 5.4.4.1, questionnaires have the following disadvantages (Schnetler *et al.*, 1989:50):

- Structured questionnaires could result in a loss of rapport and also frustrations when respondents feel that their personal options were not included.
- Questionnaire studies often do not probe deep enough to reveal a true picture of opinions and feelings.
- The absence of subtlety in structured questions makes it easy for respondents to discern the purpose behind the question, thus forming subjective opinions.
- The structured questionnaire limits the subject's response so that some vital information may be omitted. Subjects may also choose alternatives that do not really reflect their true attitudes.
- Some respondents may not feel happy about airing their views on controversial issues in black and white. Such views can be drawn out only through interviews.

- If the subject misinterprets a question, little can be done to rectify the misinterpretation.
- A low response rate is the biggest disadvantage of questionnaires. The respondents who return the questionnaire may not constitute a representative section of the entire group.

5.5 DATA ANALYSIS

Analysis is what the researcher does with data in order to develop explanations of events so that theories and generalisations about the causes, reasons and processes of any piece of social behaviour can be developed. Analysis therefore looks for the major properties of any event or set of events. Evaluation might therefore be defined as that process that subjects data and the theories developed to some kind of assessment in terms of specific criteria. The aim is to unravel the effectiveness and the success of particularly arranged activities (Hitchcock & Hughes, 1995:97).

According to Gay and Airasian (2000:238), the process of data collection, either by observation or interview, interacts with the process of data interpretation and analysis. It is difficult if not impossible for researchers to divorce data collection from data interpretation and analysis. Data analysis begins with data collection. The fact that researchers write memos to themselves demonstrates that they are thinking about what the data means or how they relate to one another. Whether consciously or unconsciously, the researcher would inevitably bring perceptions, interpretations and viewpoints from the data collection process to the data analysis process.

5.6 QUALITATIVE AND QUANTITATIVE ANALYSIS

The data obtained for this study was analysed both quantitatively and qualitatively.

Qualitative research seeks to probe deeply into the research setting in order to obtain understanding about the way things are, why they are that way, and how the participants in the context perceive them (Gay & Airasian, 2000:238).
Qualitative evaluation methods are useful in programmes where goals are in the process of being defined and to test out the workability of the evaluation methods. Because they are personalised, qualitative methods may add emotion and tone to purely statistical findings and provide a means of gauging outcomes when reliable and valid measures of those outcomes are likely to become available in time for the evaluation report (Hitchcock & Hughes, 1995:35). According to Leedy and Ormrod (2001:96), qualitative researchers are often described as being the research

instrument, because the bulk of their data collection depends on their personal involvement (direct observation, paragraph 5.4.3) in the setting. Qualitative researchers construct interpretative narratives from their data and try to capture the complexity of the phenomena under study. They use a more personal, literary style, and often include the participants' own language and perspectives.

On the other hand, quantitative approaches are used to describe current conditions descriptively (Gay & Airasian, 2000:238). In quantitative research, researchers identify one or more variables that they intend to study and then collect data specifically related to those variables. Specific methods of measuring each variable are identified. Quantitative researchers typically reduce their data to means, medians, correlations, and other summarising statistics. The results are usually presented in a report that employs a formal, scientific style, using the passive voice and impersonal language (Leedy & Ormrod, 2001:95).

In general, quantitative research is used to answer questions about relationships among variables with the purpose of explaining, predicting, and controlling phenomena. In contrast, qualitative research is typically used to answer questions about the nature of the phenomena, often with the purpose of describing and understanding the phenomena from the participants' point of view. Using both quantitative and qualitative approaches help researchers to learn more about the phenomena than when the research is limited to only one approach (Leedy & Ormrod, 2001:94).

In this study, video-taped micro-lessons form part of qualitative evaluations where data is collected from direct observations and written documents (in this case micro-lesson plans Appendices J, K, L, M, N, O and R). These evaluations aim to provide information on the dynamics of a programme and on participants' perceptions (Appendix Q) of their outcomes and impact. Video-taped micro-lessons (see transcripts of video-taped micro-lessons, Appendices D, E, F, G, H, I and S) coupled with direct observations were analysed qualitatively. As indicated in paragraph 5.4.3.2, an observation schedule with predefined categories (Appendix P) was necessary to record and analyse observations (Altrichter *et al.*, 1993:86).

The coding scheme (Appendix A) used for collecting data was analysed quantitatively. A questionnaire in the form of an assignment (Appendix B), micro-lesson plans (Appendices J, K, L, M, N, O and R) and transcripts of video-taped micro-lessons (Appendices D, E, F, G, H, I and

S) were all analysed qualitatively. The questionnaire (Appendix Q) is both quantitative and qualitative.

The ethical aspect of data collection in this study is discussed in paragraph 5.7 below.

5.7 ETHICAL ASPECTS

The ethical consideration is very important in collecting data by using video-tapes. This is because an apparently more holistic and authentic record of events increases the chances of invading the privacy of individuals and representing them in a way that goes against their interest (Altrichter *et al.*, 1993:100). In accordance with the latter, a letter (Appendix C) requesting permission to video-tape micro-lessons was written to educators participating in this study. Permission was granted by all educators.

5.8 CONCLUSION

This chapter dealt with the method of research employed in this study. The first part (paragraphs 5.2-5.3) of the chapter outlined how both the literature survey and the empirical investigation were carried out. Data collection methods (paragraph 5.4), data analysis (paragraph 5.5) and quantitative and qualitative analysis (paragraph 5.6) was discussed. Paragraph 5.7 dealt with the ethical aspect of data collection.

In the next chapter (Chapter 6) the results of the empirical survey and discussions thereof are provided.

CHAPTER 6
RESULTS OF THE EMPIRICAL SURVEY AND DISCUSSION OF RESULTS

6.1 INTRODUCTION

In this chapter the results of the empirical study are presented. As already indicated in Chapter 1 (paragraph 1.3), the aim of this study is to investigate how secondary school science educators approach practical work in physics at the FET-level in the North West Province, South Africa. The hypothesis for this study (paragraph 1.5) is: *secondary school science educators in the North West Province (South Africa) experience difficulties in approaching physics practical.* The empirical investigation was carried out in accordance with the research methodology indicated in paragraph 5.3. The data collection methods used in this study are described in paragraph 5.4, while data analysis including the quantitative and qualitative analysis are respectively described in paragraph 5.5 and 5.6.

The steps followed in the empirical study are indicated in Table 5.1. The educators who participated in this study completed the assignment (Appendix B) and the coding scheme (Appendix A). Educators' responses to the coding scheme (Appendix A) are indicated in paragraph 6.2. The coding scheme was used in accordance with reasons indicated in paragraph 5.4.1. One of the reasons is to describe in detail the characteristics of a practical task. In paragraph 6.3, the educators' responses to the assignment (Appendix B) are presented. The objectives of the assignment are described in paragraph 5.4.4.

Educators prepared and presented the micro-lessons on Ohm's law. The micro-lessons were video-taped, viewed, analysed and discussed with educators. An analysis of the video-taped micro-lessons is presented in paragraph 6.4. This analysis is aimed at giving the reader a picture of the approaches used in the presented micro-lessons.

A summary of the general findings of the micro-lessons are discussed in paragraph 6.5. The "model" micro-lesson is discussed in paragraph 6.6. The results of the questionnaire on video-taped micro-teaching (Appendix Q) (paragraph 6.7) portray the educators' feelings, views and perspectives about video-taped micro-teaching as a tool in refining educators' approaches to physics practical work.

6.2 Results: Educators' responses to aspects of the coding scheme

The responses of educators to the coding scheme are given in terms of the objectives (of the coding scheme) indicated in paragraph 5.4.1. The discussion follows in paragraphs 6.2.1 to 6.2.13.

Table 6.1: Responses of educators to the coding scheme (N=46)

Aspect A: The educators' intended teaching outcome			
To help learners to...		*N*	*%*
Content	*1. Identify objects and phenomena and become familiar with them (specify)*	*22*	*48*
	2. Learn a fact (or facts) (specify)	*14*	*30*
	3. Learn a concept (specify)	*21*	*46*
	4. Learn a relationship (specify)	*32*	*70*
	5. Learn a theory/model (specify)	*17*	*37*
	6. Address alternative conceptions (specify)	*9*	*20*
Process	*7. Learn how to use a standard laboratory instrument or piece of apparatus*	*32*	*70*
	8. Learn how to carry out a standard procedure	*22*	*48*
	9. Learn how to plan an investigation to address a specific question or problem	*22*	*48*
	10. Learn how to process data	*24*	*52*
	11. Learn how to use data to support a conclusion	*33*	*72*
	12. Learn how to communicate the results of lab work	*23*	*50*
Aspect B1.1: What the educator intends learners should do with objects and observables		**N**	**%**
Use	*13. an observation*	*27*	*59*
	14. a laboratory device or arrangement	*20*	*43*
	15. a laboratory procedure	*21*	*46*
Present or display	*16. an object*	*16*	*35*
Make	*17. an object*	*6*	*13*
	18. a material	*4*	*9*
	19. an event occur	*16*	*35*
Observe	*20. an object*	*9*	*20*
	21. a material	*0*	*0*
	22. an event occur	*8*	*17*
	23. a physical quantity (a variable)	*28*	*61*

Aspect B1.2: What the educator intends learners should do with ideas			**N**	**%**
	24. Report observation(s)		*22*	*48*
	25. Identify a pattern		*16*	*35*
Explore relation between	*26. Objects*		*9*	*20*
	27. Physical quantities (variables)		*21*	*46*
	28. Objects and physical quantities (variables)		*22*	*48*
29. Invent (discover) a new concept (a physical quantity, or an entity)			*15*	*33*
30. Determine the value of a physical quantity which is not measured directly			*20*	*43*
Test a prediction	*31. from a guess*		*6*	*13*
	32. from a law		*21*	*46*
	33. from a theory (a model based on a theoretical framework)		*15*	*33*
Account for observations	*34. in terms of a given law*		*27*	*59*
	35. in terms of a given theory (or model)		*15*	*33*
	36. by proposing a law		*6*	*13*
	37. by proposing a theory (or model)		*4*	*9*

Aspect B1.3: Objects- or ideas-driven?	**N**	**%**
38. What the learners are intended to do with ideas arises from what they are intended to do with objects.	*21*	*46*
39. What the learners are intended to do with objects arises from what they are intended to do with ideas.	*13*	*28*
40. There is no clear relation between what the learners are intended to do with objects and with ideas.	*4*	*9*
Missing data	*8*	*17*

Aspect B.2.1: Degree of openness/closure										
Aspect of lab work task	***Specified by educator***	***N***	***%***	***or decided by discussion***	***N***	***%***	***or Chosen by learners***	***N***	***%***	***Missing data***
41. Questions to be addressed		*23*	*50*		*8*	*17*		*1*	*2*	*14*
42. Equipment to be used		*28*	*61*		*8*	*17*		*3*	*7*	*7*
43. Procedure to be followed		*31*	*67*		*4*	*9*		*3*	*7*	*8*
44. Methods of handling data collected		*22*	*48*		*8*	*17*		*7*	*15*	*9*
45. Interpretation of results		*6*	*13*		*12*	*26*		*18*	*39*	*10*

Aspect B.2.2: Nature of learner involvement	**N**	**%**
46. Carried out by learners in small groups	*26*	*57*
47. Carried out by individual learners	*5*	*11*
48. Demonstrated by educator, learners observe and assist as directed	*10*	*22*
49. Demonstrated by educator, learners observe	*1*	*2*
Missing data	*4*	*8*

Aspect B.3.1: Duration of task	**N**	**%**
50. Very brief (less than 20 minutes)	*1*	*2*
51. Brief (one science lesson, say, up to 80 minutes)	*23*	*50*
52. Medium (2-3 science lessons)	*13*	*28*
53. Long (2 weeks or more)	*1*	*2*
Missing data	*8*	*17*

Aspect B.3.2: People with whom the learner interacts	**N**	**%**
54. Other learners carrying out the same lab work task	*25*	*54*
55. Other learners who have already completed the task	*3*	*7*
56. Educator	*29*	*63*
57. More advanced learners (demonstration, etc.)	*8*	*17*
58. Others (technician, glassblower, etc.)	*1*	*2*

Aspect B3.3: Information sources available to the learners	**N**	**%**
59. Guiding worksheets	*27*	*59*
60. Textbooks	*30*	*65*
61. Handbook (on apparatus), data book, etc.	*24*	*52*
62. Computerised database	*8*	*17*
63. Other	*0*	*0*

Aspect B.3.4: Type of apparatus involved	**N**	**%**
64. Standard laboratory equipment	*28*	*61*
65. Small- scale apparatus	*14*	*30*
66. All equipment (kitchen scales, domestic materials...)	*2*	*4*
Missing data	*2*	*4*

Aspect B.3.5: Source of data	**N**	**%**
67. Real world: inside laboratory	*27*	*59*
68. Real world: outside laboratory	*4*	*9*
69. Simulation on computer or CD-ROM	*0*	*0*
70. Video-recording	*3*	*7*
71. Text	*3*	*7*
Missing data	*9*	*20*
Aspect B.3.6: Tools available for processing data	**N**	**%**
72. Manual calculation	*37*	*80*
73. Computer	*10*	*22*
74. Other (specify)	*7*	*15*

Aspect C: Attitude towards practical work in physics

ITEM 75: Physics practical work is a waste of time (missing data N=9 (20%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
1	*2*	*1*	*2*	*35*	*76*

ITEM 76: I like doing physics demonstrations more than are hands-on (missing data N=7 (15%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
20	*43*	*9*	*20*	*10*	*22*

ITEM 77: Practical work in physics does not enhance my interest in physics (missing data N=9 (20%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
3	*7*	*0*	*0*	*34*	*74*

ITEM 78: I like physics practical work (missing data N=8 (17%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
38	*83*	*0*	*0*	*0*	*0*

ITEM 79: It is more interesting to do a physics practical than to conduct a theory lesson (missing data N=17 (37%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
23	*50*	*3*	*7*	*3*	*7*

ITEM 80: It is boring to do practical work in physics (missing data N=7 (15%)

Agree		*Neutral*		*Disagree*	
N	*%*	*N*	*%*	*N*	*%*
0	*0*	*1*	*2*	*38*	*83*

6.2.1 Discussion of the results of Aspect A of the coding scheme (the educators' intended teaching outcome)

Figure 6.1 represents the responses of educators to the intended teaching outcomes when preparing the lesson on Ohm's law. The items on content refer mainly to scientific knowledge, whereas items under process refer to scientific inquiry. Educators were asked to tick off one or more boxes (see coding scheme Appendix A).

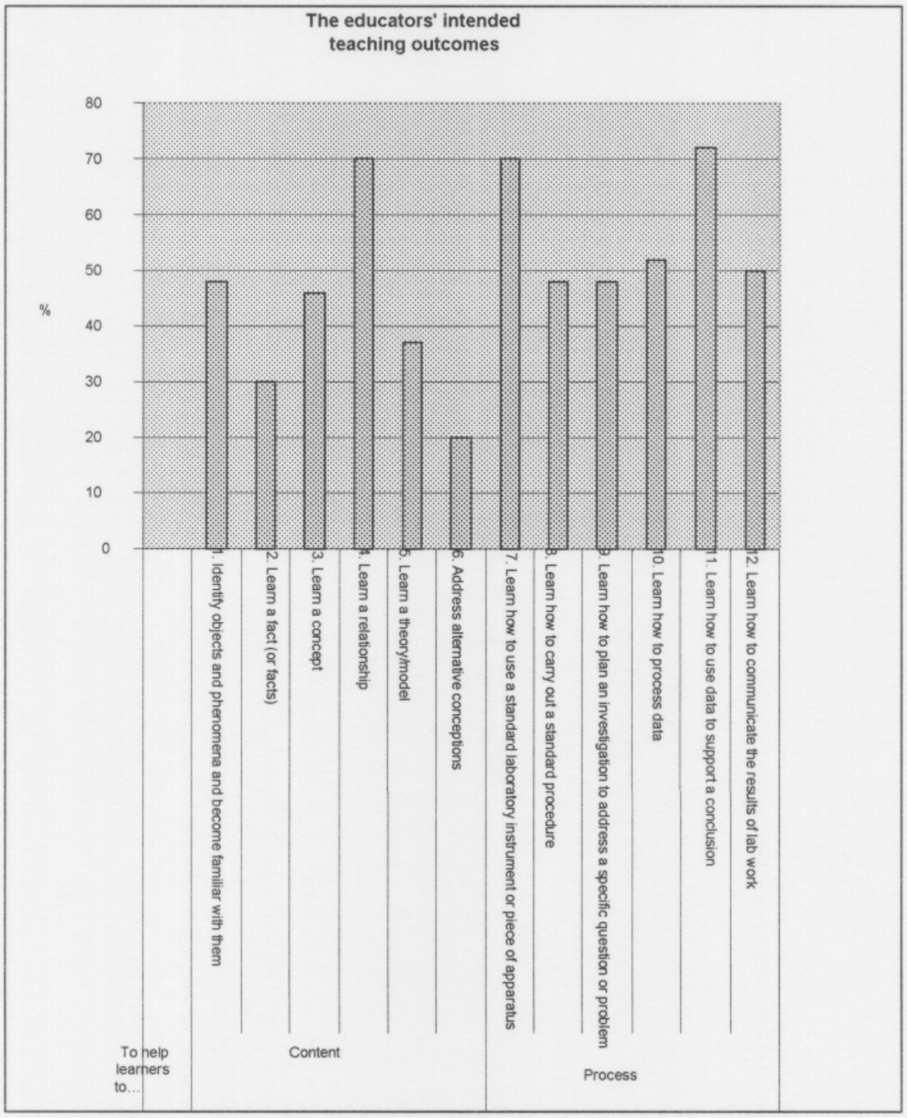

Figure 6.1: Responses to item 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 of the coding scheme

Some 70% (item 7) of the educators said that they intend to help learners learn how to use a standard laboratory instrument or piece of apparatus (in this case an ammeter and voltmeter). The educators' intended outcome was later confirmed in the video-taped micro-lessons. The educators in the micro-lessons focussed on the use and purpose of the ammeter and the voltmeter (see questions asked by educators in the video-taped micro-lessons Table 6.10). The educators did not take into account that the usage of laboratory instruments like an ammeter and voltmeter should be part of the learners' prior knowledge during the practical on Ohm's law.

The experiment used in this study (Ohm's law) is based on the relationship between the current and the potential difference. Hence 70% (item 4) of the educators said they would help learners to learn a relationship. A conclusion that can be derived from the experiment is that there is a direct proportionality between the current and the potential difference, provided the temperature remains constant. Hence item 4 correlates with item 11. This is because the results indicate that 72% (item 11) of the educators' intended teaching outcome would be to help learners to learn how to use data to support a conclusion. Both items (item 4 and 11) correlate with what transpired in the video-taped micro-lesson. In the video-taped micro-lessons the educators' main outcome was to confirm Ohm's law (see Table 6.12).

In item 6, a very low percentage of educators (20%) intended to address misconceptions. These may be due to inadequate knowledge and awareness by educators of the misconceptions that both educators and learners may bring to the classroom. This is further confirmed by the results in Table 6.14. Some of the educators displayed misconceptions in the video-taped micro-lessons. A very positive aspect about the video-taped micro-lessons is that 95% of the educators (Table 6.18) realised after viewing the tapes that video-taped micro-lessons could help to address alternative conceptions.

Inquiry and problem-solving were not adequately addressed by educators. This is because only 48% (item 9) of educators said that they would help learners how to plan an investigation to address a specific question or problem. The latter correlates with observations made in the video-taped micro-lessons (see Table 6.6).

6.2.2 Discussion of the results of Aspect B.1.1 of the coding scheme (what the educator intends learners should do with objects and observables)

Figures 6.2, 6.3 and 6.4 portray the responses of educators on what they intended learners to do with objects and observables that were presented in the practical on Ohm's law. Educators were requested to tick off one or more boxes (see coding scheme Appendix A).

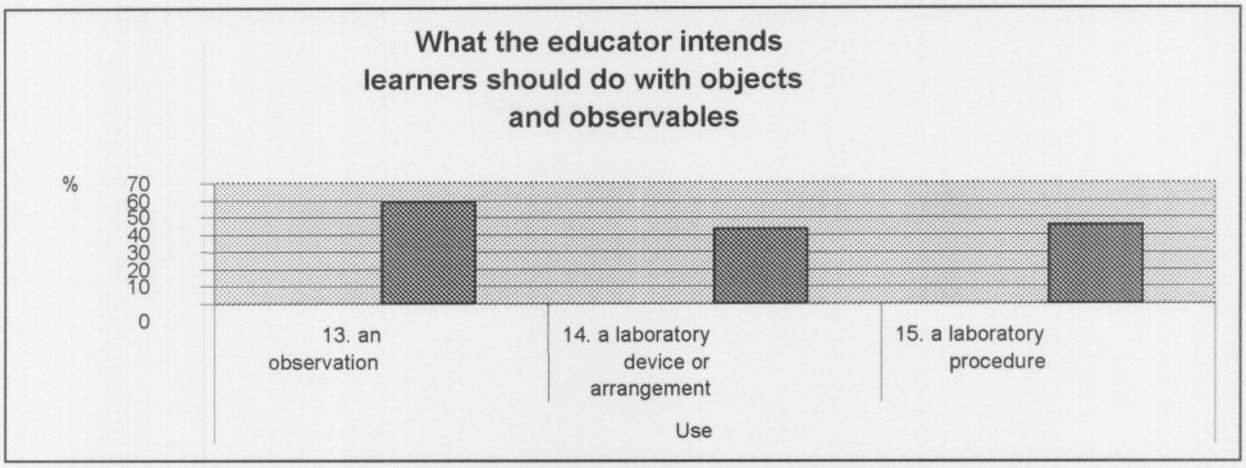

Figure 6.2: Responses to items 13, 14 and 15 of the coding scheme

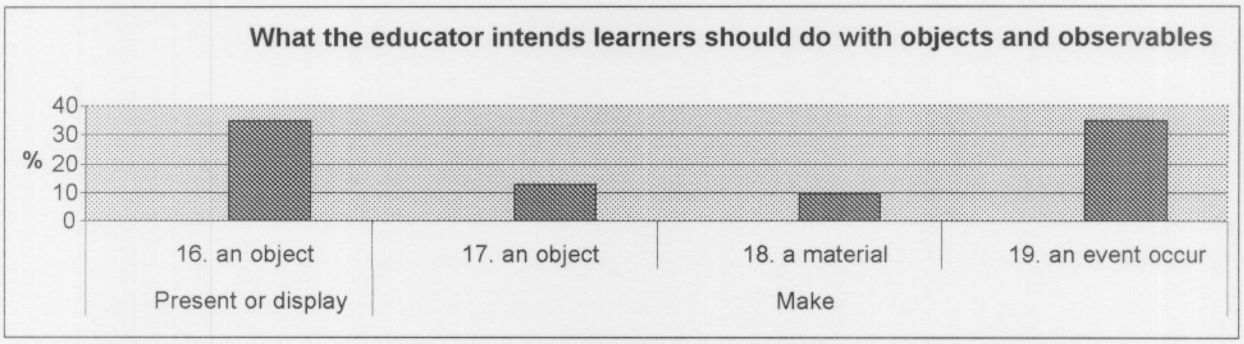

Figure 6.3: Responses to items 16, 17, 18 and 19 of the coding scheme

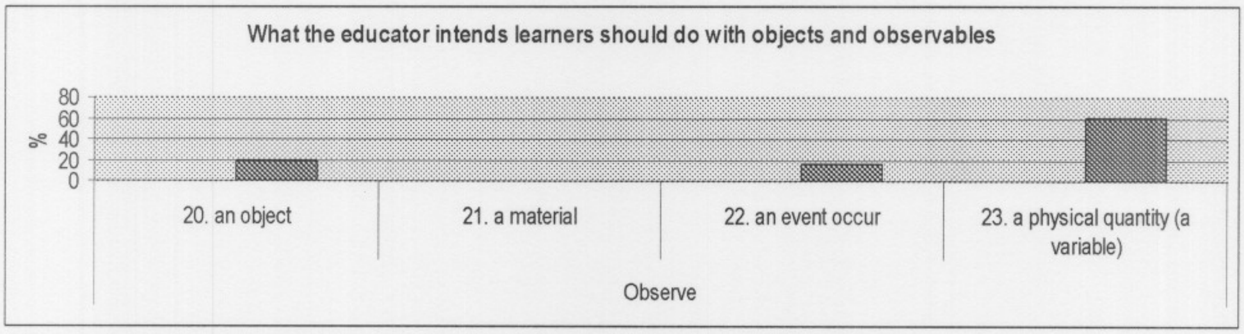

Figure 6.4: Responses to items 20, 21, 22 and 23 of the coding scheme

Observations were supposed to be made on the variables current and potential difference. Hence, 61% of the educators (Figure 6.4 item 23) intended that learners should observe a physical quantity (a variable). Approximately the same percentage of educators (59%) said that learners should use an observation (item 13). The correct use of observations (item 13) may help in observing physical quantities (item 23).

Some 46% of the educators (Figure 6.2 item 15) said that their intention was that learners should use a laboratory procedure. The results of item 15 (Figure 6.2) correlate with item 8 (Figure 6.1), where 48% of the educators intended learners to carry out a standard procedure. These educators preferred learners to use a standard way of conducting practical work. This was evident in the video-taped micro-lessons. The educators instructed learners to carry out procedures indicated in the worksheets, leading to recipe-following. The researcher believes that the latter may impact on the development of inquiry and problem-solving skills of learners. The results are in accordance with research findings by Olney (1997:1345), who argues that the approach used by educators is a "cut and dried" laboratory procedure, which minimises learner participation (see paragraph 1.1).

6.2.3 Discussion of the results of Aspect B.1.2 of the coding scheme (what the educator intends learners to do with ideas)

Responses of educators on what they intend learners to do with ideas are indicated in figures 6.5, 6.6, 6.7, 6.8 and 6.9 below. Educators were required to tick off one or more boxes (see coding scheme Appendix A).

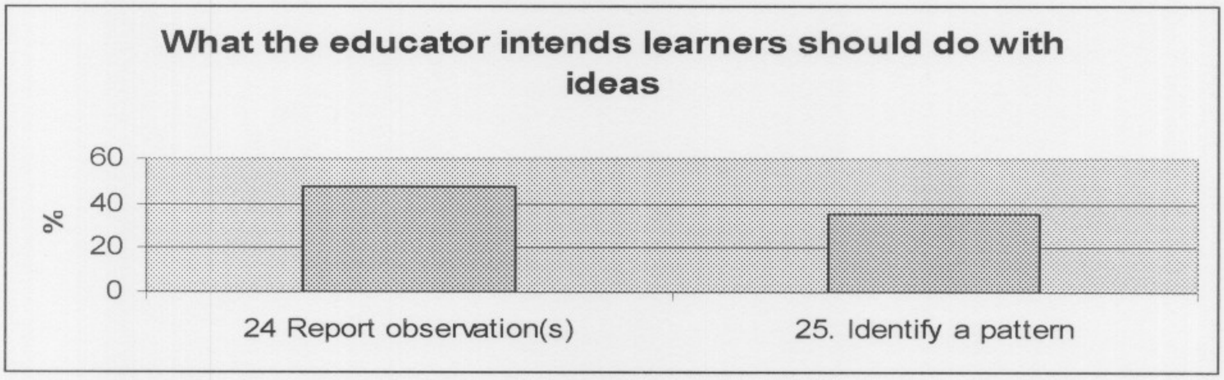

Figure 6.5: Responses to items 24 and 25 of the coding scheme

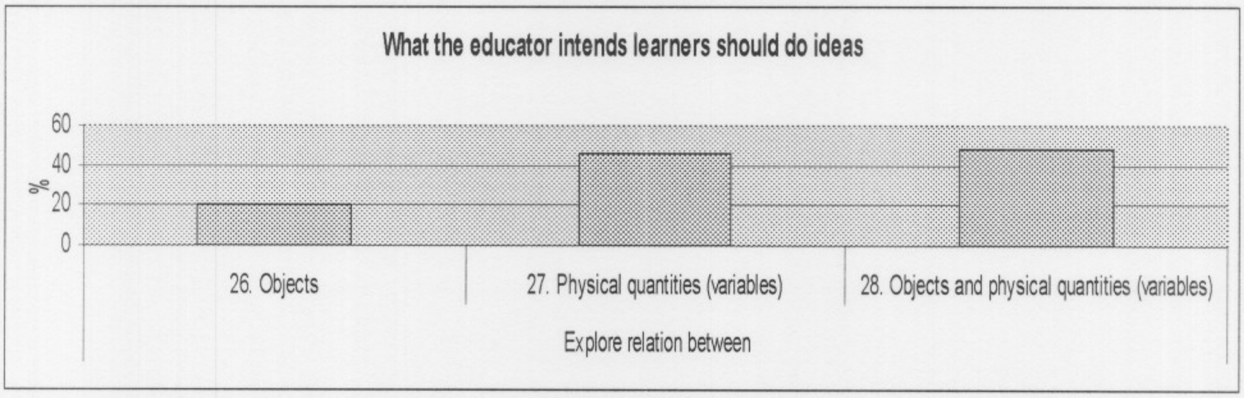

Figure 6.6: Responses to item 26, 27 and 28 of the coding scheme

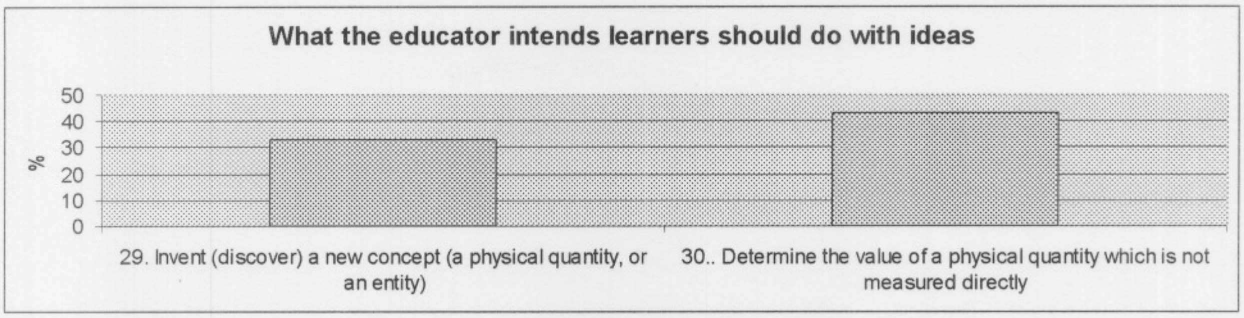

Figure 6.7: Responses to items 29 and 30 of the coding scheme

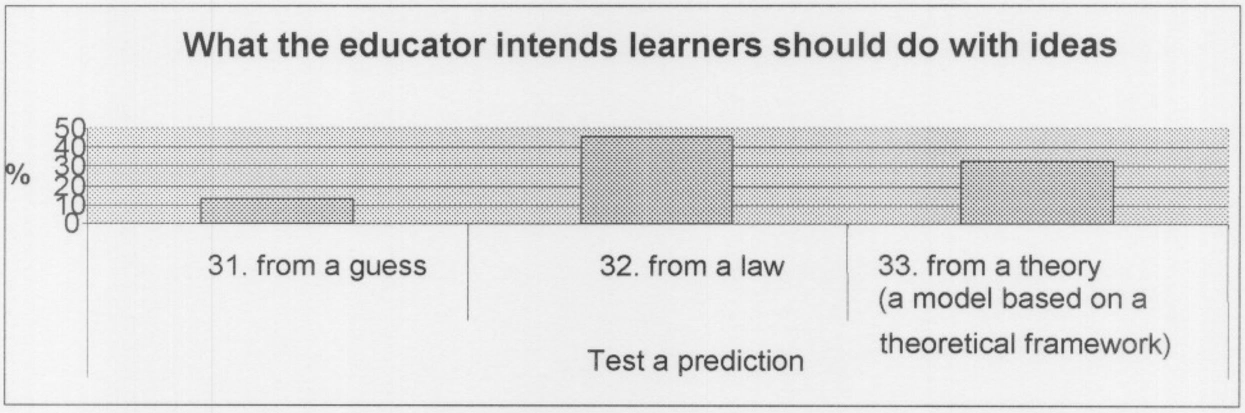

Figure 6.8: Responses to items 31, 32 and 33 of the coding scheme

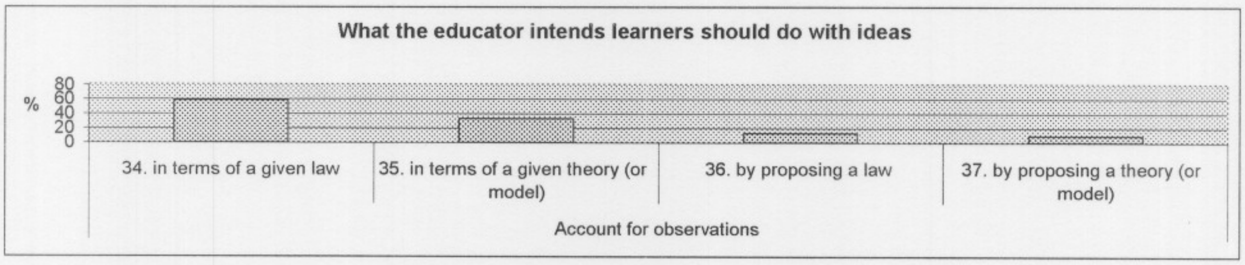

Figure 6.9: Responses to items 34, 35, 36 and 37 of the coding scheme

The results indicate that 59% of educators (Figure 6.9 item 34) said that learners should account for observations in terms of a given law. This is not a convincing percentage point. The micro-lessons indicated that in most of the lessons learners did not give a convincing account of the observations made. Instead, they depended on the theory provided by the educator. Hence, a very low percentage (9%) of educators (Figure 6.9 item 37) intended learners to account for observations by proposing a law. In the video-taped micro-lessons learners were either asked to state Ohm's law or it was dictated to them by the educator.

Some 48% of educators (Figure 6.5 item 24) intended learners to report observations. Worksheets were used in all the video-taped micro-lessons (see Table 6.13). Learners were supposed to record and report observations. Presenters in the micro-lessons were tempted to report and give an analysis of the observations to learners. That is why only 48% of the educators (Figure 6.6 item 28) intended learners to explore relations between objects and physical quantities - hence the same percentage point (48%) in item 24 (Figure 6.5) and item 28 (Figure 6.6). This indicates a more educator-centred approach.

Some 46% of educators (Figure 6.8 item 32) intended learners to test a prediction from a law (in this case Ohm's law). This constitutes a very low percentage, because it is expected that learners should make predictions in inquiry-science classrooms. These predictions should lead learners in making thorough observations in order to inquire and explore concepts such as potential difference, current and resistance. This low percentage may be the result of the inadequate knowledge of contemporary teaching methodologies that educators have.

6.2.4 Discussion of the results of Aspect B.1.3 of the coding scheme (objects- or ideas-driven?)

The results of items given in Figure 6.10 were aimed at determining whether educators regard practical work as objects- or ideas-driven. Educators were required to tick off only one box (see coding scheme Appendix A).

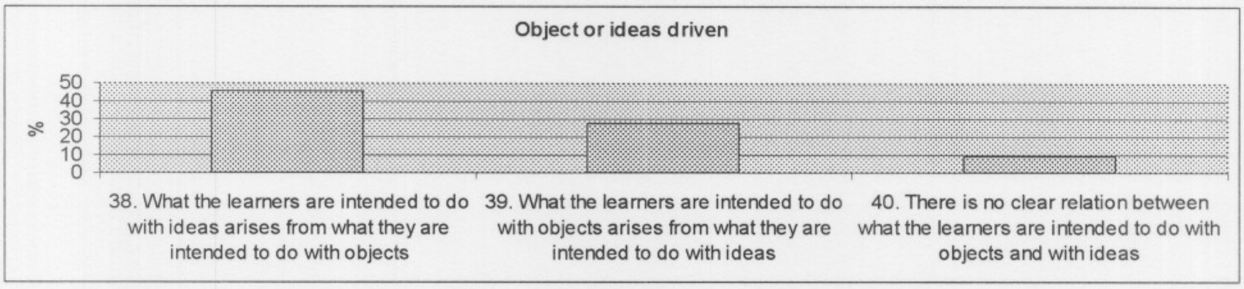

Figure 6.10: Responses to items 38, 39 and 40 of the coding scheme

The nature of the responses in Figure 6.10 (items 38, 39 and 40) above indicates that educators may not have understood the items and as a result may have struggled with the interpretation thereof. This is further confirmed by a missing 17% (N=8) of educators, who did not respond to this item. By objects the researcher refers to apparatus and equipment used by the educator in the practical work. Ideas are contributions from the learners on how to solve practical-related problems. Some 46% (item 38) of educators said that what learners are intended to do with ideas arises from what they are intended to do with objects. This means that educators would give learners apparatus and that they should come up with on ideas how to solve problems. Compared to items 39 and 40, this may be regarded as a good percentage, although it was not practically done in the video-taped micro-lessons.

The educators' responses to what learners should do with objects and observables (figures 6.2, 6.3 and 6.4) compared to what learners should do with ideas (Figures 6.5 to 6.9), indicate higher responses to the former compared to the latter. This means that what learners are intended to do with ideas arises from what they are intended to do with objects (Figure 6.10 item 38).

6.2.5 Discussion of the results of Aspect B.2.1 of the coding scheme (degree of openness/closure)

Items 41 to 45 (figures 6.11, 6.12 and 6.13) were intended to determine whether the aspects of practical work, that is, questions to be addressed, equipment to be used, procedure and methods to be followed and the interpretation of results of a practical were specified by the educator, decided by discussion or chosen by learners. The aim with those items was to see whether the educators' approaches are learner-centred or educator-centred. Educators were required to tick off one box in each row (see coding scheme Appendix A). The responses are presented below.

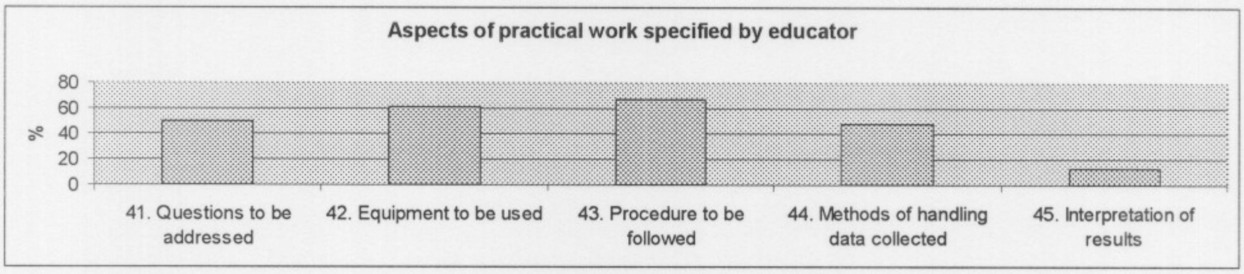

Figure 6.11: Responses to items 41, 42, 43, 44 and 45 of the coding scheme

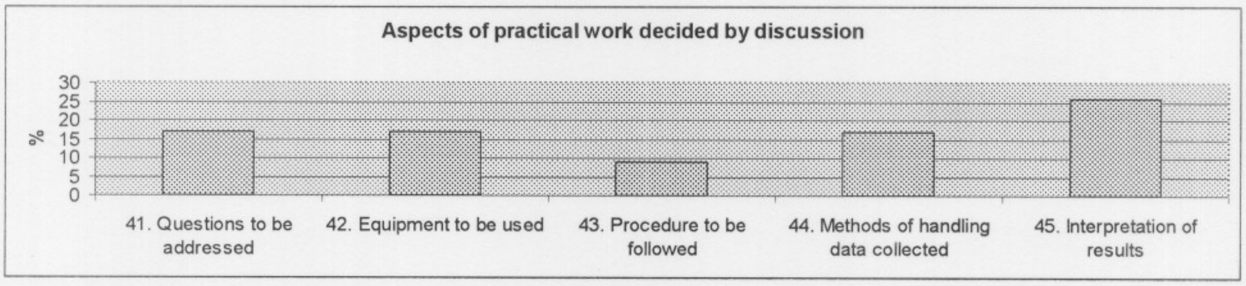

Figure 6.12: Responses to items 41, 42, 43, 44 and 45 of the coding scheme

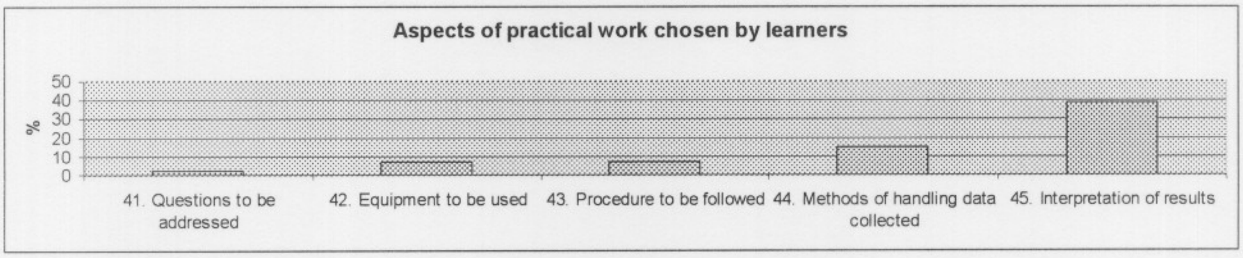

Figure 6.13: Responses to items 41, 42, 43, 44 and 45 of the coding scheme

The results show that 67% of educators (Figure 6.13 item 43) would specify the procedure to be followed in the experimental task. This approach was evident in the video-taped micro-lessons. The educators in the micro-lessons specified and instructed learners to follow procedures indicated in the worksheets, while the educators' focus was on teaching Ohm's law theoretically. Only 7% of the educators (Figure 6.13 item 43) said they would allow learners to choose the procedure to be followed, while 9% (Figure 6.12 item 43) said the procedure to be followed would be decided by discussion. This further indicates a more educator-centred approach.

Half of the educators 50% (Figure 6.11 item 41) said that they would specify the questions to be addressed in the experimental task. All the educators asked questions in the video-taped micro-lessons (Table 6.10). The nature of the questions asked (see Table 6.10) was not problem-based and inquiry-oriented. The questions may not help in achieving the outcomes of an experimental task.

Some 61% of educators (Figure 6.11 item 42) said the equipment to be used would be specified by the educator. This result was evident in the video-taped micro-lessons (Table 6.7). In the video-taped micro-lessons educators (micro-lessons 1, 2, 5 and 6 Table 6.7) specified and introduced all the apparatus to the learners.

A percentage of 48 of educators (Figure 6.11 item 44) said that methods of handling data collection would be specified by the educator. In the video-taped micro-lessons the experimental data was recorded in the worksheets (see Table 6.13). In all the micro-lessons the educator instructed learners on how to handle data. This may impact on the development of learners' manipulation skills.

Results indicate that higher percentages of the task (Figure 6.11 items 41, 42, 43, 44) will be specified by the educator. This also indicates a more educator -centred approach.

Only 13% of educators (Figure 6.11 item 45) said that the interpretation of results will be specified by the educator, 39% (Figure 6.13 item 45) said that the interpretation of results will be chosen by the learners and 26% (Figure 6.12 item 45) said that interpretation of the results will be decided by discussion. The responses in item 45 (figures 6.11, 6.12 and 6.13) indicate that educators do not fully understand their role in a practical activity. The video-taped micro-lessons indicate that educators tend to interpret the results of the experiment for the learners.

6.2.6 Discussion of the results of Aspect B.2.2 of the coding scheme (nature of learner involvement)

Items in Figure 6.14 below were intended to determine the nature of learner involvement in the practical activity. Educators were asked to tick off only one option.

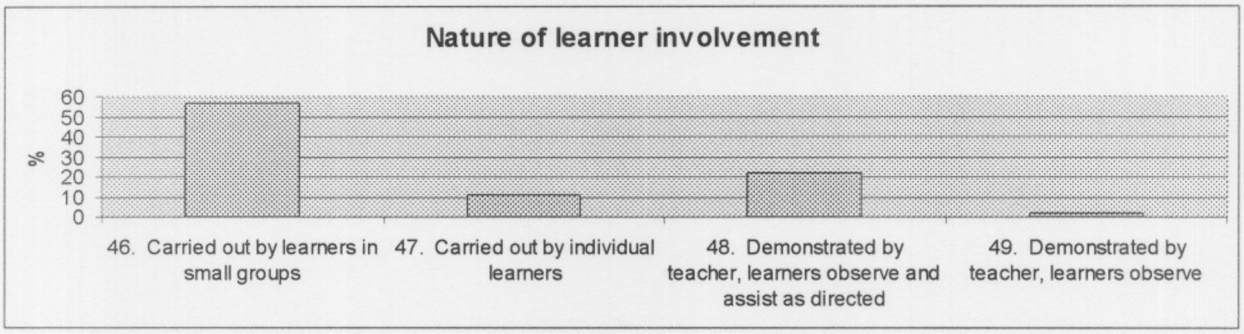

Figure 6.14: Responses to items 46, 47, 48 and 49 of the coding scheme

A total of 57% (item 46) of educators said that the experimental task would be carried out by learners in small groups. Although the percentage in item 46 is not satisfactory, it correlates with what transpired in the video-taped micro-lessons. The researcher's observation in the video-taped micro-lessons is that educators put learners in groups but do not facilitate the groups to fully participate and work co-operatively. The schematic representation of the approach used in the micro-lessons (Figure 6.28) indicates limited interaction between learners.

Only 2% (item 49) of the educators said that they would demonstrate while learners observe. Some 22% (item 48) of educators said that they would demonstrate while learners observe and assist as directed. The result indicates that some educators like to demonstrate (see Table 6.6, micro-lesson 1). The educator in this lesson (micro-lesson 1) did a demonstration before he gave learners an opportunity to perform the experiments themselves. The researcher is not against demonstration but his standpoint is that it should be used only when necessary.

6.2.7 Discussion of the results of Aspect B.3.1 of the coding scheme (duration of task)

Figure 6.15 presents responses of educators on the duration of the task if they were to present the lesson on Ohm's law in their schools with no time frames. Educators were required to tick off only one option (see Appendix A).

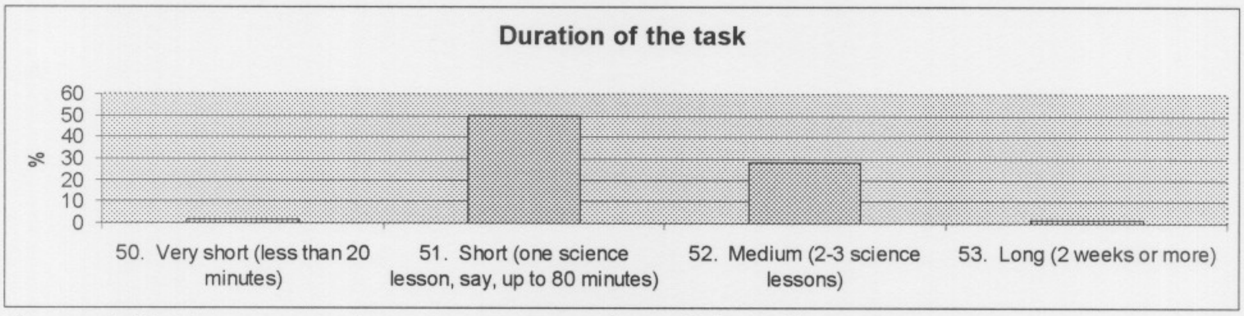

Figure 6.15: Responses to items 50, 51, 52 and 53 of the coding scheme

The response to item 51 indicates that 50% of educators said that a lesson on Ohm's law could take one science lesson of approximately up 80 minutes, while 28% (item 52) said it could take 2 to 3 science lessons. Only 2% (item 53) of educators required two weeks or more. The results confirm one of the disadvantages mentioned in paragraph 5.4.2.2, namely that the researcher limited educators' lessons to 45 minutes. This indicates that in practice, the lesson may take longer. Only 2% (item 50) said that the lesson could be very short (less than 20 minutes). Some 17% (N=8) of educators did not respond to this item. These educators may not have taught Ohm's law in the past and therefore did know how much time was needed.

6.2.8 Discussion of the results of Aspect B.3.2 of the coding scheme (people with whom the learner interacts)

The items in Figure 6.16 were intended to ascertain the type of learner interaction that would take place in the class. Educators were required to tick off one or more boxes (see coding scheme Appendix A). The responses are represented in Figure 6.16 below.

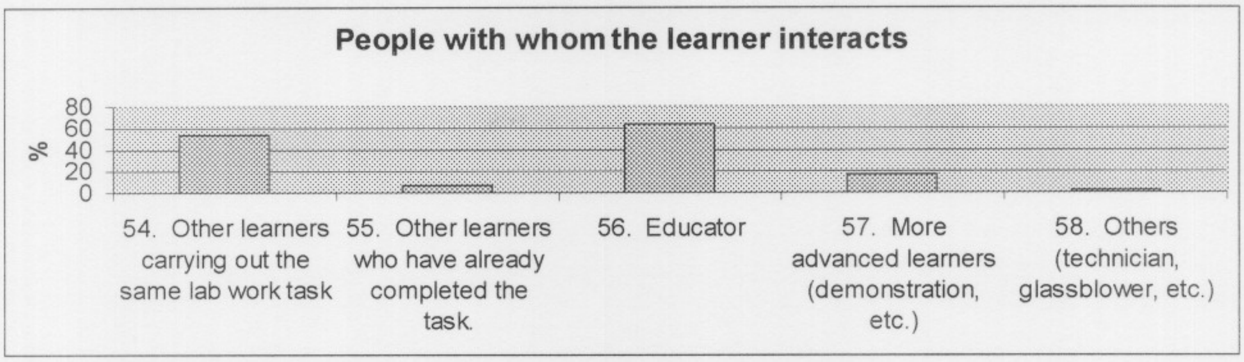

Figure 6.16: Responses to items 54, 55, 56, 57 and 58 of the coding scheme

The majority (63% item 56) of educators said that learners would interact with the educator, while 54% (item 54) said that learners would interact with other learners carrying out the same lab work task. The results correlate with the schematic representation of the approach used in the micro-lessons (Figure 6.28) and the educators' responses on aspects of practical work to be specified by the educator (Figure 6.11, items 41, 42, 43 and 44). The schematic representation (Figure 6.28) indicates that there is more interaction between the educator and the learners but limited interaction between learners. These results imply a more educator-centred approach.

6.2.9 Discussion of the results of Aspect B.3.3 of the coding scheme (information sources available to the learners)

In Figure 6.17 below the responses of educators to the information sources available to learners are presented. Educators were required to tick off one or more boxes (see coding scheme Appendix A).

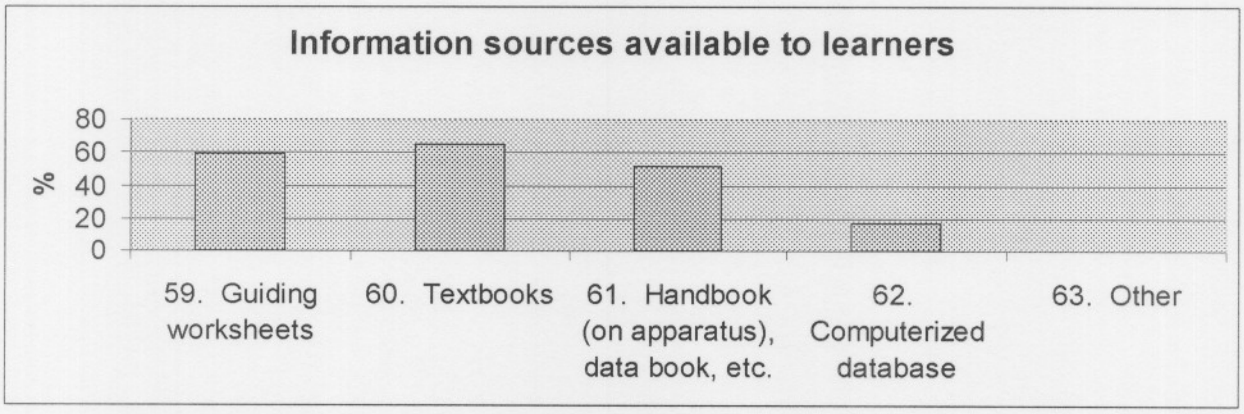

Figure 6.17: Responses to items 59, 60, 61, 62 and 63 of the coding scheme

The results indicate that 65% (item 60) of educators use textbooks as information sources available to learners. This is because most schools do not have the necessary apparatus to perform practical work in physics (see Table 6.14). Only 17% (item 62) use computerised databases and probably do not use it for physics practical work. The results indicate that educators' approaches are mostly textbook-oriented (item 60) and worksheet-driven (item 59) was evident in the micro-lessons.

6.2.10 Discussion of the results of Aspect B.3.4 of the coding scheme (type of apparatus involved)

In Figure 6.18 below the responses of educators on the type of apparatus available to learners are represented. Educators were required to tick off only one option (see Appendix A).

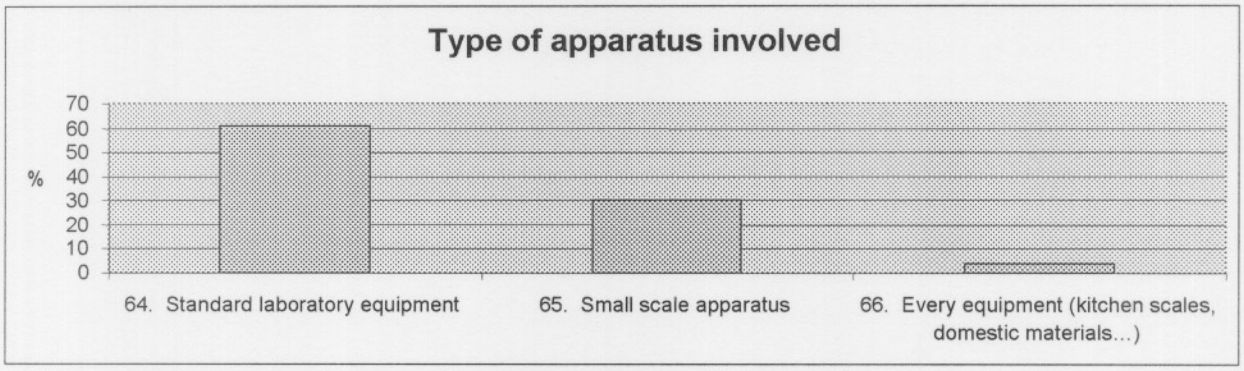

Figure 6.18: Responses to items 64, 65 and 66 of the coding scheme

Some 61% (item 64) of educators said that they would use standard laboratory equipment. It is obvious from Table 6.14 that educators (64%) do not have the necessary apparatus to perform practical work in physics. The results indicate that if educators were provided with apparatus in schools they would use the standard laboratory equipment.

6.2.11 Discussion of the results of Aspect B.3.5 of the coding scheme (source of data)

Figure 6.19 below represents the response of educators on the sources of data.

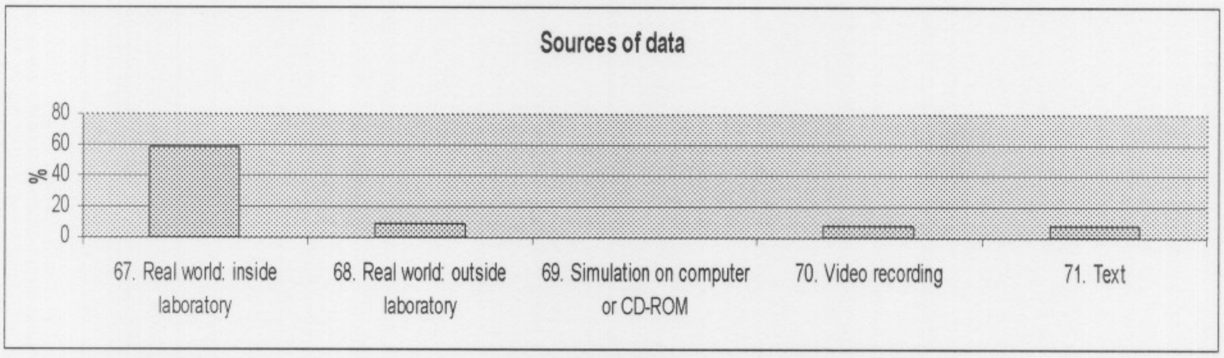

Figure 6.19: Responses to items 67, 68, 69, 70 and 71 of the coding scheme

The results indicate that 59% (item 67) of educators would derive their sources of data from within the laboratory. Educators view practical work as doing experiments in the laboratory. This result correlates with the descriptions given by educators on what is meant by practical work (Table 6.4). A large percentage did not respond N=9 (20%). This may be because schools do not have the facilities mentioned in items 67, 68, 69 and 70.

6.2.12 Discussion of the results of Aspect B.3.6 of the coding scheme (tools available for processing data)

Figure 6.20 represents the responses of educators on the tools available to learners for processing data. Educators were required to select one or more boxes (see Appendix A).

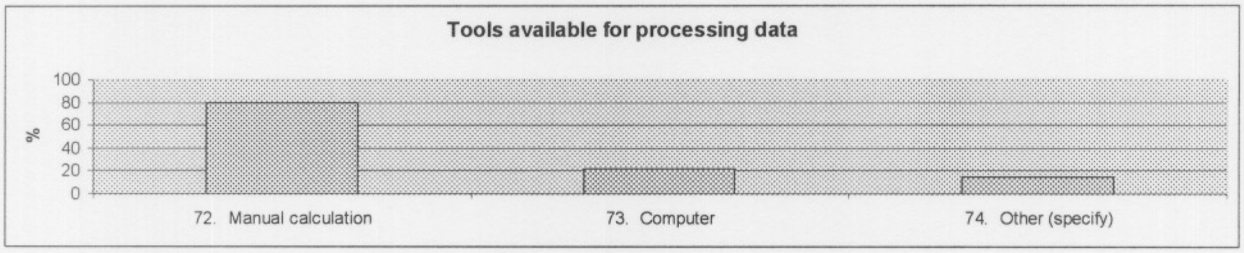

Figure 6.20: Responses to items 72, 73 and 74 of the coding scheme

With regard to the tools available for processing data, 80% (item 72) of educators said learners would use manual calculation. In the micro-lessons it was evident that educators liked calculations. Hence (Table 6.6 micro-lesson 4), the educator spends most of the time teaching the mathematical application of Ohm's law.

6.2.13 Discussion of the results of Aspect C of the coding scheme (attitude of educators towards practical work in physics)

Responses of educators on their attitude towards practical work in physics are indicated in figures 6.21, 6.22, 6.23, 6.24, 6.25 and 6.26 below. Educators were asked to choose between three possibilities, namely agree, neutral and disagree. The aim with items on attitude (Appendix A) was to probe the attitudes of educators towards practical work in physics.

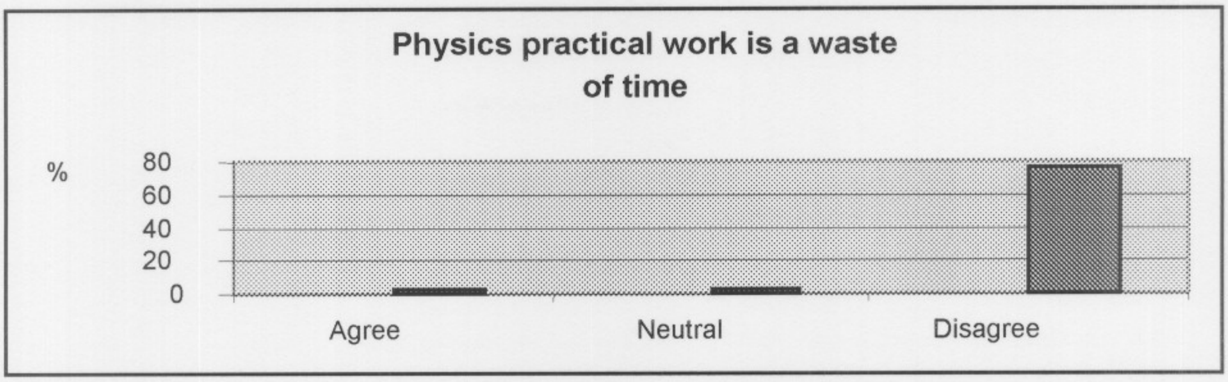

Figure 6.21: Responses to item 75

A large percentage of educators (76%) disagreed with the statement that physics practical work is a waste of time. Only 2% of educators agreed with the statement and another 2% were neutral. The results indicate that the majority of educators are positive towards practical work in physics.

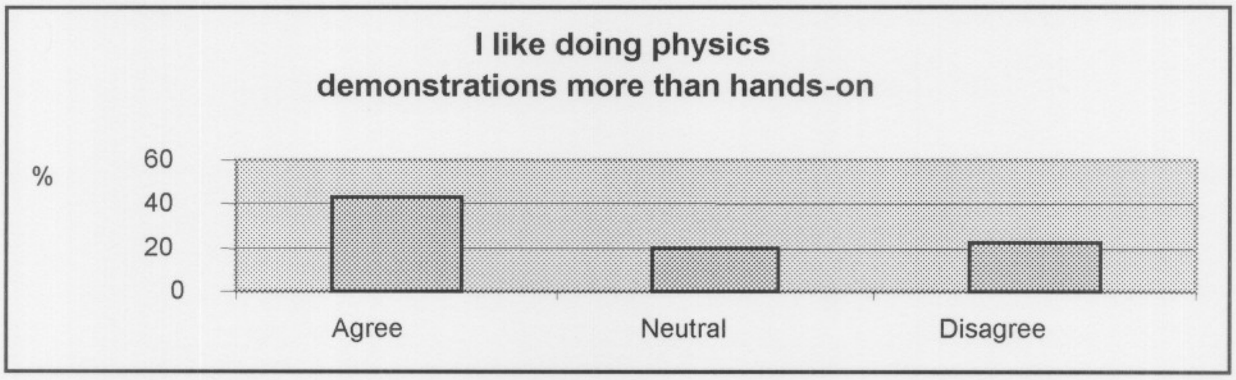

Figure 6.22: Responses to item 76

Compared with educators that are neutral (20%) and those who disagree (22%) with item 76, the result indicates that a larger percentage of the educators (43%) like to do demonstrations. This may be due to overcrowded classrooms (See Table 6.19) and lack of facilities such as apparatus for physics practical work (see tables 6.19 and 6.14).

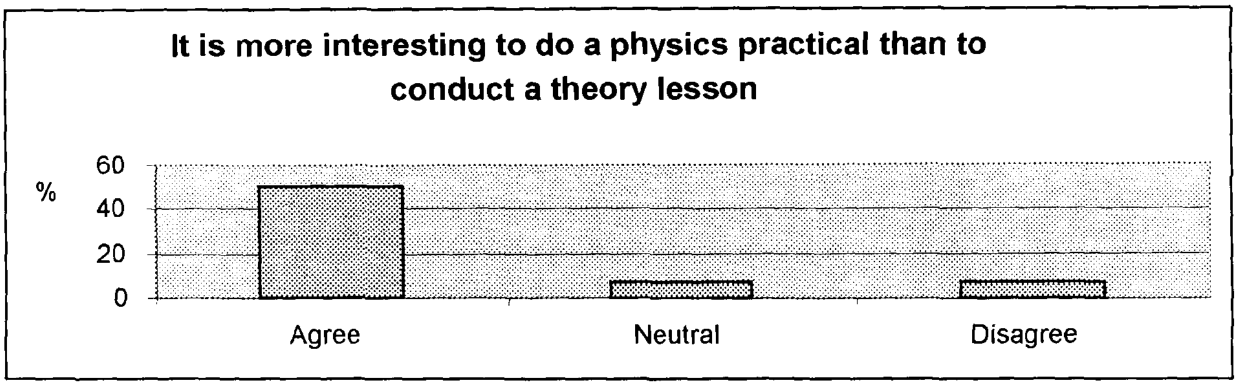

Figure 6.25 Responses to item 79

Thirty per cent (37%) (N=17) of the educators did not respond to this item, while 7% disagreed with the statement and another 7% were neutral - about half of the educators that participated in this study. The other half of the educators (50%) agreed that it is more interesting to do a physics practical work than to conduct a theory lesson. As already indicated in the discussion of item 78, the reasons behind this poor response might be that educators do not have the apparatus at school (Table 6.14) or have had no exposure to physics practical work in the past. As a result educators were unable to decide whether it is interesting to do physics practical work or to conduct a theory lesson.

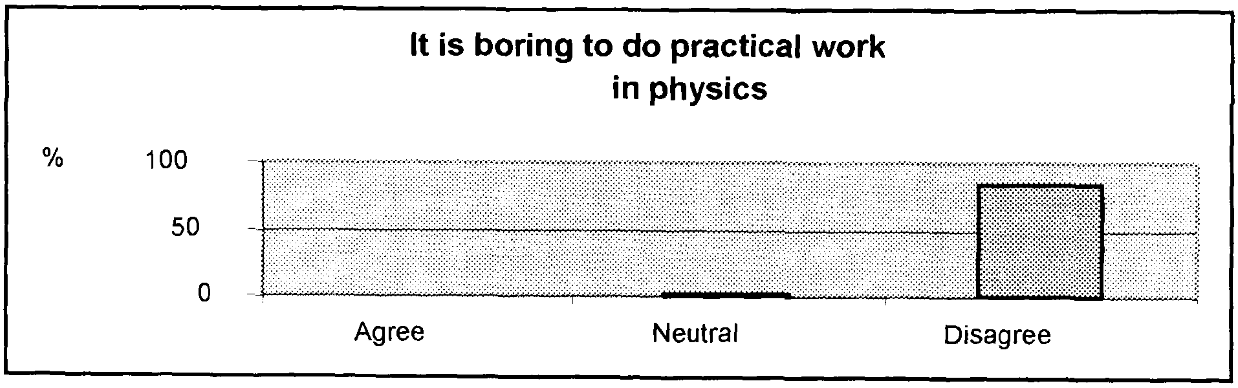

Figure 6.26: Responses to item 80

A majority of educators (83%) disagreed with item 80. Educators simply said that physics practical work is not boring. The result of item 80 correlates with those of item 78. This is because if physics practical work were not boring (item 80), educators would enjoy it (item 78). Some 83% of the educators (item 78) said that they liked physics practical work. This shows that educators have a positive attitude towards physics practical work.

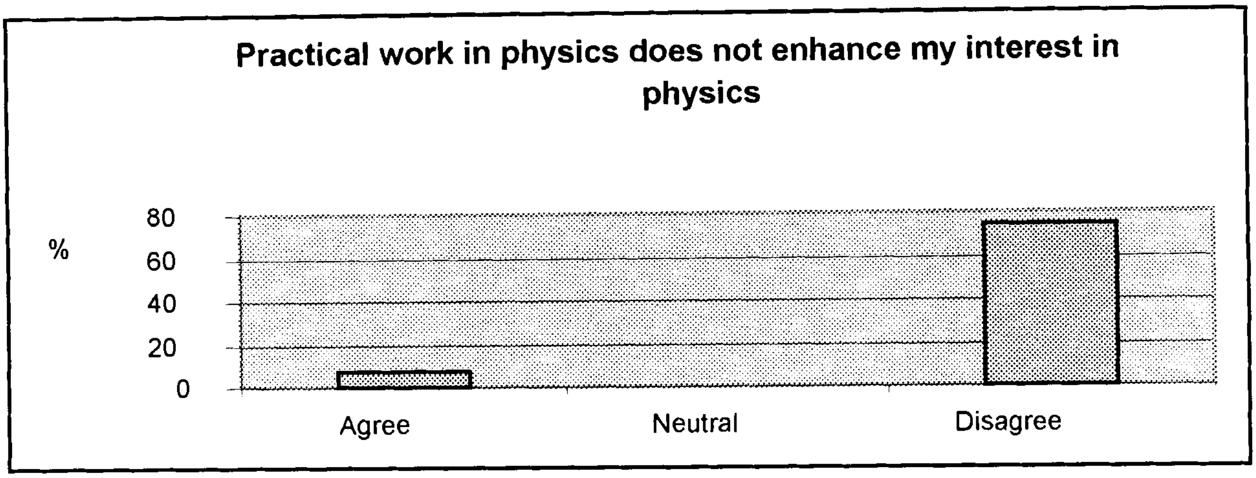

Figure 6.23: Responses to item 77

A large percentage of the educators (74%) disagreed with item 77. This result implies that educators are positive towards physics practical work, thus enhancing their interest in physics. Only 7% agreed that practical work does not enhance their interest in physics. None (0%) of educators were neutral.

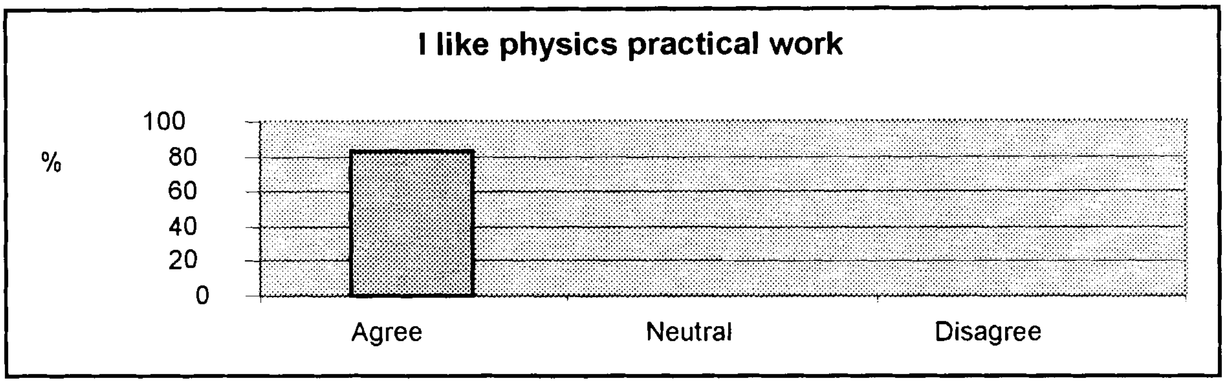

Figure 6.24: Responses to item 78

Even though educators said that they did not have the apparatus to do practical work in physics (Table 6.14), the results indicate that a majority of educators (83%) agreed that they enjoy physics practical work. This indicates a positive attitude towards physics practical work. Only 17% of the educators did not respond. This might be that they did not have the necessary exposure to physics practical work in the past.

In paragraph 6.3 below educators' responses to the assignment (Appendix B) are given.

6.3 Educators' responses to the assignment (Appendix B)

The responses of educators to items 2(a), 2(b), 2(c) and 2(d) of the assignment (Appendix B) are outlined in paragraphs 6.3.1 (Table 6.2), 6.3.3 (Table 6.3), 6.3.5 (Table 6.4), and 6.3.7 (Table 6.5) respectively. The educators' responses are discussed in paragraphs 6.3.2, 6.3.4, 6.3.6 and 6.3.8 respectively.

6.3.1 Educators' views about an OBE lesson in physics (item 2(a) of the assignment

The following table (Table 6.2) indicates educators' responses to item 2(a) of the assignment (Appendix B). The aim with this item was to get viewpoints of educators on their understanding of what an OBE lesson in physics entails. Educators were allowed to give more than one viewpoint in each item.

The viewpoints of educators are classified under the following headings:

- OBE-related viewpoints;
- educators' viewpoints based on the traditional approach to science teaching; and
- other viewpoints.

The last columns indicate the number of and percentage of educators that share the same viewpoint.

Table 6.2: Educators' viewpoints

Item 2(a) What is an OBE lesson in physics. N=46		
OBE- related viewpoints of educators	*N*	*%*
- A learner-centred lesson, active participation of learners, the learners do most of the work, learners discuss concepts in collaboration with the educator, solve problems, do research, conduct experiments. Learners must be given the opportunity to make observations and write reports.	*20*	*43*
- The educator facilitates the process of learning and provides guidance and help when necessary. The educator does 25% of the work.	*8*	*17*
- A lesson with clearly defined outcomes.	*7*	*15*
- A lesson where learners take responsibility for their own learning and work independently.	*6*	*13*
- A lesson meant to enable learners to reach and explore their maximum learning potential.	*5*	*11*
- An activity-based lesson, doing science practically, discovering about science.	*5*	*11*
- A lesson where learners participate actively and think critically.	*4*	*9*

- A lesson where learners are able to demonstrate an understanding of concepts and principles and acquired knowledge in physics.	*3*	*7*
- A lesson where learners are expected to investigate, solve problems, do experimental work, class-work and practical demonstrations.	*3*	*7*
- A lesson which focuses on the development and use of science process skills in a variety of settings, the development of scientific knowledge and understanding, appreciation of the relationship and responsibilities between science, society and the environment.	*3*	*7*
- An investigative lesson.	*2*	*4*
- A lesson where there is integration of knowledge.	*2*	*4*
- A lesson that defines essential competencies, attitudes and values which learners should acquire and develop.	*2*	*4*
- A lesson that is interactive.	*1*	*2*
- A lesson that enables learners to apply scientific methods, skills and knowledge to problems in innovative ways.	*1*	*2*
- An OBE lesson consists of phase organisers, programme organisers, specific, outcomes, range statements, activities, methods and time frames.	*1*	*2*
- A lesson based on the philosophy that all learners can learn.	*1*	*2*
- A lesson that encompasses both what learners learn and are able to do at the end of the learning process.	*1*	*2*
- A lesson that promotes scientific literacy.	*1*	*2*
- A lesson based on scientific inquiry.	*1*	*2*
- A lesson that aims to develop learners' basic skills, focusing and planning, investigation, gathering, manipulating and analysing data, and communicating findings.	*1*	*2*
- A lesson that prepares learners for scientific research.	*1*	*2*
- A lesson driven by society's needs.	*1*	*2*
- A lesson that includes all types of teaching methods.	*1*	*2*
- A lesson that describes concretely and in detail teaching, learning and assessment activities that are to be implemented.	*1*	*2*
- A lesson where outcomes are achieved through practical work and asking questions.	*1*	*2*
- A lesson that enables a learner to formulate and utilise ideas and knowledge.	*1*	*2*
- A lesson that takes learners' differences into account.	*1*	*2*
- A lesson where learners learn things practically with the help of the educator.	*1*	*2*
- A lesson with different assessment methods.	*1*	*2*
- A lesson that encourages learners to be more creative.	*1*	*2*
- A lesson that develops self-confidence because of being able to discover the outcomes of the activity.	*1*	*2*
Educators' viewpoints based on the traditional approach to science teaching		
- A lesson with specific aims that the educator wants to impart to learners.	*1*	*2*
- A lesson where physics concepts are taught as content to the learners to achieve the set outcomes.	*1*	*2*
- A lesson that guides the educator in what he is supposed to do.	*1*	*2*
Other viewpoints		
- A lesson focussing on the laws of nature and that explains the properties and interactions of matter.	*3*	*7*
- A lesson that investigates physical and chemical phenomena through scientific enquiry, planning models, theory and laws to explain and predict events in our physical environment.	*2*	*4*

- Anything that a learner can show.	*1*	2
- A lesson where learners collect data from a practical and use it to achieve his/her objectives and goals.	*1*	2
- One of the learning areas classified under natural sciences.	*1*	2
- Much of the work is done through experiments.	*1*	2
- A lesson that enables learners to make sense of the natural world.	*1*	2
- During physics practicals learners are given clear instructions that they must follow as they perform experiments in groups or individually.	*1*	2
- A lesson that enables a learner to deduce the objective of each activity done.	*1*	2
- A lesson with themes energy and change of matter and materials.	*1*	2
- A lesson where a learner is expected to understand relationships between quantities.	*1*	2
- It is an outcomes-based education.	*1*	2

6.3.2 Discussion of item 2(a) of the assignment

Compared to other viewpoints, some 43% of the educators seemed to think that an OBE lesson was any learner-centred activity with certain expectations from learners. These expectations include investigating, solving problems, and doing experimental work, class-work, and practical demonstrations using scientific knowledge and skills. The lesson emphasises the development of learners' basic skills such as focussing and planning, investigating, gathering and manipulating data and communicating findings. Educators have very good ideas but this was not practically shown in the video-taped micro-lessons.

In Figure 6.28 the interaction described does not correlate with the viewpoints expressed by educators regarding OBE and learner-centeredness. The reality is that educators are still tempted to go back to the traditional "chalk and talk" method and the interaction between learners is not satisfactory.

A percentage of 15 of the educators view an OBE lesson as an activity-based lesson with clearly defined outcomes. According to educators, the outcomes refer to what the learners learn and are able to do at the end of the learning process. The objectives of an activity-based lesson are the development of and use of science process skills in a variety of settings, the development of and application of scientific knowledge and understanding, appreciation of the relationship and responsibilities between science, society and the environment (Department of Education, 2003).

A very low percentage of educators (17%) said the educator facilitates in an OBE lesson. The results indicate that educators do not fully understand their role in OBE lessons. As a result, they cling to traditional "chalk and talk" and lecturing as a teaching method. This was evident in the video-taped micro-lessons (see Figure 6.28). These results also correlate with responses of educators in Figure 6.16 item 56, where the majority of educators (63%) said learners would interact with the educator.

The majority of the views expressed by the educators (Table 6.2) correlate with the outcomes in the Revised National Curriculum Statement (Department of Education: 2003). This is encouraging, although implementation is still a challenge to physics educators. This is because ideas expressed by educators were not put to practical use in the video-taped micro-lessons.

Overall, there is a slight change in the methodology employed by educators in the micro-lessons compared to the traditional approach. The approach used by educators in the micro-lessons is illustrated schematically in Figure 6.28. It may take some time before educators can practically implement what they have learned from workshops and books about OBE. A majority of the educators (95%) indicated (Table 6.15) that they needed more knowledge on how to plan and execute OBE lessons in physics.

The researcher has developed the CD-ROM containing video-clips of micro-lessons to serve as a framework for educators, lectures, and subject advisors. These video-clips can help educators, lecturers and subject advisors to understand the approaches used by physics educators in order to improve on them for the improvement of physics education within the context of OBE.

In paragraph 6.3.3 below the viewpoints of educators on item 2 (b) of the assignment are listed. The discussion of the viewpoints follows in paragraph 6.3.4.

6.3.3 Educators' views on the characteristics of an OBE lesson in physics (item 2(b) of the assignment

The following table (Table 6.3) indicates educators' responses to item 2(b) of the assignment (Appendix B). The aim with this item was to get viewpoints of educators on the characteristics of an OBE lesson in physics, i.e. what makes a lesson outcomes based?.

A similar classification of viewpoints as in Table 6.2 was done. The viewpoints of educators are classified under the following headings:

- OBE-related viewpoints;
- educators' viewpoints based on the traditional approach to science teaching; and
- other viewpoints.

The last columns indicate the number and percentages of educators that share the same viewpoint.

Table 6.3: Educators' viewpoints

Item 2(b): What makes a lesson outcomes based? N=46		
OBE-related viewpoints	***N***	***%***
- When it states both the critical and developmental outcomes, or is characterised by a set of outcomes.	*13*	*28*
- It is learner-centred and learners are involved through discussions and doing a practical or theory, and manipulate the available resources.	*11*	*24*
- Learners can show their skills, e.g. to think, solve problems, collect data, organise and analyse data, observing, predicting, communicating and interpreting.	*5*	*11*
- When an integrated approach is used (within and across subjects and field of learning).	*5*	*11*
- The educator acts as a facilitator of learning.	*4*	*9*
- When learners are able to apply the skills, ideas and knowledge acquired throughout the lesson.	*4*	*9*
- Prepares learners for future learning.	*3*	*7*
- When it contributes to the holistic development of learners.	*3*	*7*
- When learners show competency and acquire and develop attitudes and values in the subject.	*3*	*7*
- When learners are actively involved.	*3*	*7*
- When it provides guidelines on how learners are to progress.	*3*	*7*
- When specific outcomes are achieved, e.g. independence, creativity, co-operation, sense of responsibility, inquisitiveness and communication.	*2*	*4*
- When it stimulates curiosity and interest.	*2*	*4*
- Flexibility of the lesson.	*2*	*4*
- For a lesson to be outcomes-based, it should help the learner demonstrate or apply	*2*	*4*

the content in real-life situations.		
- When a learner achieves certain specific goals at the end of the lesson.	*2*	*4*
- Learners work independently and in groups.	*2*	*4*
- When it puts emphasis on team work and group work.	*2*	*4*
- Provides the details of the content and processes that the learner should master.	*2*	*4*
- Progression, and assessment standards for each learning outcome become more complex.	*1*	*2*
- Teaching and learning outcomes are interlinked.	*1*	*2*
- It should enable learners to use scientific enquiry.	*1*	*2*
- When it contributes to the economy of the country.	*1*	*2*
- When different teaching methods are used.	*1*	*2*
- Includes assessment strategies.	*1*	*2*
- When it enhances understanding.	*1*	*2*
- Learners are able to identify and solve problems.	*1*	*2*
- Learners can organise themselves and their activities responsibly and effectively.	*1*	*2*
Viewpoints based on the traditional approach to science teaching		
- Aims and objectives make a lesson outcomes-based.	*3*	*7*
- When the objectives and aims of the educator are stated.	*3*	*7*
- The lesson is content-based not textbook-based.	*1*	*2*
Other viewpoints		
- Its sets high expectations for learners.	*2*	*4*
- When the learner is in a position to make use of the apparatus to investigate some concepts and also to explain the observations.	*1*	*2*
- Allows statements to be made about the quality of achievement and whether the achievement is at the level required.	*1*	*2*
- The manner in which the lesson is presented.	*1*	*2*
- When the lesson is organised.	*1*	*2*
- The response given by learners determines the type of lesson.	*1*	*2*

6.3.4 Discussion of item 2(b) of the assignment

Educators expressed a variety of different views. The major challenge regarding OBE lessons is how to plan and execute an OBE lesson (Table 6.15) in physics and provide more practical knowledge of OBE lessons (see Table 6.12). Only 4% of the educators indicated that an outcomes-based lesson involves learners working "independently" in groups. Instead, learners should be guided in their inquiries. In one of the video-taped micro-lessons (See video-clip 3) the educator left almost everything to the learners. His responsibility was to make notes that he later used to explain the expected experimental results.

Some 24% of the educators said that an OBE lesson is learner-centered. According to some educators (24%), learners in a learner-centered lesson are involved through discussions, do practical work or theory and manipulate available resources. Some 28% said that an outcomes-based lesson should state both the critical and developmental outcomes, hence it should give guidelines on how learners are to progress. The majority of views elaborated upon by educators are in line with the characteristics of the OBE approach (Table 3.1), even though other educators said that an OBE lesson was supposed to be content-based with aims and objectives.

As already indicated in paragraph 6.3.4, educators did not put their views to practical use in the video-taped micro-lessons. Figure 6.28 gives a schematic representation of the approaches used in the micro-lessons. Compared to what is expected (Figure 6.29), the educators are slowly moving towards the implementation of OBE. The challenge is that the traditional "chalk and talk" methodology is still overpowering the required OBE approach. Only 9% of educators said that the educator facilitates in an OBE lesson, indicating that educators have limited understanding of their role in an OBE lesson.

6.3.5 Educators' views on practical work in physics (item 2(c) of the assignment

Table 6.4 below indicates viewpoints of educators on item 2(c) of the assignment (Appendix B). The aim with this item was to get educators' viewpoints on their understanding of practical work in physics. The last columns indicate the number and percentages of educators that share the same viewpoint.

Table 6.4: Educators' viewpoints

Item 2(c): What is practical work in physics? N=46		
Viewpoints of educators	***N***	***%***
- When learners in the laboratory or outside the laboratory perform experiments (experimental work) to clarify certain concepts, the educator first have to demonstrate, whereafter the learners should perform the experiment.	*15*	*33*
- An activity where learners are given the opportunity to formulate and prove hypotheses, investigate, explore, think independently, designing experiments, gathering data and drawing conclusions.	*6*	*13*
- The environment whereby learners, educators and scientists are able to	*5*	*11*

demonstrate different skills, such as interpretation, problem-solving, information selections, observing, comparing, classifying and reflecting.		
- An activity to verify laws, theories and hypotheses.	*5*	*11*
- Deals with observing, investigating, demonstrating, measuring, predicting, explaining and experimenting with scientific theory.	*5*	*11*
- Demonstration of experiments to learners (the educator uses the following procedure: aim, apparatus, diagram, procedure, results, interpretation and conclusion).	*6*	*13*
- Hands-on experiments, where learners are involved in motor skills such as hands, sight and taste, measure, construct and fix.	*4*	*9*
- Active participation of learners. Learners do practicals themselves (learner-centred).	*4*	*9*
- It is a formative assessment.	*3*	*7*
- It is carried out in the laboratory.	*3*	*7*
- An activity that allows learners to demonstrate manual and or behavioural skills.	*2*	*4*
- A piece of independent study that leads learners to discovering something they did not know before.	*2*	*4*
- When learners apply scientific knowledge and skills to problems in innovative ways.	*2*	*4*
- It is done in groups for optimum participation.	*2*	*4*
- Involves handling and usage of apparatus to illustrate what has to be learned.	*2*	*4*
- Putting theory into practice.	*1*	*2*
- An activity designed to help both the educator and learners to discover reality by studying relevant examples and generalised statements.	*1*	*2*
- Learners must be aware of the aims and products of the experiment.	*1*	*2*
- Practical work bridges the gap between content or syllabus, and daily life.	*1*	*2*
- Experimenting to prove whether physics laws are correct.	*1*	*2*
- Solving science problems.	*1*	*2*
- Discussing theory, using examples from daily life.	*1*	*2*
- Any work done by learners, using apparatus.	*1*	*2*
- When practicals are performed.	*1*	*2*
- Using the apparatus, recording data from experiments and measuring.	*1*	*2*
- Role play, projects and simulations.	*1*	*2*
- An activity to enhance scientific knowledge.	*1*	*2*
- Discussion of learners.	*1*	*2*

In paragraph 6.3.6 below the viewpoints of educators on item 2 (c) of the assignment are discussed.

6.3.6 Discussion of item 2(c) of the assignment

Educators have varied opinions on the meaning of practical work in physics. The explanations and descriptions attached to practical work in physics largely determine how educators approach this issue.

Some 33% of the educators said that practical work was when learners perform experiments in or outside the laboratory with the aim of clarifying concepts. Compared to other views expressed by educators on item 2(c) (Table 6.4), 33% is a larger percentage.

Even though the educators' views differ from one educator to another, the views corresponds with the literature reviewed in this study (paragraph 2.2), namely:

- Bekalo and Welford (2000:187) assert that practical work should always involve learner participation.

- Bradley and Maake (1998:3) say that the scope of practical work can be extended to include activities such as project work, library research, field work, site visits, environmental monitoring, and investigating technologies.

- Hodson (1992:67) argues that any learning method that requires the learner to be active rather than passive is in accordance with the belief that learners learn best by direct experiences, which is exactly what practical work is.

- Hodson (1992:66) asserts that practical work need not always comprise activities at the laboratory bench. Legitimate alternatives would include computer-assisted learning (CAL), use of worksheet activities in conjunction with an educator demonstration or video/film presentation, working with case study materials, interviewing, debating and role playing, writing tasks, making models, posters and scrapbooks, library work of various kinds and making videos.

- Yager (1991:22) argues that the term could be reserved to describe a place where learners can test their own ideas and/or their own explanations for objects and events they have encountered as they explore their curiosities about the universe in which they find themselves.

- Tamir (1977:311) asserts that the laboratory should be used as a place where science learners engage in hands-on activities such as observations and experiments, that is, not only to verify but to find.

6.3.7 Educators' views on the outcomes of practical work (item 2(d) of the assignment

Table 6.5 indicates educators' viewpoints on item 2(d) of the assignment (Appendix B). The aim of this item was to probe educators' understanding regarding the outcomes of physics practical work. In other words, what are the outcomes of physics practical work according to educators?

The viewpoints of educators are classified under the following headings:

- Acquisition of knowledge;
- skills-related outcomes;
- development of problem-solving skills;
- development of co-operative learning skills;
- development of attitude; and
- other viewpoints.

The last columns in Table 6.5 represent the number of and percentages of educators that share the same viewpoint.

Table 6.5: Educators' viewpoints

Item 2(d): What are the outcomes of physics practical work? N=46		
Acquisition of knowledge		
- Demonstrate an understanding of concepts, principles and acquired knowledge in physics.	*6*	*13*
- Developing knowledge and understanding of some of the fundamental concepts in physics so that it serves as a basis for further studies in physics.	*3*	*7*
- To learn the facts, concepts, theories and laws and determine the relation between variables and quantities.	*2*	*4*
- Comprehend knowledge.	*1*	*2*
- Enhance the understanding of physics content.	*1*	*2*
- Constructing science knowledge: Learners know, interpret and apply scientific technological and environmental knowledge.	*1*	*2*
Skills-related outcomes	*N*	*%*
- To develop the following skills: observing, predicting, comparing, measuring, estimating, recording information, researching, sorting and interpreting, hypothesising and classifying, handling and using the apparatus, drawing	*19*	*41*

conclusions, as well as psychomotor skills.		
- *Use process skills to investigate phenomena related to physics.*	*10*	*22*
- *Using scientific knowledge and skills to support responsible decision-making.*	*10*	*22*
- *Learners should be able to collect data, organise, analyse, manipulate, critically evaluate and use science and technology effectively in order to make decisions and solve problems.*	*8*	*17*
- *Apply scientific knowledge and skills in innovative ways.*	*4*	*9*
- *Demonstrate an understanding of how scientific knowledge and skills contribute to the management, development and utilisation of scientific and other resources.*	*2*	*4*
- *To teach practical skills with safe and correct lab techniques.*	*1*	*2*
- *To investigate certain principles.*	*1*	*2*
- *Facilitating the idea that the world is a set of related systems.*	*1*	*2*
Development of problem-solving skills		
- *Learners should identify and solve problems by using creative and critical thinking.*	*6*	*13*
- *Development of scientific reasoning.*	*3*	*7*
- *Scientific investigations: To help learners act confidently on their curiosity about natural phenomena, to investigate relationships and solve problems in science.*	*1*	*2*
- *To broaden the mind of the learner.*	*1*	*2*
- *To identify and solve problems and make informed decisions.*	*1*	*2*
Development of co-operative learning skills		
- *To encourage co-operative learning.*	*4*	*9*
- *Develop communication skills, e.g. reading, writing, focusing, following instructions and listening.*	*2*	*4*
- *To enable learners to organise themselves and their activities responsibly and effectively.*	*1*	*2*
- *Show responsibility towards the environment, health and others.*	*1*	*2*
- *Learners should work effectively with others in a team, group, organisation and community.*	*1*	*2*
Development of attitudes		
- *Development of scientific attitude and values.*	*6*	*13*
- *To make the subject accessible, interesting and relevant.*	*2*	*4*
Other viewpoints		
- *An understanding of the interrelation between science, culture and technology.*	*4*	*9*

- *Demonstrate understanding of the world in a related system.*	*2*	*4*
- *To improve self-management*	*2*	*4*
- *To make observations during experimentation.*	*2*	*4*
- *To confirm laws and hypotheses.*	*2*	*4*
- *To assess learners.*	*1*	*2*
- *To assist learners to discover facts on their own.*	*1*	*2*
- *To assist learners to have better understanding of the work they are doing.*	*1*	*2*
- *Learn about the nature of science.*	*1*	*2*
- *They are evidence of the hypothesis.*	*1*	*2*
- *They support existing knowledge.*	*1*	*2*
- *Demonstrate how physics work in everyday life.*	*1*	*2*
- *Prepare learners for specific activities.*	*1*	*2*
- *Perform and monitor tasks according to pre-set preparations or methodology.*	*1*	*2*
- *To supply expected or unexpected results.*	*1*	*2*
- *To experiment scientific concepts.*	*1*	*2*
- *To analyse performed experiments.*	*1*	*2*
- *Understanding perfect demonstrations.*	*1*	*2*
- *To explore the relationship between physical quantities and objects.*	*1*	*2*
- *To invent theory.*	*1*	*2*
- *To learn relationships between quantities.*	*1*	*2*
- *To identify phenomena and objects.*	*1*	*2*
- *To link the concept to the outside world.*	*1*	*2*
- *To give a detailed report about the experiment.*	*1*	*2*
- *To prove theory through experimental evidence.*	*1*	*2*
- *The outcomes of practical work are achieved if the results of a practical supports the laws being investigated.*	*1*	*2*
- *To be aware of the importance of physics in the outside world.*	*1*	*2*
- *To understand the importance of scientific methods such as accurate experimental work.*	*1*	*2*
- *Demonstrate the relationship between science and socio-economic development.*	*1*	*2*
- *Develop an understanding of the dynamic nature of science.*	*1*	*2*

In paragraph 6.3.8 below the viewpoints of educators on item 2 (d) of the assignment are discussed.

6.3.8 Discussion of item 2(d) of the assignment

As already indicated in paragraph 2.4.1, the list of the aims and outcomes of practical work vary enormously in format of presentation and detail (Kempa, 1988:148). Generally views expressed by educators on item 2(d) (Table 6.5) correlate with the reviewed literature on the outcomes of practical work (paragraph 2.4.1) by Van der Linde *et al.*,1994:50; Allsop, 1991:33; Bradley *et al.*, 1998:1406 and Treagust & Thair, 1999:358.

The literature surveyed for this study indicates that practical work should:

- Reinforce the understanding of scientific concepts and principles, making abstract concepts more understandable and supporting theoretical learning;
- develop practical skills and techniques;
- teach the processes of science, involvement in problem-solving and thinking styles that expose learners to work like a scientist; and
- stimulate learners' interest and motivate them to realise that science is enjoyable.

These outcomes of practical work correlate with the outcomes of natural science indicated in the Revised National Curriculum Statement (Department of Education, 2003) and the central principles of constructivism (paragraph 3.4.1). The challenge facing educators is to practically implement these outcomes in the classrooms.

The outcomes specified by the educators (Table 6.5) are an elaboration of the outcomes of practical work reviewed in paragraph 2.4.1. The concentration in practical work on these outcomes is justified because of the adoption of what is essentially a discipline-centred approach to the determination of the aims of science education (Kempa, 1988:148).

6.4 ANALYSIS OF MICRO-LESSONS

The video-taped micro-lessons were viewed several times during the analysis. In addition, all the video-taped micro-lessons were transcribed (Appendices D, E, F, G, H and I) together with the educators' micro-lesson plans (Appendices J, K, L, M, N and O). Tables 6.6 to 6.14 provide an analysis of the micro-lessons. The items (Appendix P) were used to analyse the micro-lessons.

A comparison was made between the micro-lessons presented and the OBE requirements or expectations of the Revised National Curriculum Statement (Department of Education, 2003). The findings of the micro-lessons are summarised in Table 6.15. The schematic representation of the approach used by the educators in the micro-lessons is illustrated in Figure 6.28.

Table 6.6: The structure of the lessons

Micro-lesson 1
The educator followed the structure below: • Introduced the apparatus to be used. • Asked questions about the apparatus (pre-knowledge). • Gave a demonstration. • Asked learners to connect two cells in series with a bulb and an ammeter and then three cells in series, a bulb and an ammeter). • Ended the lesson by giving learners homework.
Micro-lesson 2
The educator followed the protocol below. • Specified the outcomes of the lesson, which he said was to investigate the relationship between the current and potential difference. • Indicated the requirements to reach the outcome. • Introduced the apparatus. • Asked questions about the apparatus (cell and its function, voltmeter and its use or function, ammeter and its function, rheostat and its function). • Involved learners in activities where learners connected three cells in series with an ammeter and rheostat and the voltmeter in parallel to a bulb. • Concluded the lesson by asking learners to state Ohm's law.
Micro-lesson 3
The following structure was followed and the educator: • Specified the outcomes of the lesson • Used daily experiences to introduce the lesson. • Distributed the worksheets.

- Read through the procedure of conducting the experiment as indicated in the worksheets with learners.
- Gave learners the opportunity to do the experiment and complete worksheets on their own while the educator made notes on the flip-board.
- Read through the notes to round off the results of the experiment.

Micro-lesson 4

The following structure was adopted:

- The educator discussed the importance and dangers of electricity and then indicated the aim of the lesson.
- The educator went through the worksheets and elaborated on the contents with the aim of explaining it.
- Learners were given homework to do the experimental part of the lesson.

Micro-lesson 5

The educator followed the structure indicated below.

- The educator told learners about the outcome of the lesson, which was to learn about electricity, distributed the apparatus and asked questions on pre-knowledge.
- Learners were asked to connect an electric circuit, with one cell, a switch, an ammeter, a voltmeter in parallel to the bulb. The number of cells was then increased to two and finally three cells, all in series.
- The results were discussed. The educator led the discussion by asking questions about learners' observations and conclusions.
- End of lesson: The educator ended the lesson by showing learners how to use a multi-meter to arrive at the same conclusions.

Micro-lesson 6

The structure of the lesson was as follows:

- The educator indicated the outcomes of the lesson and asked learners questions.
- Learners performed the experiment in groups and completed the worksheets.
- The educator asked learners questions about the experimental results.
- End of the lesson: Homework was given.

What the researcher generally observed was the cookbook style of practical work that does not represent the features of inquiry. This style of practical work is always organised around five steps, which are: purpose, procedure, data, analysis and conclusions (Volkmann & Abel, 2003:38).

The procedure indicated by educators in the video-taped micro-lessons describes recipe-like steps that learners should follow to verify Ohm's law (see worksheets attached to micro-lesson plans in Appendices J, L, M and N).

In contrast, the literature surveyed for this study (Volkmann & Abel, 2003:38) indicates that learners should be:

- Engaged with scientifically-orientated questions;
- given priority to evidence;
- given an opportunity to formulate evidence-based explanations;
- allowed to compare and evaluate the merit of explanations; and
- given the opportunity to communicate and justify explanations.

Classroom educators should raise productive questions that provide opportunities for learners to (Volkmann & Abel, 2003:38):

- Define variables and develop procedures;
- challenge learners to look for patterns in data;
- guide learners as they develop evidence-based explanations;
- create situations where learners communicate; and
- justify explanations on the merit of evidence.

Table 6.7: How were the lessons introduced?

Micro-lesson 1
Learners were arranged into groups. The educator introduced the apparatus one by one, starting with a cell, cell holders, then circuit board, ammeter, voltmeter, bulbs, bulb holder, and conductors. These were all in a box. The educator took a cell from the box and asked the learners what it was. The learners responded that it was a cell. A follow-up question was asked by the educator, namely to write down the symbol of the bulb. The same procedure was used with all the other apparatus. Learners were asked how they would connect a voltmeter and the ammeter in a circuit.
Micro-lesson 2
The lesson was introduced by specifying the outcome of the lesson, that is, to investigate the

relationship between the current and potential difference across the ends of the conductor. The educator mentioned what was needed to investigate the relationship between the current and potential difference. These requirements included the apparatus to be used, cells, a voltmeter, an ammeter, rheostat, connecting wires, switch and a circuit board. The apparatus were introduced by questioning learners about the names of the apparatus and their functions as indicated in Appendix E.
Micro-lesson 3
The lesson was introduced by specifying the outcome of the lesson. A question on learners' daily experiences of electricity was asked, based on the appliances used at home. Learners were requested to name appliances that use electricity, such as a stove, kettle, hair-drier, television and radio.
Micro-lesson 4
The educator started the lesson by asking whether learners have studied the section on Ohm's law. Only one of the learners raised a hand. The educator advised learners to always study the section to be taught before coming to class. The importance of electricity to human life and the dangers of electricity were discussed with learners. The aim of the lesson was indicated by the educator, which he said was to help learners understand this law.
Micro-lesson 5
The educator told learners about the outcome of the lesson, which he said was to learn about electricity. He then distributed the apparatus and asked questions about the two instruments, namely an ammeter and voltmeter. The questions included learners' knowledge of the two instruments, their functions, and how they are connected in a circuit.
Micro-lesson 6
The educator introduced the lesson by stating the outcome of the lesson, namely to study Ohm's law. Questions on learners' knowledge of the symbols used in electricity were asked. In addition, the educator asked questions about how to connect the ammeter and the voltmeter.

The educators started the lessons by introducing the apparatus to the learners (micro-lessons 1, 2, 5 and 6). In micro-lesson 3 the educator questioned learners on their daily experiences of electricity, while in micro-lesson 4 the educators discussed the dangers and importance of electricity.

The introduction of a practical lesson needs to stimulate the interest of learners. This means that educators should use inquiry- and problem-orientated approaches when introducing practical work. The educator specified the procedure to be followed by learners (Figure 6.11 item 43). Volkmann and Abell (2003:40) emphasise that new inquiry-based practical work should commence with a challenge. Challenges should urge learners to design procedures and data, gather materials, and start their investigations. These challenges were not evident in the micro-lessons.

Table 6.8: Comment on the outcomes specified

Micro-lesson 1

The educator did not specify any outcomes during the entire lesson, while the micro-lesson plan (Appendix J) indicated the following:

Learning area	SOs	ACs
NS	SO1	
	SO2	
EMS	SO2	
LLC	SO1	AC1
MLMMS	SO5	
TECH	SO1	AC1

SOs indicate specific outcomes, SO1, SO2, SO5 indicate specific outcomes 1, 2 and 3 respectively.

SO1: To use process skills to investigate phenomena related to the natural sciences.

SO2: Demonstrates an understanding of the concepts, principles and knowledge acquired in natural sciences.

SO5: Uses scientific knowledge and skills to support responsible decision-making.

The following abbreviations NS, EMS, LLC, MLMMS and TECH mean natural sciences, economic management sciences, language, literacy and communication, and technology respectively.

The fact that the educator did not specify the outcomes of the lesson during the lesson could mean that he/she believed that he/she was the only one who should know the outcomes.

Micro-lesson 2

The outcomes were specified at the beginning of the lesson, that is, to investigate the relationship between the current and potential difference. The micro-lesson plan (Appendix K) indicates the latter outcome and two other outcomes (referred to as specific outcomes). The two outcomes are:

1. To use process skills to investigate phenomena related to the natural sciences;

2. demonstrating an understanding of how scientific knowledge and skills contribute to the management, development and utilisation of natural and other resources.

In addition, two critical outcomes are specified in the micro-lesson-plan (Appendix K). The critical outcomes specified are:

1. The use of science and technology effectively and critically, showing responsibility towards the environment and health of others; and

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

Micro-lesson 3

The educator specified the outcome of the lesson at the beginning of the lesson, namely to determine the resistance. However, three outcomes were indicated in the micro-lesson plan (Appendix L). The outcomes indicated in the micro-lesson plan (Appendix L) were to be able to:

1. Construct and draw electric circuit diagram in series connection;

2. identify the relationship between potential difference, current and resistance;

3. plot the graph by using the data collected from the voltmeter and ammeter.

There is no indication on how scientific inquiry and problem-solving skills were going to be developed.

Micro-lesson 4

The educator used the phrase 'aim of the lesson', which was to help learners understand Ohm's law. The latter is what the educator said, but three outcomes were specified in the micro-lesson plan (Appendix M). The learners should namely be able to:

1. Apply Ohm's law by solving practical problems;

2. complete an electric circuit for determining V/I;

3. draw a graph showing the relationship V/I and determining resistance of a circuit.

The worksheet attached to the micro-lesson plan (Appendix M) indicated the 'aim' of the practical as: To verify Ohm's law.

Micro-lesson 5

The educator indicated the outcome of the lesson as to learn about electricity. The micro-lesson plan (Appendix N) indicated the critical outcomes and the specific outcomes as follows.

The critical outcomes were to:

1. Collect, analyse, organise and critically evaluate information; and

2. communicate effectively by using mathematical and language skill in modes of written presentation.

The specific outcomes were that:

1. Learners should be able to measure potential difference and current and work efficiently and safely; and
2. should be able to measure and calculate resistance and research factors.

Micro-lesson 6

The outcomes specified were to study Ohm's law. The micro-lesson plan (Appendix O) indicated the following outcomes, namely that learners should be able to:

1. Collect;
2. record; and
3. interpret data; and
4. draw a graph.

The outcomes focussed on the development of skills such as interpretation, collection and recording of data.

The majority of the outcomes specified in micro-lessons 1, 2, 5 and 6 are similar to the outcomes in the Revised National Curriculum Statement (Department of Education, 2003). The researcher's observation of the micro-lessons was that the educators have limited understanding on the interpretation of the outcomes of practical work. The educators' presentations were formal, traditional and topical (Table 6.15). The primary outcome of the educators in the micro-lessons were to confirm Ohm's law, hence they used practical work primarily to confirm theory.

Table 6.9: What pre-knowledge was probed?

Micro-lesson 1

The educator probed learners' pre-knowledge (see Appendix D). For example, the educator took a cell and asked what it was. Learners respond by saying it was a cell, where after the educator asked the learners to write down the symbol of cell.

The pre-knowledge probed was related to the learners' recognition of the apparatus and its symbol, which is whether they knew the apparatus, for instance the cell, the circuit board, the voltmeter, the ammeter, cell holders, bulbs and the rheostat. Questions on how to connect both the ammeter and the voltmeter were asked.

Micro-lesson 2

Knowledge of the concepts electric current and potential difference was probed. The electric current was explained by learners as a flow of charge and the potential difference as the work done in moving one positive charge from one point to another. The educator asked learners to give the units of both the electric current and the potential difference and to indicate how both the ammeter and the voltmeter are connected in an electric circuit.

Micro-lesson 3

The educator probed the learners' daily experiences by asking them to name the electrical appliances used at home. He then asked them to explain what the effect would be if all of them were connected in series.
Micro-lesson 4
The pre-knowledge probed included learners' knowledge of the symbols for current, potential difference and the unit of potential difference (see Appendix G).
Micro-lesson 5
Pre-knowledge probed by the educator was only based on learners' knowledge of the two instruments ammeter and voltmeter, their use and how they are connected.
Micro-lesson 6
The educators probed the learners' knowledge of electrical symbols and the connections of both the ammeter and the voltmeter.

The educators used questions to probe the learners' pre-knowledge. The questions used were simple objective questions (Table 6.10). By objective, the researcher means that the questions required learners should raise their hands. One learner was then selected to give the correct answer. If the educator wanted to know how effectively learners could connect the ammeter or voltmeter, learners should instead be engaged in practical-related activities where the educator could assess their competencies and knowledge thereof. The reality is that learners are able to provide the correct answers when verbally questioned on the correct connections of the ammeter and the voltmeter, but fail to practically make the correct connections. Arons (as quoted by Trumper, 2003:657) argues that learners should through modes of inquiry and thinking figure out how a piece of equipment works and how it might be used. According to Trumper (2003:657), the modes of inquiry and thinking seem to promise greater effectiveness and firmer justification for maintaining practical work as a critical part of physics teaching. Educators should have knowledge of learners' existing understanding in the targeted conceptual areas and be able to use this as a starting point for the designing of appropriate activities (Trumper, 2003:657).

Table 6.10: Examples of the questions asked by the educators

Micro-lesson 1
Write down the symbol of the cell. Which side of cell is positive and which side is negative?

How do we connect the voltmeter in the circuit? Write down the symbol of the bulb?
Micro-lesson 2
What is the function of the voltmeter in the circuit? What is potential difference? What is the function of the cell in the circuit? What is the function of the ammeter in the circuit? What is electric current? Define resistance.
Micro-lesson 3
Name examples of electrical appliances that are used at home. What would happen if all appliances were connected together? These are the only two questions asked and they were asked in the introductory part of the lesson.
Micro-lesson 4
What would life be without electricity? Is electricity dangerous? Examples of questions asked during the lesson (see Appendix G). What is the symbol for potential difference? What is the unit for potential difference? What is the symbol for current? Why is the symbol for ampere (capital A)?
Micro-lesson 5
What is the function of the ammeter? How do we connect the ammeter? What is the function of the voltmeter?

How do we connect the voltmeter? Examples of questions asked during the lesson (see Appendix H). Will current flow with an opened switch? What do you observe if you increase the number of cells? Why is there current in the x-axis?
Micro-lesson 6
How do you connect the ammeter? How do you connect the voltmeter?

Educators should reconsider which questions to ask, since their questions were only content-based. The questions should rather be problem-based and enquiry-oriented. For example, instead of asking questions such as: "What is the symbol of a cell?" and "How is the ammeter connected?" a question such as "Construct a circuit to measure the physical features of the bulb" could be asked. The latter question poses a problem that a group of learners could solve, while the former questions are usually asked to a group as a whole and a learner who knows the answer responds. Educators should ask questions that stimulate reasoning and understanding of learners. Such questions urge learners to solve problems co-operatively in groups. This standpoint is further supported by Trumper (2003:657), who asserts that educators should ask and pursue questions such as "How do we know...? Why do we believe...? What evidence is there for...?. Such questions should be inherently associated with the practical at hand. Educators should involve learners in activities where they generate questions to investigate. Challenging learners to solve new problems promotes thinking and deepens understanding of concepts (Volkmann & Abell, 2003:40).

Science classes should be planned in such a way that it engages learners in important problem-solving activities, which include asking questions, making observations, analysing data, wrestling with interpretations and explanations, and seeing applications of scientific concepts in the world around them (Lunetta, 1988:164).

Table 6.11: If learners were involved, how were they involved?

Micro-lesson 1
Learners were involved through answering questions asked in the introductory part of the lesson and in doing the experiment in the middle of the lesson. Learners were given the apparatus to connect two cells in series with a bulb and then measure the current in the circuit using an ammeter, three cells in series with the bulb and measuring the current that flows with an ammeter.
Micro-lesson 2
In the introductory part of the lesson learners' involvement was through answering questions (see Appendix K) asked by the educator. The educator took the lead by instructing learners on the procedure to be followed when doing investigations. Learners would wait for instructions on what to do next and how. The educator was doing the talking, while learners were doing the investigations.
Micro-lesson 3
Learners were mostly involved by doing experiments and completing the worksheets. They were also involved by answering the questions in the worksheet provided and those asked by the educator in the introduction of the lesson.
Micro-lesson 4
Learners were only involved through answering the educators' questions.
Micro-lesson 5
Learners connected the electric circuits, completed the worksheets, held group discussions, which were facilitated by the educator and answered questions asked by the educator.
Micro-lesson 6
Learners were involved through doing the experiment, answering questions, and completing the worksheets.

Learner involvement in the micro-lessons was mainly based on learners' answering the educators' questions and following the instructions (recipe) for constructing the electric circuit.

Volkmann and Abell (2003:40) argue that educators should throw away the recipe (or part of it) and give learners and groups the opportunity to:

- Define variables, develop procedures, set up data tables and make predictions;
- expect learners to develop evidence-based explanations as a central step in practical work;
- provide learners with opportunities to work and talk together;
- engage learners in the analysis of data by looking for patterns, using evidence and logic to support explanations, and sharpen their skills at constructing evidence-based explanations;
- provide opportunities to present explanations to other group members through discussion, writing and drawing; and
- ask learners to evaluate the logic of their explanations in terms of evidence.

The results of this study correspond with research findings by Haury and Rillero (1994), who indicated that most learners live in an authoritarian world with little or no opportunity to practise decision-making because nearly everyone tells learners what to do and when to do it. This was evident in the observed micro-lessons.

Table 6.12: Does the lesson emphasise theory or practical, or both?

Micro-lesson 1
It emphasised both theory and practical, but the practical was used to confirm theory.
Micro-lesson 2
There was a lot of theory.
Micro-lesson 3
The lesson emphasised both practical and theory.
Micro-lesson 4
The lesson emphasised theory. A purely theoretical approach was adopted. No practical was done, al though apparatus were available. The educator avoided the use of apparatus either by learners or himself.
Micro-lesson 5
The lesson emphasised practical to confirm theory and Ohm's law.
Micro-lesson 6
The lesson as observed was aimed at doing the practical to confirm the theory behind Ohm's law.

Almost in all the micro-lessons educators were mainly interested in the learning of theory. This is typical of the theoretical practical work described in paragraph 3.12.1.1. What happened in the micro-lessons is in contrast with the constructivist approach to science teaching (paragraph 3.4). According to Hodson (1992:68), practical work should fit into a constructivist psychology of learning and the current emphasis should be on the affective goals and learners' control of learning. While theoretical understanding is of vital importance, practical work should be a way of exploring and developing learners' conceptual understanding. Practical work should be used to help learners understand the role of direct observation in physics and to distinguish between inferences based on theory and the outcomes of experiments. A broad array of basic skills such as inquiry and data analysis should be developed. This means that practical work should engage each learner in significant experiences with experimental processes, including some experience in designing investigations (Trumper, 2003:649).

For practical work to have an effect on learners' theoretical knowledge, learners need to reconstruct and link concepts in different ways. They also need to spend more time interacting with ideas and apparatus (Gunstone, 1991:74).

Table 6.13: Comment on worksheets used during the lesson

Micro-lesson 1
Readings obtained were recorded on a worksheet attached to a micro-lesson plan (Appendix J).
Micro-lesson 2
Learners used their notebooks to note down observations during the lesson. The educator had a micro-lesson plan indicated in Appendix K, which he used to give instructions on the procedure to be followed in the practical.
Micro-lesson 3
Learners used worksheets to record their observations and to read the procedure for doing the experiment.
Micro-lesson 4
Although worksheets were provided to learners, learners used it to refer to notes attached (see Appendix M). The practical part was not done, since the educator focused on learning theory.
Micro-lesson 5
The worksheet attached to the micro-lesson plan (Appendix N) was used in this lesson. This worksheet was meant to give directions to learners on the procedure to be followed when conducting the experiment. The worksheet also made provision for recording the results and questions based on the experimental results were indicated.
Micro-lesson 6

Learners used worksheets to record their results and to read instructions on how to do the experiment.

The educators used a worksheet-driven approach to practical work. The worksheets used were meant to give instructions on the procedure to be followed. The results correlate with item 59 (Figure 6.17). Some 59% of educators said that information sources available to learners are guiding worksheets. The challenge to educators is to effectively use the worksheets to guide rather than instruct the learners.

McDowell and Waddling (1985:1037) assert that worksheets should guide learners through their inquiries in the same way as the educator would facilitate and guide learners. This means that through the use of well-constructed worksheets learners can keep records of their experiments. These will assist learners in constructing and reconstructing their knowledge and thus make links with other areas of knowledge in new situations.

Table 6.14: Misconceptions identified during the lesson

Micro-lesson 1
The educator gave learners the impression that they could see the electric current in a circuit. The educator said: "The current is flowing from positive and is looking for negative, can you see it?"
Micro-lesson 2
The educator said: "Arrows in the circuit diagram indicate that electrons are withdrawn from one point to another". "When the tap is opened, water will flow and when it is closed, water will not flow. The same would apply for a closed switch and an opened switch".
Micro-lesson 3
None.
Micro-lesson 4
None.
Micro-lesson 5
The current flow when the switch is opened.
Micro-lesson 6
None.

The educator in micro-lesson 1 (Table 6.14) gave learners the impression that they could see the current flowing in the conductor, which is not the case. A practical lesson should be meant to address and clear misconceptions that learners hold about certain concepts and phenomena in physics. A misconception such as: "Arrows in the circuit diagram indicate that electrons are withdrawn from one point to another" (Table 6.14, micro-lesson 2) creates confusion between the flow of current and the movement of electrons. The electrons make up the flow of charge, and as a result they are called charge carriers.

"When the tap is opened water will flow and when it is closed water will not flow. The same would apply for a closed switch and an open switch" (Table 6.14, micro-lesson 2). This was an explanation given by one of the learners to differentiate between the open switch and the closed switch. What is explained by the learner is the opposite of what really happens in an electric circuit with a closed and an open switch. Closing a switch in an electric circuit will allow current to flow, while closing a tap water will not allow water to flow. The same applies to an open switch: opening a switch in an electric circuit will not allow electric current to flow, while opening a tap water will allow water to flow. This is an incorrect analogy, and the educator did well by correcting such an analogy. The latter also explains a misconception that current flows when the switch is opened (Table 6.14, micro-lesson 5). The terminology 'opened' and 'closed switch' or on and off switch seems to confuse educators. They believe that when circuit is drawn we talk of an open or closed switch, but when doing the practical we talk about the fact that the switch is on or off.

Trumper (2003:657) emphasises that educators should provide experiences that will help learners confront discrepancies between their own incorrect or limited views and accepted scientific views. Consequently, general teaching approaches should incorporate both instructional methodology and content and induce learners to make changes in their beliefs of how the world works.

Redish (as quoted by Trumper, 2003:657) summarise principles that may get learners to hear what they are trying to say and to change their deeply held ideas:

- Go from the concrete to the abstract.
- Put whatever is new into a known and understood context.
- Make learners articulate what they have seen, done and understood in their own words.

- To change learners' ideas, the educator should first get them to understand the situation, make a prediction, and finally to see the conflict between their prediction and their observation.
- Learning should not only be hands-on but minds-on, leading to the reconstruction of the currently held concepts or the emergence of new ones.
- Engage learners in constructive activities where they feel in control.

6.5 SUMMARY OF THE GENERAL FINDINGS OF THE MICRO-LESSONS

A comparison was made between the micro-lessons presented and the OBE requirements of the Revised National Curriculum Statement (Department of Education: 2003). The findings of the micro-lessons are summarised in Table 6.15.

Table 6.15: A comparison between OBE requirements or expectations and the micro-lessons

Aspect of the micro-lessons	OBE requirement or expectations	Micro-lessons presented
Outcomes	Specified in context Problem-oriented Contextual	Formal and traditional Topical Everyday life context Worksheet-driven
Approach	Learner-centred Co-operative learning in groups Emphasis on outcomes	Educator-centred Group work Content-based
Questions	Inquiry-based and problem-solving-oriented Critical thinking Scientific reasoning Stimulate thinking, reasoning and understanding	Content-based
Experimental procedure	Inquiry-based and problem-oriented Hypothesising Observing Gathering information Comprehension Synthesising Generalising Communicating results and making conclusions Discovery	Content-based and recipe-following Worksheet-driven Instructed by the educator

Role of educator	Facilitator Observe progress and problems experienced Intervene Guide Assess Identification and remedy of alternative conception	Instructor Lesson leader Passive Watch learners working Teacher demonstration Provider of knowledge Control the learners' work Writing of notes "Chalk and talk" Educators conveyed alternative conceptions
Role of learners	Active learners Co-operative learning	Learners participate when instructed
Problem-solving	Identification of problem Analysis of problem Design of procedures to reach solutions Application in scientific, technological, environmental and everyday contexts	Formal calculations Not contextual Educator-centred
Misconceptions	Address misconceptions	Conveyed misconceptions
Skills	Development of practical skills, e.g. investigative skills, manipulative skills, observation, recording, interpreting, making deductions and analysing	Little attention paid to skills development Emphasis mainly on observation and recording skills

It is clear that the educators did not successfully comply with the OBE requirements in the micro-lessons. Although they have theoretical knowledge of the requirements, they did not succeed in putting theory into practice.

A comparison between the conventional approach, the approach used in the micro-lessons presented and the new outcomes based approach is indicated schematically in figures 6.27, 6.28 and 6.29 below.

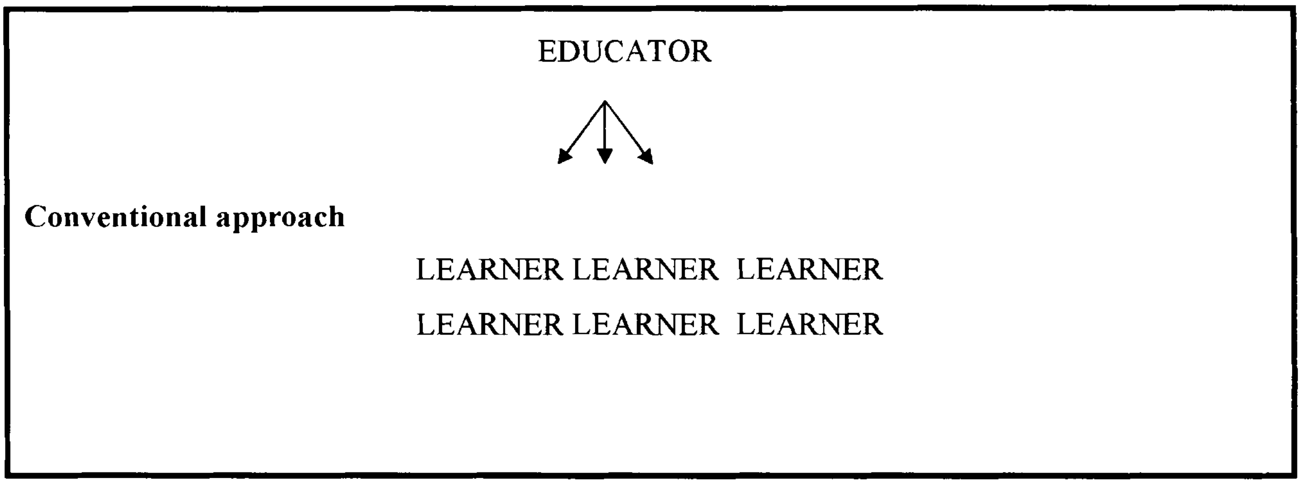

Figure 6.27: Schematic representation of the conventional approach

In the conventional approach (Figure 6.27) the educator is the source of knowledge. Learners are seated in rows and the educator dish out the knowledge. In general, no or little interaction between learners occurs.

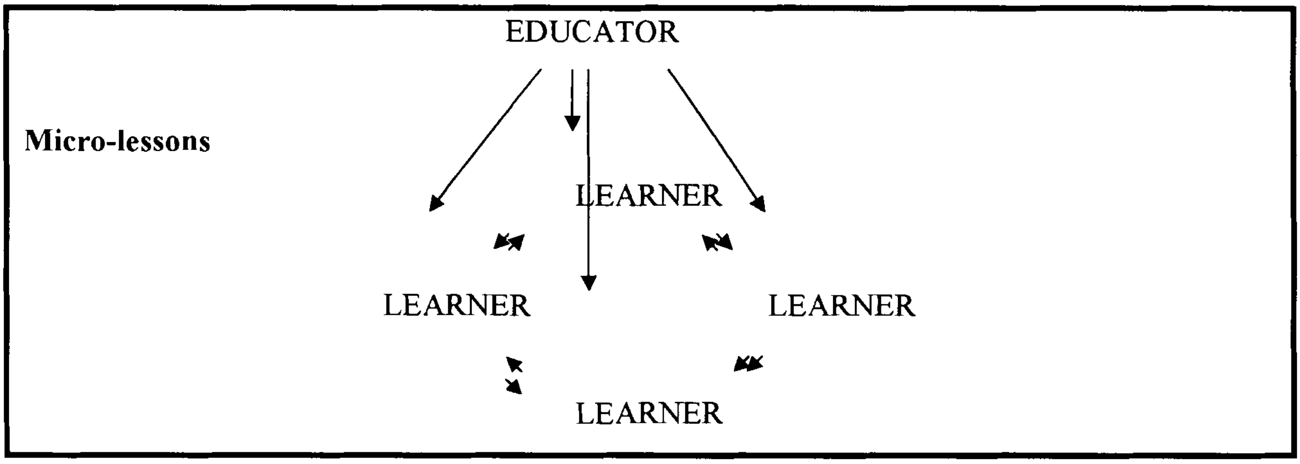

Figure 6.28: Schematic representation of the approach used in the micro-lessons

The researcher call the approach used by the educators in the micro-lessons (Figure 6.28) an improved conventional approach. The educator divides learners into groups but hardly ever uses group work. Instead, the educator goes back to the conventional approach as a provider of knowledge and watch learners carrying out the instructions. Learners are seated in groups but there is limited interaction between them.

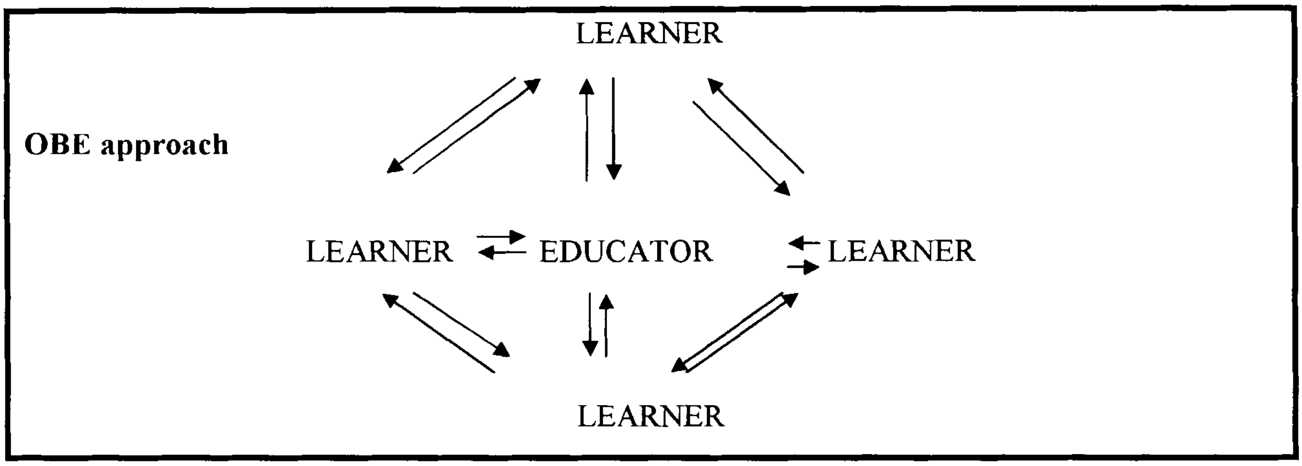

Figure 6.29: Schematic representation of an OBE approach

In the OBE approach (Figure 6.29) the educator facilitates learning and takes part by interacting with learners, assisting those who experience problems and assessing the learning process. Learners interact with each other and engage in problem-solving.

It is clear from the results of the study that educators who participated in this study experience difficulties and lack skills in approaching and facilitating practical work in physics.

6.6 THE "MODEL" MICRO-LESSON

The "model" micro-lesson plan used for this study is indicated in Appendix R. Educators modified the format in Table 3.5 and developed a "model" micro-lesson plan after discussing the merits and demerits of micro-lessons 1, 2, 3, 4, 5 and 6. The "model" micro-lesson plan (Appendix R) is an improvement on the micro-lesson plans (Appendices J, K, L, M, N, and O). It does not serve as a perfect plan, but as a framework from which educators could plan practical work in physics. The "model" micro-lesson plan, together with the presented "model" micro-lesson, is open to criticisms by everyone involved in the teaching of practical work in physics. Hence, the term "model" is written in inverted commas.

The micro-lesson plan is based on problem-solving and inquiry activities. With specific reference to Ohm's law as was used in this study, learners were expected to:

- Formulate an action plan to determine the resistance of the unknown resistor;
- choose/select appropriate apparatus;
- use the apparatus and take measurements to obtain data; and
- manipulate data to determine the required resistance.

A major difference between this lesson ("model" micro-lesson) and the 6 micro-lessons (referred to as micro-lessons 1, 2, 3, 4, 5 and 6) analysed in paragraph 6.4 is that:

- The educator (presenter) in the "model" micro-lesson spends a lot of time facilitating and guiding learners (educators who role-played learners) through their inquiries (see transcript of the "model" micro-lesson Appendix S).
- The transcript (Appendix S) of the "model" micro-lesson is very brief compared to (Appendices J, K, L, M, N, and O) because the "model" micro-lesson was not characterised by a lot of "chalk and talk" methodology.
- There was an improvement on the approach as compared to micro-lessons 1, 2, 3, 4, 5 and 6.

It should be noted that it may take time before educators become experts in facilitating inquiry and problem-solving activities. Reasons for the latter may include the following:

- They are used to the traditional ways of conducting practical work in physics;
- they were educated and trained in traditional ways;
- they continue to use traditional ways in their classrooms; and
- a paradigm change does not occur overnight.

Through viewing and critically analysing all the video-clips of the micro-lessons and the presented "model" micro-lesson included in this report (CD-ROM), the current traditional approach to practical work can be changed into an inquiry approach.

6.7 RESULTS OF THE QUESTIONNAIRE ON VIDEO-TAPED MICRO-TEACHING

As indicated in paragraph 5.4.4, the objective of the questionnaire (Appendix Q) was to gauge perceptions of educators on video-taped micro-teaching as a tool in modelling educators' approaches to physics practical work.

Only 41 of 46 educators completed the questionnaire (Appendix Q). Five (5) educators did not attend the last contact session. The results are given item by item in tables 6.16 to 6.31.

Table 6.16: Response to item 1

Do you think that the teaching strategy using video-taped micro-lessons will help to improve your approach to OBE lessons in physics? N=41

Response	N	%	Comments
Yes	40	98	I can learn from my mistakes and other people's mistakes and correct them. I can realise my weaknesses and strong points. Yes, because we are not trained to apply OBE. I can realise my role as an educator. I can learn from other educators' presentations. I can understand better when I see others presenting an OBE lesson. It is important especially in assessing yourself. Shortcomings can be revisited by watching the video-tapes from time to time. I learned new techniques. It improved my confidence in presenting a lesson. I can compare my approach to those used in video-taped lessons and improve on my own. I can watch the video-tapes and improve my errors. I can determine what to improve and how. I can see different teaching approaches. It will help a lot. It can be shown to many educators and they will thus know what to expect. It helps us to shift from an old approach to the new approach. It will improve our attitude towards OBE. An educator can learn how to use different strategies. It serves as a demonstration model lesson.
No	1	2	Sometimes learners do not concentrate because they take it as part of entertainment.

No less than 98% of the educators said that the teaching strategy using video-taped micro-lessons would help to improve their approach to OBE lessons in physics. These results are further confirmed by the educators' positive comments indicated in Table 6.16 above. The results of this study are supported by Haury and Rillero (1994), who indicate that some practical experience in teaching science is often the most effective way to gain proficiency with hands-on science in the shortest time.

Table 6.17: Response to item 2

Do you think video-taped micro-lessons can aid in the training of educators? N=41

Responses	**N**	**%**
Yes	41	100
No	0	0

All the (100%) educators thought that video-taped micro-lessons could aid in the training of educators. The results indicate that educators really learned from the use of video-taped micro-lessons in their training.

Table 6.18: Response to item 3

Do you have a better understanding on how to approach practical work after this project? N=41

Responses	**N**	**%**
Yes	37	90
No	4	10

The majority of educators (90%) have a better understanding on how to approach practical work. The results indicate a positive move towards improving educators' approaches to practical work, an indication that the project was a success.

Table 6.19: Response to item 4

Did the micro-lessons change your ideas about the role of the educator as facilitator? N=41

Response	N	%	Comments
Yes	40	98	An educator should guide learners to discover the facts on their own. The educator should facilitate, clarify, and guide where necessary. The lesson should be learner-centred not educator-centred. I have learnt that the educator should not do everything for the learners. The educator should facilitate the process of learning, guide learners through their discoveries, and should not sit there, dictate and give solutions to problems. It gave me a clear indication of how I should facilitate in the real classroom situation. Yes, previously I used to do a lot of demonstrations. I was a lesson leader and guided learners a lot, but now I have learnt that the educator should use a problem-based approach. It has opened my eyes. After having presented a lesson and looked at myself, I realised that I did not give learners sufficient support as far as assisting and guiding them. Now I realise that through spontaneous facilitation in a lesson, time can be well managed and outcomes reached. I was able to detect that it is important for the facilitator to constantly move around the groups to monitor the progress of learners, encourage participation and guide those who experience problems. I now know how to facilitate. It changed our ideas because we will now be able to use some new approaches we did not know. The micro-lessons improved my ideas about the role of the facilitator. I gained some new ideas from the lessons.
No	1	2	I am used to what was done in the micro-lessons.

A total of 98% of the educators said that the micro-lessons changed their ideas about the role of the educator as facilitator. The educators' comments (Table 6.19) indicate that they gained new ideas about facilitation of practical work from the viewing and discussions of the video-taped micro-lessons. The new ideas correspond with those of inquiry teaching.

Table 6.20: Response to item 5

Were the discussions held after viewing the video-taped micro-lessons helpful? N=41

Responses	N	%
Yes	36	88
No	5	12

The majority of the educators (88%) said that the discussions held after viewing the video-taped micro-lessons were helpful. This result indicates that an in-depth discussion of the video-taped micro-lessons is very necessary. The weak and strong points of the video-taped micro-lessons need to be pointed out and discussed constructively. It is the intention of the researcher that the latter should be done with the CD-ROM contained in this report.

Table 6.21: Response to item 6

Do you need more knowledge on how to conduct OBE lessons in physics? N=41

Response	N	%	Comments
Yes	38	93	I lack knowledge on OBE. I need more knowledge on how to involve learners in the class. More workshops should be conducted at different schools. Categories of assessment are still a problem (e.g. using rubrics). OBE in overcrowded classrooms is a problem. Lack of facilities and the time factor make OBE impossible. We need re-training. I cannot pay attention to the outcomes of my lesson. Introducing the lesson is problematic. Implementation of OBE in the classroom is a problem. I need the skills to help learners in the classroom. OBE is not understandable. More time should be attributed to OBE teaching. One cannot always say I have enough knowledge. There should always be space for more knowledge. OBE is a new approach and it is sometimes difficult to prepare a lesson, especially a learner-centred lesson.
No	3	7	I attended several workshops concerning OBE. I have gained a lot from the micro-lessons presented.

Although 88% of the educators indicated that the discussions held after viewing the video-taped micro-lessons were helpful, 93% said they needed more knowledge on how to conduct OBE lessons in physics. The comments of educators (Table 6.21) indicate a range of problems. In order to solve such problems, regular workshops should be conducted. In these workshops video-clips of micro-lessons can be used to train educators. The results correlate with research findings by Haury and Rillero (1994), who indicated that most educators report a need for help in learning new teaching methods and obtaining information about instructional materials. Jacobs and Chalufu (2002:107) assert that there is a widespread feeling that educators have not been prepared for OBE.

Table 6.22: Response to item 7

Is practical work necessary in OBE lessons in physics? N=41

Responses	N	%
Yes	41	100
No	0	0

All the (100%) educators said practical work was necessary in OBE lessons, particularly in physics. The results indicate that educators are positive towards practical work. Such an attitude is necessary to effectively meet the outcomes of practical work. Of utmost importance is when educators can instil such an attitude to learners in the schools.

Table 6.23: Response to item 8

Do you have apparatus in your school to do practical work in physics? N=41

Responses	N	%
Yes	15	37
No	26	63

Some 63% of educators said that they have no apparatus in their schools to do practical work in physics. Only 37% said that they have apparatus in their schools to do practical work in physics. This result indicates that educators face environmental difficulties in their schools. This implies that 63% of the educators teach the theory of physics and that no practical work is done. This situation coincides with studies done in developing countries, including South Africa (paragraph 2.3). Research findings by Jacobs and Chalufu (2002:107) indicate that the Department of Education frequently fails to supply schools with teaching materials.

Table 6.24: Response to item 9

I need more knowledge on how to plan and execute an OBE lesson in physics. N=41

Responses	N	%
Yes	39	95
No	2	5

No less than 95% of the educators said that they needed more knowledge on how to plan and execute an OBE lesson in physics. During the discussions held with educators it was evident that limited workshops were conducted on how to plan and execute OBE lessons in physics. The results suggest that educators need more workshops on the planning and execution of OBE lessons in physics. This standpoint is also supported by Haury and Rillero (1994), who indicate that a wealth of ideas in the form of workshops and presentations should be used often in such a way that educators participate in the activities, thereby gaining valuable experience.

Table 6.25: Response to item 10

What did **you like** about the following aspects of the micro-lessons? N=41

(a) Preparations
(b) Presentation
(c) Discussions / Feedback

Categories	Responses
Preparations	Lessons were well-prepared beforehand. Group discussions prior to presentations helped us a lot. Joint preparations aroused the spirit of working together as educators. The preparations were outstanding. Educators were very co-operative. Very interesting. Very well done. Apparatus were available. Good. Every role player was actively involved in the initial planning and rehearsal of the lessons. We shared ideas and came up with one mature lesson. It becomes so easy when you prepare with colleagues. It stimulated my interest.
Presentations	Role-playing the learners helped us to experience the problems that learners face. Facilitators tried to present their lessons to suit the needs of learners. First experience but everything went well with me. I learnt a lot. Well-presented. It enhanced my interest.

	I learnt that a learner-centred approach and class participation are important in a practical. The idea of video-taping the lessons was wonderful. Good. I had an opportunity to see myself presenting a lesson and it was a learning experience. The micro-lessons helped me improve my standard of teaching. I realised that the facilitator should guide learners. I enjoyed the presentations. The class was able to view themselves in the video.
Discussions / Feedback	The discussion on the micro-lessons themselves and our weak points, aspects that were overlooked by presenters, were fully discussed. Exceptionally well done. It provided me with knowledge on how to improve other aspects of practical work. We were able to see our strong and weak points. I liked the discussion on how to improve on certain aspects of practical work. Good. It gave us a clear picture of what has to be done in practical work. Educators can conduct peer evaluation throughout the lesson. I have a better understanding of the OBE model lesson. Motivated to improve and adopt the OBE model as the best model to be used. The discussions cleared up things that were not clear to us, especially misconceptions. Each educator was given the opportunity to give his opinion. Opposing views led to solutions. New practical facts were discovered. I liked the sharing of ideas by educators. Discussions were very constructive. They made science meaningful to us.

The comments of educators are very positive. With regard to the preparation, educators liked a joint preparation by educators, as it aroused the spirit of working together. Their comments indicate that the preparation encouraged co-operative learning. Educators liked the presentations and commended the idea of video-taping the lessons. The discussions gave educators a clear picture of what has to be done in practical work. More positive comments were indicated in Table 6.25 above. These comments indicate that the use of video-taped micro-lessons were of value to the educators, showing the importance of personal experience to educators.

Table 6.26: Response to item 11

What did **you not like** about the following aspects of the micro-lessons? N=41

(a) Preparations:
(b) Presentation
(c) Discussions / Feedback

Categories	Responses
Preparations	Not all materials were at hand for preparations. The outcomes were not clearly specified. Other educators were passive during our preparations. Lack of preparation from other educators. Limited time for preparations. Presenters were not free at first. The preparation was very long. Since OBE is new to us, our preparations looked like the old traditional way, which is educator-centred.
Presentations	Educators who role-played learners did not know how to connect an electric circuit. Presenters gave irrelevant examples. Presenters focused on unnecessary aspects. Presentations did not involve the learners. Some presentations were not OBE- oriented. The educator was always in control. The presenters gave the impression that all learners were following the lesson. Due to cameras in the studio, the presenters were not free. Presentation time was limited to 45 minutes. The presentation can be time-consuming and incomplete in large classes. The presenters were nervous and not relaxed because of the cameras. Integration of concepts was not done. Educators who role-played learners did not get sufficient time to ask questions. Since we do not have apparatus in our schools, we were not familiar with the use of the apparatus used in the micro-lessons.

	The presenters told the learners what to expect in their conclusions. Presenters did not communicate effectively with learners. Facilitators hardly looked at what learners were doing. Other facilitators were very formal, hence learners were not free to do experiments. The environment was tense. The studio was strange to some of us.
Discussions / Feedback	The video-taped micro-lessons may mislead the viewers because the lesson involves a small group of learners. This may not be possible with large numbers of learners as in our schools. It took a long time. It was too little. Time was very short. It is embarrassing to see yourself making mistakes in the video-taped lesson.

Item 11 (Table 6.26) was intended to get the negative aspects regarding the preparation, presentation and discussions/feedback. Educators complained about limited time for preparations. With regard to the presentation, the majority of educators said they were not free because of the setup in the studio with cameras all over. The educators said that the video-taped micro-lessons might mislead the viewers because they involved a small group of learners. The comments indicated in Table 6.26 above should be taken into consideration when using video-taped lessons in educator training. These comments (Table 6.26) correlate with the disadvantages of using video-tapes as surveyed in Chapter 5 (paragraph 5.4.2.2).

The comments of educators regarding the presentations of the micro-lessons indicate that they knew what was expected of them. For instance, they said that presenters did not involve learners, presenters focused on unnecessary aspects, facilitators hardly looked at what learners were doing and presentations were not OBE-oriented.

Table 6.27: Response to item 12

Video-taped micro-lessons can help in addressing misconceptions in physics. N=41

Response	N	%
Yes	39	95
No	2	5

No less than 95% of educators said that video-taped micro-lessons could help in addressing misconceptions in physics. The results suggest that a list of misconceptions can be video-taped and used in the training of educators. Viewing the misconceptions on the tapes may help in addressing them.

Table 6.28: Response to item 13

Mention major problems that you encounter at school regarding the teaching of physics, especially practical work. N=41

Responses
Insufficient, inadequate, little, shortage, limited apparatus and no apparatus to do the experiments, especially in rural schools.
Lack of funds to purchase apparatus.
Principals not prepared to purchase apparatus.
Lack of commitment from learners.
Those of us who have apparatus do not know how to use them because of lack of exposure.
Time is limited for practical work.
Educators lack the knowledge of the subject.
Large number of learners in our classrooms and little space for practical work.
Resources available for demonstration by the educator.
Lack of textbooks.
Workload too heavy.
No electricity.
Learners regard physics as a complicated subject.
Lack of knowledge of some aspects related to OBE.
No laboratories.
Learners take a longer time to understand.
Practical work takes longer and we are expected rush and finish the syllabus.
Emphasis is placed on the completion of the syllabus.
The syllabus is too long.
Lack of educators.
Lack of interest by some educators.
Learners get excited by some of the apparatus and do not pay attention to the practical.
Mishandling of apparatus by some learners.
Learners have certain misconceptions about the experiments.

Educators' problems range from lack of facilities to do practical work in physics, lack of knowledge of the subject (physics), overcrowding of learners in science classrooms, to too a long syllabus. The list goes on and on (Table 6.28). The results of this study correlate with studies done in developing countries (Waterman & Thompson, 1989:31, Bradley & Maake, 1998:21) (see paragraph 2.3). The problems indicated above (Table 6.28) may impact on the effective teaching of physics, especially practical work. According to Jacobs and Chalufu (2002:107, in approximately 60% of the schools the conditions are so critical that no improvement of learner achievements would be possible until massive reconstruction has been done to upgrade the facilities. The outcomes of the Revised National Curriculum Statement could take a long time before they are successfully achieved if the situation were to remain the same. These results imply that the North West Department of Education faces a challenge to make sure that the situation in schools improves.

Table 6.29: Response to item 14

Did the micro-lessons represent (model) a realistic class situation? N=41

Responses	N	%	Comments
Yes	30	73	The presenter and the learners asked questions as they would ask in a real classroom. The educators behaved like learners (role-playing the learners). There were learners with varied abilities and personalities. Some learners were active and others were passive. Learners struggled with the connections of an electric circuit. The micro-lessons illustrate what happens in a classroom if facilities are available. There are dull and good learners.
No	11	27	It is not real because few learners were used and we have large numbers of uncontrollable learners in our classrooms. The lesson can take more hours to complete with the situation in our classrooms. The educators already knew what was expected of them as learners. It must be done with real learners in schools. The facilities were available, not limited as in our schools. Time was too limited. The learners and their presenter in other micro-lessons were not relaxed because of the cameras.

The majority of educators (73%) said the micro-lessons represent (model) a realistic class situation. The researcher tried to ensure that the micro-lessons resembled the classroom situation, but did not fully succeed. Educators did not feel free because of the cameras in the studio. Some 27% of educators said that the micro-lessons did not represent (model) a realistic class situation. The researcher conducted a literature survey on the disadvantages of video-recordings (paragraph 5.4.2.2) before the micro-lessons were video-taped. It is important to note that although these disadvantages were taken into account during the video-recordings, the micro-lessons may not represent a perfect classroom situation.

Table 6.30: Response to item 15

Have you presented micro-lessons before during your training as an educator?
If yes, how did these micro-lessons differ from your previous experience? N=41

Response	N	%	Comments
Yes	25	61	The idea of video-taping is excellent. In our college the micro-lessons were not recorded. The micro-lessons we did in the past were educator-centred. We were only given 20 minutes to present in the past. In the video-taped micro-lessons 45 minutes was given. We prepared individually in the past but with these micro-lessons we were given an opportunity to prepare as a group. We did not have facilities in the past as a result the micro-lessons where theory-based and no practical work-based micro-lessons were done.
No	16	39	

A percentage of 61 of the educators said that they have presented micro-lessons before during their training as educators. Educators said that in their colleges the micro-lessons were not video-taped and educators were only given 20 minutes to present the lessons. Some 39% said that they have not present micro-lessons before during their training as educators. These results imply that training institutions should consider the introduction of video-taped micro-lessons.

Table 6.31: Response to item 16

Please write down any other comments. N=41

Comments
The micro-lessons should be repeated in the near future so that we can correct the mistakes identified after the discussions. The video-taped micro-lessons should be extended to primary and middle school educators. Keep it up. Lack of facilities is our main problem. Micro-lessons are a good way of improving our standard of presentation and preparation of lessons, especially by sharing ideas with colleagues. Video-taped micro-lessons are very helpful and were an eye-opener to us. More time is needed to train, retrain and workshop educators about practical work. Presented lessons can be a good aid to help other educators. I suggest that high school learners should be used in future micro-lessons. We should be given an opportunity to choose the topics we want to present. Visit our schools to see what we have and make suggestions on how to improve.

The comments indicated above (Table 6.31) serve as suggestions to improve the quality of physics practical work. A comment like "Video-taped micro-lessons are very helpful and were an eye-opener to us" shows that video-taped micro-lessons made an impact in addressing educators' problems in approaching practical work in physics.

6.8 CONCLUSION ON THE RESULTS OF THE QUESTIONNAIRE ON VIDEO-TAPED MICRO-TEACHING

The results concluded in this questionnaire (Appendix Q) suggest that the use of video-taped micro-teaching lessons could aid in the training of educators. This view was shared by all (100%) educators (Table 6.17) who participated in this study. This was actually the result of their first-hand experience of the video-taped micro-lessons in this study. No less than 98% (Table 6.16) of the educators thought that the teaching strategy using video-taped micro-lesson would help to improve their approach to OBE lessons in physics. Their comments (Table 6.16) were very positive. The educators' approaches to practical work in physics could be modelled and improved. As indicated in Table 6.16, educators commented that by viewing of the tapes, shortcomings can be revisited and new techniques and approaches can be learnt. Watching at video-tapes with educators would help them to identify their weaknesses and strong points.

A total of 95% of the educators (Table 6.27) said that video-taped micro-lessons could help in addressing misconceptions. This is because educators were practically made aware of the misconceptions they convey to learners by viewing of the tapes. Awareness of these misconceptions could help educators in addressing the misconceptions when they teach.

Discussions held with educators proved to be effective in addressing educators' difficulties in approaching practical work. A total of 90% (Table 6.18) of the educators said that they now had a better understanding on how to approach practical work, while 98% (Table 6.19) said that the micro-lessons changed their ideas about the role of the educator as a facilitator. It is clear from the educators' comments as indicated in Table 6.19 that they have learnt a lot regarding the role of facilitators in practical work.

The challenge is to overcome the technicalities associated with video-taping.

6.9 IMPLICATIONS OF THIS STUDY TO PHYSICS PRACTICAL WORK

The results of this study imply the following:

- Educators should be trained to present activities that promote the development of inquiry and problem-solving skills needed in physics practical work. These inquiry skills include investigative skills, manipulative skills, making deductions and analysing.
- The educators' ability to create a suitable context for learners in an outcomes-based classroom needs special attention.
- Attention should be paid to the mismatches between learners' intended and actual outcomes and activities.
- The educators' approach to practical work should direct learners towards the accomplishment of the outcomes of practical work (paragraph 2.4.1) and the Revised National Curriculum Statement.
- Inquiry teaching (paragraph 3.5.2) should receive major emphasis in physics practical work.
- Constructivist teaching (paragraph 3.3.4) should be used in an integrated setting as a channel to engage learners in critical thinking and problem-solving.
- The hands-on approach (paragraph 3.3) should focus on the development of practical skills.
- The educator's role (paragraph 3.4.2) should change from being an instructor to a facilitator of the learning process.
- Problem-solving (paragraph 3.7.2) as a teaching strategy should be incorporated in practical work. The latter embodies most of the techniques and learning skills physics educators should consider important when teaching physics by means of investigative methods. The educator's role (paragraph 3.7.3) in problem-solving should involve thinking about and presenting everyday situations and experiences that relate to each concept or fundamental law discussed. Table 3.2 outlines a framework by means of which problem-solving can be used by indicating the key elements in problem-solving activities.
- Co-operative learning (paragraph 3.9) should be encouraged.

6.10 CONCLUSION

It is clear from the results of this study that secondary school educators in the North West Province (South Africa) experience difficulties in approaching physics practical work. Secondary school science educators who participated in this study do not fully understand their role in a practical activity, hence this impact on the way they approach practical work in physics. The study indicates that educators experience difficulties with and lack skills in the facilitation of practical work in physics at the FET-level.

Generally, educators continue to use traditional educator-centred chalk and talk and lecturing methods. Viewed from the perspective of the camera, the micro-lessons presented were mainly concerned with confirming theory. In this case, the outcomes were mainly concerned with confirming Ohm's law.

Although educators realised many mistakes they made after viewing the tapes (see Table 6.26(b)), they still experienced problems in correcting them in the "model" lesson. Realisation of necessary changes is the first step in accomplishing the paradigm change.

The results of this study correlate with studies done in developing countries (see paragraph 2.3) including South Africa (Bekalo & Welford, 2000:203, Treagust & Thair, 1999:358). The main feature of most classroom transactions in developing countries, including South Africa, revolve around the transfer of factual information through "chalk and talk" and confirmation of taught concepts through routines-guided experimental approaches. This is because the educators themselves often do not have the necessary expertise to organise, carry out and evaluate practical-oriented courses.

The results of the questionnaire on video-taped micro-teaching indicate that the video-taped micro-lessons can be effective in addressing educators' difficulties in approaching practical work in physics. The results prompted the researcher to compile video-clips of the micro-lessons on a CD-ROM. The video-clips should be critically analysed at workshops, seminars, conferences and training institutions with the aim of modelling educators' approaches to practical work. Periodic meetings between educators and subject advisors to share successes and troubleshoot problems encountered in approaching practical work in physics should be a regular part of the business of physics education. This standpoint is also supported by Haury and Rillero (1994).

Recommendations and conclusions are given in the next chapter (Chapter 7).

CHAPTER 7

RECOMMENDATIONS AND CONCLUSIONS

7.1 INTRODUCTION

This chapter summarises the literature and empirical studies. Conclusions and recommendations for this study are indicated. Recommendations for educator training are discussed, based on the results of this study.

7.2 SUMMARY OF THE LITERATURE STUDY

The traditional view of science was scrutinised (Carr *et al.*, 1994:149). This scrutiny resulted in science being located in a new paradigm (Zacharia & Anderson, 2003:625). The latter is the result of the fact that traditional methods of teaching emphasise static aspects and do not help learners to develop an intuition about the dynamics of different phenomena (Hirsch, 2002:31).

Although the National Department of Education in South Africa sees outcomes based education as a shift from an educator-centred, objective-driven education to a learner-centred, outcomes-orientated education (Halloun, 1998), developing countries often use practical activities as a means of confirming theory (Bekalo & Welford, 2000:203). The literature findings strongly emphasised that there is little educational value in using practical activities only to confirm the theory that has been taught earlier in the course (McDowell & Waddling, 1985:1038). Learners should be placed in a problem-solving situation where they can immediately perceive the problem being presented.

Practical work forms a major component of the school science curriculum (Treagust & Thair, 1999:358; Tamir, 1991:13; Hofstein & Cohen 1996; Van der Linde *et al.*, 1994:50). Hence, the development of an outcomes-based curriculum should have as starting point the intended outcomes of the learning experience (Van Rensburg & Potloane, 1998:27). The approaches used in practical work should as far as possible involve inquiry. Approaches to physics practical work discussed in chapter 3 should focus on the accomplishment of the outcomes of practical work (paragraph 2.4.1).

7.3 SUMMARY OF THE EMPIRICAL STUDY

7.3.1 Summary of results of the assignment (Appendix B)

This assignment (Appendix B) probed the educators' views on an OBE lesson in physics and its characteristics, practical work and its outcomes. The majority of the views expressed by the educators regarding an OBE lesson in physics (Table 6.2) and the characteristics of an OBE lesson (Table 6.3) correspond with the requirements in the Revised National Curriculum Statement (Department of Education, 2003). However, implementation is still a challenge to physics educators because ideas expressed by the educators were not put to practical use in the video-taped micro-lessons.

The educators have varied opinions on the meaning of practical work in physics. Their explanations and descriptions of practical work emphasised active participation of learners, which is in accordance with the literature reviewed (paragraph 2.2). The indicated outcomes of practical work (Table 6.5) are an elaboration of the outcomes reviewed in paragraph 2.4.1. The challenge is to implement these outcomes in the classrooms.

7.3.2 Summary of results of the coding scheme

The summary of features prominent in the practical on Ohm's law is as follows:
Learners should:
Learn a relationship between resistance, current and potential difference (Figure 6.1). They should learn:

- How to use a standard laboratory instrument (Figure 6.1);
- how to use data to support a conclusion (Figure 6.1);
- use an observation (Figure 6.2);
- report observations (Figure 6.5); and
- account for observation in terms of a given law (Figure 6.9).

Most of the task would be specified by the educator (Figure 6.11, items 41, 42, 43 and 44) and the learners would interact with the educator (Figure 6.16), a fact that was evident in the micro-lessons. The educators are generally positive towards practical work in physics (see Figures 6.21 to 6.26).

Although certain features of the practical on Ohm's law were indicated in the coding scheme, educators did not put them to practical use. Educators continued to use an educator-centred approach in the micro-lessons.

7.3.3 Summary of the results of the micro-lessons

Paragraphs 7.3.3.1 to 7.3.3.9 summarise the results of the micro-lesson. Specific reference is made to the aspects of the micro-lessons indicated in Table 6.15.

7.3.3.1 Outcomes of the micro-lessons

The study indicates that the educators have limited understanding of the interpretation of the outcomes of practical work. The outcomes of the micro-lessons presented by the educators were mainly intended to teach the content. The educators' presentations were formal, traditional and topical. The primary outcome of the educators was to confirm Ohm's law; hence they used practical work primarily to confirm theory. This correlates with the findings of Bekalo and Welford (2000:203).

7.3.3.2 Questions asked by educators in the micro-lessons

The questions asked by educators required that learners should raise their hands, and one should then be selected to answer. Educators should ask questions that stimulate the reasoning and understanding of learners to urge learners to solve problems co-operatively in groups.

According to Hofstein and Cohen (1996), inquiry questions should be identified. Learners should be asked to suggest ways of solving problems. This may be done by formulating hypotheses, planning experiments, performing them, collecting data, and constructing tables and graphs. Learners should be offered the opportunity to analyse and interpret results, leading to conclusions and generalisations.

7.3.3.3 Role of the educator in the micro-lessons

The role of the educator as indicated by Lally (1994:223) should change from that of lesson leader to a lesson co-ordinator and activity facilitator, since learners are not just passive recipients of what is taught. Learners should be actively involved in interpreting and constructing knowledge. The educator's role should be that of a facilitator of the learning process and not an instructor, as was the case in the micro-lessons.

The educators who participated in this study did not fulfil the role of facilitator effectively. Their understanding of what a learner-centred approach is that they should watch learners carrying out instructions. Educators should not be passive, but actively involved in facilitating the learning process. The educators still prefer the authoritarian style of teaching, the emphasis being on the acquisition of factual knowledge and preparation for examinations.

7.3.3.4 Role of learners in the micro-lessons

Learners are expected to be active participants in the practical activity. This would, however, depend on the type of activities planned by the educator. In the micro-lessons observed learners were confined to carrying out the instructions, answering questions, and completing the worksheets. The interaction between learners was limited (see Figure 6.28). The majority of educators (63%) (Figure 6.16 item 56) said that learners would interact with the educator and most of the aspects of practical work would be specified by the educator (Figure 6.11 items 41, 42, 43 and 44). This indicates that educators do not fully understand their role and the role of learners in a practical activity.

7.3.3.5 Experimental procedures in the micro-lessons

During practical work, learners should be engaged in several activities. These activities are probed by specific task featured in a variety of contexts. Some activities intend to teach learners how to handle apparatus, while others intend to teach learners how to interpret data obtained from experimental results. Since learners are expected to be doing science, their activities concern objects, ideas or data, such as calibrating and using an instrument such as an ammeter and a voltmeter, or plotting a graph of potential difference against current or predicting phenomena.

The study indicates that educators have their own perceptions of practical work. These perceptions include getting the right answer during practical activities, for instance obtaining the straight-line graph when doing a practical on Ohm's law. The educators were interested in getting the straight-line graph, irrespective of whether the data obtained to draw such a graph was correct.

The differences in what learners and educators perceive as practical work may cause mismatches between the intended outcomes of practical work and the actual activities of learners. The experimental procedures used in the micro-lessons did not incorporate activities requiring learners to inquire and solve problems. Instead, the experimental procedures used in the micro-lessons were content-based. It mainly focused on following recipes in the form of worksheets and instructions from the educator. The approach that Olney (1997:1345) refers to as a cut-and-dried laboratory procedure minimises learner involvement.

7.3.3.6 Misconceptions in the micro-lessons

Hodson (1992:68) argues that the success of learning depends on the learners' existing knowledge and experience. The results of this study indicate that educators themselves hold misconceptions that were conveyed to learners (see Table 6.14). For example, one of the educators said: "When a tap is opened, water will flow and when it is closed, water will not flow. The same would apply for an open switch and a closed switch". Misconceptions such as these may lead to an improper match between theory and practical. Educators' conceptual problems could account for improper understanding of concepts by learners, as they would transmit misconceptions to learners.

7.3.3.7 Problem-solving in the micro-lessons

The micro-lessons were not problem-oriented but focused on educator-centred and formal mathematical calculations. As already indicated, learners should be asked questions that urge them to solve problems co-operatively in groups. A context should be created by the educator where learners would be stimulated to solve problems. The activities should develop learners' reasoning and general problem-solving skills.

7.3.3.8 Practical skills in the micro-lessons

One of the outcomes of both practical work and OBE is to develop practical skills and techniques (paragraph 2.4.1.2). Development of skills such as investigative skills, observation, recording, making deductions, synthesising, generalising and communicating results should be accommodated in the planning and execution of practical work. In the micro-lessons little attention was paid to skills development, while learners were not engaged in activities in which inquiry skills were developed. The emphasis was mainly on observation and recording of the results. Learners should be helped to make sense of their recorded results (Leach & Paulsen, 1999:18). Learners should not just register what happens (observation and recording), but also why it happens.

7.3.3.9 Approach used in the micro-lessons

Hodson (1992:68) suggests that experiments should be devised by the learner, while the educator should act as facilitator. The educators did not understand how to facilitate a lesson and to what extent they should assist the learners. Educators still believe that they should be providers of knowledge through the "chalk and talk" approach. The educators tried to involve learners in doing the practical but took the lead in providing the analysis and conclusions of the results of the practical. Their role as providers of knowledge did not allow learners to discover on their own, thus impacting on the level and nature of learners' participation.

The worksheet-driven approach followed by these educators focused on the completion of the worksheets rather than on the actual outcomes of the practical activity. The worksheets used in the presentations of micro-lessons were not sufficient to guide learners to establish links between Ohm's law and the experimental field.

The interaction between the educator and the learners is indicated in chapter 6 (Figures 6.27 to 6.29). The approach in the micro-lessons (Figure 6.28) corresponds more with the conventional approach (Figure 6.27) than the required OBE approach (Figure 6.29).

7.3.4 Summary of the results of the questionnaire on video-taped micro-teaching

The results of the questionnaire on video-taped micro-teaching (Appendix Q) indicate that video-taped micro-lessons could be effective in addressing educators' difficulties in approaching practical work in physics. No less than 98% (Table 6.16) of the educators think the teaching strategy using video-taped micro-lessons would help to improve their approach to OBE lessons in physics. Their comments (Table 6.16) were very positive, while 90% (Table 6.18) said that they now had a better understanding on how to approach practical work.

7.4 CONCLUSION

The results of this study correlate with studies done by Van der Linde *et al.* (1994:48), who argue that little or none has come of the efforts to introduce a more practical approach in science teaching, mainly on account of the fact that the educators cling to lecturing as a major teaching method. Hodson (1992:68) indicates that if educators expect learners to learn physics in that way, we have to think about tasks that guide (more or less strongly) learners to establish relations between theoretical knowledge and experimental activities.

The focus of outcomes based teaching and learning according to Van Rensburg and Potloane (1998:27) is on what learners know and are able to do at the end of their learning experience. The development of an outcomes based curriculum, therefore, will have as starting point the intended results (outcomes) of the learning experience. These results refer to the knowledge, skills, learning of processes of science, attitudes and values that learners must acquire, and not merely to the prescribed content. The researcher observed that the educators' approach to practical work did not fulfil these requirements. Instead of outcomes based approaches, the educators' approaches were educator-centred and content-based.

7.5 INTERVENTION STRATEGIES

The following intervention was done with educators who participated in this study:

- The educators were shown all the tapes and a discussion was held between the researcher and the educators.
- The educators combined efforts and prepared a "model" lesson.

- One educator volunteered to present the lesson, while another 8 educators role-played the learners.
- A questionnaire (Appendix Q) was given to educators immediately after the "model" lesson was presented. The results of the questionnaire (Appendix Q) are given item by item in tables 6.16 to 6.31.

The results of this study suggest that intervention should be done by introducing the video-taped micro-lessons in educator training (paragraph 7.5.1). Workshops on OBE teaching (paragraph 7.5.2) should be presented.

7.5.1 Introduction of video-taped micro-lessons in educator training

As indicated by the results of the questionnaire on video-taped micro-teaching (Appendix Q), the video-taped micro-lessons could play an important role in the training of educators. This standpoint is further supported by Zuber-Skerritt (1984:269), who argues that watching video-tapes helps to overcome the difficulties and is a confidence builder. Educators should view the video-taped lessons of their colleagues so that they can learn from their colleagues' strong and weak points. By discussing the strong and weak points of colleagues educators could be helped to approach lessons in a more constructive and educative manner. Educators should analyse these lessons and then come up with an approach which is outcomes based. The results indicate that it was a learning experience for educators to look at video-taped lessons of their colleagues.

Table 6.28 indicates a number of problems that educators face regarding the teaching of physics, especially practical work. These include lack of proper facilities (physics apparatus) at their schools, fixed timetables, emphasis on the completion of the syllabus, which is too long, overcrowding of learners and stressful work loads. According to educators, the latter makes OBE teaching and practical work impossible in their schools. The researcher believes that these problems could impact on the proper teaching of physics, particularly practical work. The Department of Education should intervene in this matter so that schools become suitable environments for the teaching of physics and physics practical work.

The teaching of practical skills to educators is of the utmost importance if we were to reach the outcomes of both practical work and science education in general. Designing practical activities that encourage the development of essential inquiry skills could contribute to the creation of an effective learning environment. Educators involved in training programmes should be involved in practical activities that develop inquiry skills so that they can effectively learn how to plan such activities in their schools.

A more hands-on and minds-on approach to activities should be adopted. These activities should allow learners to make deductions and conclusions from practical activities. If educators were more empowered in inquiry and problem-based activities, implementation in their classrooms might be easier.

The discussion held after viewing the video-tapes indicated that most educators did not know how to plan an OBE lesson. As many as 95% (Table 6.24) of educators still need more knowledge on how to plan and execute an OBE lesson in physics. Educators pointed out during the discussions that they asked educators in the GET (General Education and Training) band about OBE. Educators indicated lack of training on how to approach OBE lessons in physics.

The video-taped micro-lessons where samples of hands-on inquiry activities are shown could help educators in the planning of practical activities. The training programmes should adopt a more conceptual and practical approach to science teaching and learning. By this the researcher means that conceptual teaching should be fully integrated with practical work in physics. Thorough knowledge of concepts in physics would help in understanding the practical component thereof.

Video-clips of micro-lessons (CD ROM) should be used as a bench mark in the training of present and future educators. Such video-clips can be "bench-marks" according to which educators could evaluate their own lessons and understand the differences.

7.5.2 Workshops on OBE teaching

From the results of the study, it is clear that the educators do not yet know what OBE education is. For instance, they think if the educator asks questions and the learners are doing experiments themselves, it is learner-centered. No less than 93% (Table 6.21) of the educators indicated that they needed more knowledge on how to conduct OBE lessons in physics. Their comments (Table 6.21) clearly indicate that they lack information on OBE. Their comments include that more time should be attributed to OBE teaching, since they do not understand it (Table 6.21).

Educators said that they struggle with the implementation of OBE in their overcrowded classes (Table 6.21). Educators suggest that more workshops should be conducted. Some (7%) (Table 6.21) of the educators said that they do not need knowledge on OBE lessons in physics because they have attended several workshops concerning OBE. The results suggest that workshops should be conducted to educators on OBE teaching.

7.6 RECOMMENDATIONS

The results of this study are important for a better understanding of the role of existing practical work activities in the learning of physics. Improvement in the text accompanying existing practical work could enable learners to use varied modelling activities and thus improve the learning of concepts underlying practical work. These improvements might be reinforced by the educators' guidance, which could focus learners' attention on the elements that they do not usually take into account. Attention should be paid to the difficulties that educators encounter when interpreting the outcomes of practical work and when approaching practical work in physics during initial educator and in-service training.

When conducting experiments, learners should not be given instructions to follow a "recipe", but should be guided in their inquiries. The educator should plan the activities in such a manner that learners could investigate, discover and solve problems. The educator should facilitate, not control the learners' work.

The purpose of schooling has changed from being a preparation for further studies for a small number of the most able learners to an educational enterprise geared to the needs of all future citizens (Leach & Paulsen, 1999:17). The subject physical science should prepare learners for future learning, specialist learning, employment, citizenship, holistic development, social development, socio-economic development and environmental management. The educator should develop the following competencies (Department of Education, 2003:10):

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

In order to develop the above-mentioned competencies, the educators' approaches to the teaching of practical work should be changed to meet the challenges of these competencies. The study reported in this thesis suggests that educators could facilitate and approach practical work effectively if the following were taken into consideration:

- Introduction of micro-teaching to institutions involved with the training of educators.
- Workshops where educators could interact with each other in small groups in a more logical and effective way should be organised. Video-clips (CD-ROM) should be shown to educators in workshops. These video-clips should be discussed further to model and re-shape educators' teaching approaches.
- The Department of Education should address the following problems (Table 6.28) as outlined by educators: lack of facilities for practical work especially in rural schools, overcrowded classrooms and lack of textbooks. The approach to practical work may largely depend on the availability of facilities such as physics apparatus. For instance, if the school has only one circuit board, one ammeter, one voltmeter, three cells and connecting wires, the only option for the educator is to adopt a demonstration approach or conduct a theory lesson, especially when the class is overcrowded.
- Educators should be trained effectively on OBE teaching.
- Workloads of educators should be revised.
- Sufficient time should be allocated for practical work.

Through this study video-clips were developed for discussion by educators in training institutions, workshops and seminars to model educators' approaches to practical work in physics. These have been put together in a CD-ROM. The merits and the demerits should be discussed critically by educators, subject advisors and lecturers. On the basis of the merits and the demerits of these video-clips, educators, subject advisors and lecturers should develop guidelines on how to approach practical work in physics.

7.7 FINAL CONCLUSION

Debates about the effectiveness of the approaches used in physics practical work are not new. In fact, the important contribution of this study is that it highlights the educators' inadequate shift to inquiry-oriented approaches to practical work. The results of this study confirms the hypothesis that: *secondary school science educators in the North West Province of South Africa experience difficulties in approaching physics practical work.* Practical work in physics is still based on recipe-following, with little attention being paid to the learning of skills, interactive, inquiry and learner-centred teaching strategies. In this regard, the aim and objectives of the study were achieved.

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APPENDIX A

CODING SCHEME

Coding scheme for Aspect A: The educators' intended teaching outcome		
To help learners to...		**Tick off one or more boxes**
Content	1. Identify objects and phenomena and become familiar with them (specify)	
	2. Learn a fact (or facts) (specify)	
	3. Learn a concept (specify)	
	4. Learn a relationship (specify)	
	5. Learn a theory/model (specify)	
	6. Address alternative conceptions (specify)	
Process	7. Learn how to use a standard laboratory instrument or piece of apparatus	
	8. Learn how to carry out a standard procedure	
	9. Learn how to plan an investigation to address a specific question or problem	
	10. Learn how to process data	
	11. Learn how to use data to support a conclusion	
	12. Learn how to communicate the results of lab-work	

Coding scheme for Aspect B1: The cognitive structure of the task		
B1.1: What the educator intends learners should do with objects and observables		**Tick off one or more boxes**
Use	13. An observation	
	14. a laboratory device or arrangement	
	15. a laboratory procedure	
Present or display	16. an object	
Make	17. an object	
	18. a material	
	19. an event occur	
Observe	20. an object	
	21. a material	
	22. an event occur	
	23. a physical quantity (a variable)	

B1.2: What the educator intends learners should do with ideas	**Tick off one or more boxes**
24. Report observation(s)	
25. Identify a pattern	

Explore relation between	26. Objects	
	27. Physical quantities (variables)	
	28. Objects and physical quantities (variables)	
29. Invent (discover) a new concept (a physical quantity, or an entity)		
30. Determine the value of a physical quantity which is not measured directly		
Test a prediction	31. From a guess	
	32. from a law	
	33. from a theory (a model based on a theoretical framework)	
Account for observations	34. In terms of a given law	
	35. in terms of a given theory (or model)	
	36. by proposing a law	
	37. by proposing a theory (or model)	

Choose between two (or more) given explanations	
B1.3: Objects -or ideas-driven?	**Tick off one box**
38. What the learners are intended to do with ideas arises from what they are intended to do with objects.	
39. What the learners are intended to do with objects arises from what they are intended to do with ideas.	
40. There is no clear relation between what the learners are intended to do with objects and with ideas.	

Coding scheme for Aspect B2: Level and nature of learner involvement			
B2.1: Degree of openness/closure		**Tick off one in each row**	
Aspect of lab-work task	**specified by educator**	**Or decided by discussion**	**Or chosen by learners**
41. Questions to be addressed			
42. Equipment to be used			
43. Procedure to be followed			
44. Methods of handling data collected			
45. Interpretation of results			

B2.2: Nature of learner involvement	**(Tick off one box)**
46. Carried out by learners in small groups	
47. Carried out by individual learners	
48. Demonstrated by teacher, learners observe and assist as directed	
49. Demonstrated by teacher, learners observe	

Coding scheme for Aspect B3: The practical context	
B3.1: Duration of task	**Tick off**

	one box
50. Very brief (less than 20 minutes)	
51. Brief (one science lesson, say up to 80 minutes)	
52. Medium (2-3 science lessons)	
53. Long (2 weeks or more)	
B3.2 People with whom the learner interacts	**Tick off one or more**
54. Other learners carrying out the same lab-work task	
55. Other learners who have already completed the task.	
56. Educator	
57. More advanced learners (demonstration, etc.)	
58. Others (technician, glassblower, etc.)	

B3.3: Information sources available to the learners	**Tick off one or more boxes**
59. Guiding worksheets	
60. Textbooks	
61. Handbook (on apparatus), data book, etc.	
62. Computerised database	
63. Other	
B3.4: Type of apparatus involved	**Tick off one box**
64. Standard laboratory equipment	
65. Small-scale apparatus	
66. All equipment (kitchen scales, domestic materials...)	
B3.5: Source of data (Tick off one box)	
67. Real world: inside laboratory	
68. Real world: outside laboratory	
69. Simulation on computer or CD-ROM	
70. Video recording	
71. Text	

B3.6: Tools available for processing data	**Tick off one or more boxes**
72. Manual calculation	
73. Computer	
74. Other (specify)	

Aspect C: Attitude towards practical work in physics		**Tick off one in each row**	
75. Physics practical work is a waste of time	Agree	Neutral	Disagree
76. I like doing physics demonstrations more than hands-on	Agree	Neutral	Disagree
77. Practical work in physics does not enhance my interest in physics	Agree	Neutral	Disagree
78. I like physics practical work	Agree	Neutral	Disagree
79. It is more interesting to do a physics practical than to conduct a theory lesson	Agree	Neutral	Disagree
80. It is boring to do practical work in physics	Agree	Neutral	Disagree

APPENDIX B
ASSIGNMENT

NDNK 521
DUE: 01 March 2004

In the next contact section you will be expected to present a lesson on Ohm's law to a group of students. In order to accomplish this, answer the following questions and post them to:

Sediba Project
Private Bag X6
Potchefstroom
2531

NOTE: In addition to answering the under-mentioned questions, complete the attached sheet (coding scheme) and post it together with your answers.

1. Prepare an OBE lesson on Ohm's law.
2. In your own words, write a paragraph on each of the following:

a. What is an OBE lesson in physics?
b. What makes a lesson outcomes-based?
c. What is practical work in physics?
d. What are the outcomes of physics practical work?

APPENDIX C

PERMISSION LETTER

North-West University
Potchefstroom Campus

31 March 2004

Dear Educator

RE: VIDEO RECORDING OF LESSONS

We hereby request your permission to video-tape (film) the lessons that you are going to present on the following dates:

31 March and 01 April 2004.

Sincerely,

Mr. AT Motlhabane
(Lecturer) North-West University (Potchefstroom Campus)

APPENDIX D

TRANSCRIPT OF MICRO-LESSON 1

The educator divides learners into two groups of three members each, introduces the apparatus and asks questions to probe learners' knowledge of the apparatus.

This is how the introductory questions were asked:

Educator: *What is this? (Showing a cell).*
Learner: *It is a cell.*
The educator asks learners to write down the symbol of the cell in their notebooks and moves around to check whether they are writing down the correct symbol.
The educator explains: *A cell has two sides and what I know is that a cell has a positive and a negative side.*
Educator: *Which side of cell is positive and which side is negative?*
Learner: *The flat (bottom) side is positive and the other side is negative.*
Another learner: *No, the flat side is negative and the other side is positive.*
Educator: *What is this? (Showing conductors)*
Learner asks: *Are they not insulators?*
Educator: *No, they have been insulated.*
Another learner: *It is a conductor.*
Learner: *What is a conductor?*
The educator responds: *It is wire that conducts electricity. There is a black and a red conductor, the red wire is positive and the black wire is negative.*
Educator: *What is this? (Showing an ammeter).*
Comment by the educator: *It is written A.*
Learner: *It is an ammeter.*
Learner: *What is the difference between a speedometer and the ammeter?*
The educator explains: *The speedometer is used to measure distance and the ammeter is used to measure current.*
Educator: *What is the name of this instrument? (Showing a voltmeter). Comment by the educator: It is written V.*
Learner: *It is a voltmeter.*

***Educator**: There are two types of connections - parallel and series. How do we connect the voltmeter in the circuit?*

***Learner**: It is connected in parallel.*

***Another learner:** What will happen if we connect the voltmeter in series and the ammeter in parallel?*

***The educator explains:** It will not give the correct reading for current which is flowing and potential difference in the circuit.*

***Educator**: What is this (showing bulb in a bulb holder)? It is present in our classroom.*

***Learner**: It is a bulb.*

***The educator asks learners to** write down the symbol of the bulb.*

***The educator moves around** the class to check whether they have written the correct symbol of a bulb. He then draws the symbol of a bulb on the flip-board.*

***The educator lifts a circuit board and asks**: What is this board?*

***Learner**: It is a circuit board.*

***Educator:** What is this? (Showing a cell holder).*

***Learner**: It is a cell holder.*

***The educator comments:** The cell holder holds the cell.*

Demonstration by the educator:

The educator connects a circuit with one cell and a bulb (learners are watching).

***Comment by the educator:** Oh! There is light and it indicates that current is flowing. We can also measure the current by using the ammeter (the educator then connects the ammeter in series with circuit components to measure the current). Learners are watching.*

Learners are shown how to connect the ammeter.

***Comment by the educator**: The current is now at 49 milli-ampere. Now I have measured current. That is how we measure current, now I disconnect and I take a voltmeter and measure the potential difference. Come and take the readings. That is how we connect the circuit. Let me draw the circuit diagram. (The educator draw the circuit diagram on the flip-chart).*

***Comment by the educator:** Current is flowing from the positive pole and is looking for the negative pole. I can see it.*

The educator distributes the apparatus and the worksheets.

***Activity by learners**: One group of learners is asked to connect two cells in series with a bulb, an ammeter and a voltmeter in parallel to the bulb. The educator instructs the another group to connect three cells in series, a bulb, an ammeter and a voltmeter in parallel to the bulb.*

Learners make observations and record them on their worksheets.

***The educator concludes the lesson** by giving homework. Learners are asked to answer the questions at the end of the worksheet provided.*

APPENDIX E

TRANSCRIPT OF MICRO-LESSON 2

The educator specifies the outcomes of the lesson: *We are going to investigate the relationship between the current and the potential difference.*

Comment by the educator: *The requirements needed to reach the outcome are current and potential difference.*

The educator introduces the apparatus *by asking questions. Learners are asked questions on the apparatus*

***Educator**: What is this? (Referring to cell).*

***Learner**: It is cell.*

***Educator**: What is the function of the cell?*

***Learner**: Is to provide emf.*

***Educator**: What is this? (Referring to a voltmeter).*

***Learner**: It is a voltmeter.*

***Educator**: What does it measure?*

***Learner**: It measures the potential difference between two points.*

***Educator**: What is potential difference?*

***Learner**: The work done in moving a positive charge from one point to another.*

***Educator**: What is the unit for potential difference?*

***Learner**: Volts.*

***Educator**: What is this?(Referring to an ammeter).*

***Learner**: It is an ammeter.*

***Educator**: What is the function of the ammeter?*

***Learner:** To measure the electric current.*

***Educator**: What is electric current?*

***Learner:** The flow of charge from the positive to the negative terminal.*

***Educator**: How do we connect the ammeter in a circuit?*

***Learner**: The ammeter is connected in series.*

***Educator**: What is this? (Referring to the rheostat).*

***Learner**: It is a rheostat.*

***Educator**: What is the function of the rheostat?*

***Learner**: To adjust the current.*

***Educator**: What are these? (Referring to connecting wires).*

Learner: *Connecting wires.*

Educator: *What is this? (Referring to a switch).*

Learner: *It is a switch.*

Argument *on the terms 'open' and 'closed' switch, and 'on' and 'off' switch.*

Comment by a learner: *It is like a tap of water, if you open a tap the water comes out, and when you close a tap, the water does not come out. The same applies to an open and a closed switch.*

The educator tries to explain *the operation of a switch with the aid of a diagram.*

Educator: *What is this? (Referring to a bulb in a bulb holder).*

Learner: *A bulb and a bulb holder.*

Educator: *What is this? (Referring to a circuit board).*

Group activity; the educator gives the following instructions to learners:

- *Connect three cells in series with an ammeter.*
- *Connect the rheostat and adjust it to the maximum.*
- *Connect the voltmeter in parallel to bulb.*

The educator alerts *learners to observe what is happening to the voltmeter and the ammeter readings when the rheostat is moved.*

The educator asks *one volunteer learner to come and draw the circuit diagram on the flip-board.*

Comment by the educator: *The arrows in the circuit diagram indicate that the electrons are withdrawn from one point to another.*

Educator: *What do you observe when looking at the relationship between the current and potential difference?*

Learner: *When the current increases the potential difference also increases.*

The educator writes down the relationship on the board and learners note down their observations in their notebooks.

The educator asks *one of the group members to write their results on the flip-board. In the mean time, the other learners are asked to feel the temperature of the bulb.*

Educator: *What do you feel?*

Learners: *It is hot.*

Educator: *Why is it hot?*

Learner: *Electrical energy is converted into light energy.*

The educator explains the term resistance: *The difficulty experienced by charges.*

The educator asks *one learner to come and draw the graph of potential difference against current from their results on the flip-board.*

The educator summarises the lesson *by writing down the relationship as a proportion in the form of an equation. He then asks learners to state Ohm's law.*

APPENDIX F

TRANSCRIPT OF MICRO-LESSON 3

The educator divides learners into groups.

***The educator indicates the purpose of the lesson**: The purpose of this lesson is to determine the resistance.*

***Educator**: At home we have some electrical appliances. Name any electrical appliance.*

***Learner:** Stove*

***Another learner:** Iron*

***Another learner:** Hair-drier*

***Another learner:** Television*

***Another learner:** Kettle*

***Another learner:** Radio*

***Comment by the educator**: We have a lot of electrical appliances at home. I just want to find out from you what would happen if we connect all of these appliances.*

***Learner:** The red light in the main switch will move faster.*

***Another learner:** More current will be passing through and the main switch will drop.*

***Educator:** What will happen if we increase the number of cells?*

***Learner:** There will be more current and more energy.*

***Educator:** Keep those questions in mind. The experiment will help to answer them.*

***The educator then distributes the worksheets**, read through the purpose of the experiment (to investigate the relation between the current and potential difference). He continues to read through the procedure of doing the experiment on the worksheet attached to the micro-lesson plan (Appendix L).*

***The educator asks questions** on the connections of both the ammeter and voltmeter.*

***Educator:** How do we connect the ammeter?*

***Learner:** In series.*

***Educator:** How do we connect the voltmeter?*

***Learner**: In parallel.*

***The educator instructs** learners to set up the apparatus by following the procedure indicated on the worksheets. Learners start doing the experiment, while the educator writes notes on the flip-board. The educator does not actually facilitate and learners are left to do the experiment on their own. The educator just reminds them to record their results on the worksheets. When the* *learners are finished, the educator asks them to tidy up, disconnect everything and finalise the completion of the worksheets.*

Educator: *I am going to ask you that we draw the graph and make conclusions together.*

The educator comments: *We expect our graph to be a straight line.*

The educator then draws the graph *of the relationship between potential difference and current on the flip-board.*

Learners: *We have it.*

Comment by the educator: *We may not all get a straight line because of some errors.*

Educator: *What does a straight line means?*

Learner: *When the potential difference increases the current also increases.*

Educator: *The relationship tells us about the resistance that charges experience.*

The educator then refers learners to the notes *he has written while they were busy with the experiment. He refers them to Ohm's law written on the flip-board. The educator emphasises that the temperature should be kept constant.*

Comment by the educator: *The* ***ratio of potential difference versus current is resistance.***

The *educator then concludes the lesson by writing Ohm's law in the form of an equation.*

Comment by the educator: *This is what we call Ohm's law.*

APPENDIX G

TRANSCRIPT OF MICRO-LESSON 4

The educator starts the lesson by asking whether learners have studied the section on Ohm's law. Only one learner responded positively.

Educator: *Do we need electricity? Do you think electricity is important?*

Learner: *We use it for radios.*

Educator: *What is life without electricity?*

Educator: *Is electricity dangerous?*

Learner: *It can choke you.*

Educator: *Electricity is dangerous. We are going to study Ohm's law and this law is very important in the study of electricity. The aim of this lesson is to help you understand the law.*

The educator distributes the worksheets *with notes attached to them.*

Educator: *There are notes that we are going to go through on the worksheets. In the first activity we are going to look at the law and try to understand and apply. In activity 2 we are going to do an experiment to verify the law.*

Educator: *Let us go through the first part, and analyse the law.*

Educator: *Let one of you read the law for us as written in the worksheet.*

One learner reads the law: *The current in the metallic conductor is directly proportional to the potential difference provided the temperature remains constant.*

The educator reads the law again.

Educator: *The law is telling us the story, the relationship. What relationship?*

Learner: *The relationship between the current and the potential difference.*

Educator: *What is the symbol for current?*

Learner: *It is I.*

Educator: *What is the symbol for potential difference?*

Learner: *p.d or V.*

Educator: *What is the unit for current?*

Learner: *Ampere.*

Educator: *What is the unit for potential difference?*

Learner: *Volts.*

Educator: *What is the symbol for volts?*

Learner: *v.*

Learner: *Why is a symbol for ampere written as a capital letter?*

Educator: *Science has a language of its own, scientists agree on certain things.*

Educator: *Let us look at the law again. What kind of a relationship is indicated?*

Learner: *It is a direct proportion.*

The educator writes down the symbol *for proportionality on the flip-board.*

Educator: *What does it mean when two things are directly proportional?*

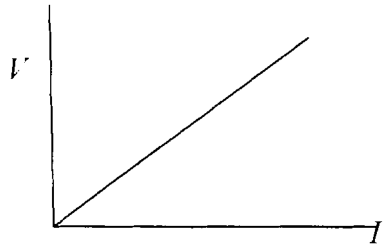
Learner: *When current increases, the potential difference also increases.*

Educator: *We can represent this in the form of a graph. What type of graph are we going to get? Remember, we have different types of graphs.*

Learner: *Straight line.*

Educator: *Yes, because they are directly proportional.*

The educator then draws the graph *of potential difference versus current on the flip-board.*



Educator: *What is the slope of this graph?*

Learner: *delta y over delta x*

Educator: *What is our change in y on this graph?*

Learner: *V*

Educator: *Our change in x.*

Learner: *I*

Educator: *Now we have a ratio V/I.*

Educator: *What would be the slope of this graph at different points oin the line?*

Learner: *It would be the same.*

Educator: *Yes, the ratio V/I is a constant.*

Educator: *Let us look at the worksheet again.*

Educator: *The notes indicate the ratio of V/I. What is this ratio called? Look at the worksheet.*

Learner: *It is R.*

Educator: *What is R?*

Learner: *R is a constant.*

Educator: *What is R in science?*

Learner: *It is a resistance or resistor.*

The educator refers learners to the table *of results on the worksheet.*

Educator: *What do you think will be the relationship? Do you think the resistance will be the same? Think about the graph.*

Learner: *The graph will be the straight line.*

Educator: *We would have verified Ohm's law if we get a constant.*

Educator: *Let us go back to the notes. There is a condition for this law to hold. What is this condition?*

Learner: *The temperature must be kept constant.*

Educator: *How do we keep the temperature constant?*

Educator: *What do you think about the temperature of the batteries?*

Educator: *How do you ensure that the temperature remains constant? Think about it.*

The educator then refers learners to the circuit diagram *on the notes, then connects the voltmeter across the resistor, holds the switch. Is it open or closed? He goes around showing learners. No response.*

Educator: *Back to the notes again. How do we keep the temperature constant?*

Learner: *We can use the rheostat.*

Educator: *The person taking the reading from the ammeter and voltmeter must be quick or slow?*

Learner: *Quick.*

Educator: *You must take readings quickly on the ammeter and voltmeter for Ohm's law to hold.*

Educator: *Point number 5 says what?*

Learner: *Ohm's law only applies to metal conductors.*

Educator: *This means that it does not apply to insulators. Why?*

Learner: *They do not conduct electricity.*

Educator: *What do we call conductors that do not uphold Ohm's law?*

Learner: *Non-Ohmic conductors.*

Educator: *Yes, all conductors that do not uphold Ohm's law are called Non-Ohmic conductors.*

Educator: *What do we call all those conductors that uphold Ohm's law?*

Leaner: *Ohmic conductors.*

Educator: *Let us look at point 6 in the notes.*

Educator: *Which formula are we going to use? Look at the notes. Do you have to memorise the formula?.*

Learner: *No, as long as you know the law.*

Educator: *No, you don't, because you are going to be given an information sheet in the exam. Science needs to be understood. The educator solves the problem in the notes. He draws the circuit diagram and calculates the current, then the potential difference.*

Educator: *Take current as cars or traffic, conductors as a road, and the battery as petrol station, resistors as speed humps. The latter are used to explain the concept of resistance.*

The educator then concludes the lesson *by giving learners activity 1 as homework.*

APPENDIX H

TRANSCRIPT OF MICRO-LESSON 5

The educator starts the lesson by saying: *We are going to learn about electricity.*

The educator divides learners into groups and distributes box of apparatus, instructing them to take out everything from the box.

Educator: *I want you to look at the instruments with symbols A and V. What is the one with A?*

Learner: *An ammeter.*

Educator: *What is the function of the ammeter?*

Learner: *To measure the amount of current.*

Educator: *How do we connect the ammeter?*

Learner: *In series.*

Educator: *Why in series?*

Learner: *It has a lower resistance.*

Educator: *What is the name of the other instrument with a symbol V on it?*

Learner: *A voltmeter.*

Educator: *How do we connect the voltmeter?*

Learner: *In parallel.*

Educator: *Obviously we connect it in parallel because it has a high resistance.*

The educator draws the circuit diagram *on the flip-board.*

Educator: *Will the current flow with an open switch?*

Learner: *It will flow.*

Learners are now asked to connect an electric circuit *as indicated in the circuit diagram drawn by the educator on the flip-board - one cell, an ammeter in series, voltmeter across the bulb and a switch.*

The educator comment: *I want to know whether you can connect a simple electric circuit, especially how to connect an ammeter and a voltmeter. Take readings from the ammeter and the voltmeter, I will now give you the worksheets to record your readings. If the bulb does not glow you must establish where the fault lies.*

Learners do the experiment and the educator facilitates.

Educator: *Now connect two cells and record the readings from the ammeter and voltmeter.*

Learner: *Why does the brightness increase when we increase the number of cells?*

The educator redirects the question to the class.

Another learner: *Because of the increased potential difference.*

Educator: *Now connect three cells.*

Educator: *What do you observe if you increase the number of cells?*

Learner: *If the potential difference increases the current also increases.*

The educator discusses the experimental results with learners.

Educator: *Can you put this relationship in mathematical form?*

Learner: $V \alpha I$.

Educator: *This is a mathematical way of representing Ohm's law.*

Educator: *Now plot the graph of V versus I on your worksheets.*

Group discussions and they draw the graph.

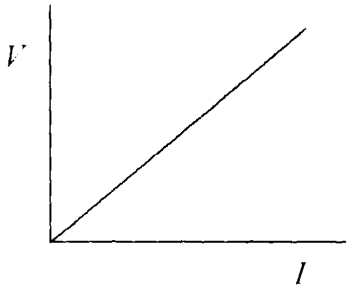
Learner: *Why is the current is in the x-axis?*

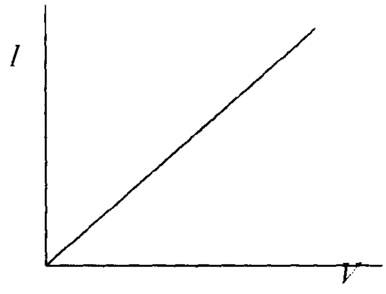
Learner: *V is an independent variable and I is dependent.*

The educator asks one group *to plot V versus I and the other group to plot I versus V.*

Educator: *I want to know whether we are going to get the same pattern or shape.*

The educator draws both groups' graph, *which is a straight line as follows.*





Educator: *Which one is independent?*

Learner: *V.*

Educator: *Why?*

Educator: *The pressure gives the flow of current. You cannot have a flow without a pressure, and the batteries give a pressure.*

Educator: *Give the relationship between potential difference and current in verbal form.*

Learner: *V increases with increase in I.*

Educator: *This is what we normally call Ohm's law. If the potential difference between two points in the conductor increases, the current also increases.*

Educator: *For interest sake I will show you how to use the multi-meter to arrive at the same conclusion.*

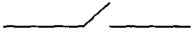
The educator shows learners *how to use the multi-meter to arrive at the same conclusion and ends the lesson.*

APPENDIX 1

TRANSCRIPT OF MICRO-LESSON 6

***The educator starts the lesson by saying:** We are going to study Ohm's law. To refresh your memories, I am going to ask you questions on some components of electricity.*

***The educator draws symbols** of some components used in electricity and then asks learners to give the names of the each component.*

Symbol	*Name*
	
	
	
	

***The educator now asks questions** on how to connect the ammeter and the voltmeter.*

***Educator**: How do we connect the ammeter?*

***Learner**: In series.*

***Educator**: How do we connect the voltmeter?*

***Learner**: In parallel.*

***The educator divides learners into two groups**. The group leader is asked to come and collect the apparatus and worksheets.*

***Educator**: Follow the instructions on the worksheets and construct an electric circuit similar to the one indicated on the worksheets and flip-board. The educator gives learners time to do the experiment. The educator explains the correct procedure for connecting the ammeter and voltmeter.*

***Learners start with the experiment**. They connect an electric circuit with one cell, an ammeter and a voltmeter in parallel with a bulb, then increase the number of cells to two and then three.*

***The educator facilitates** and helps where necessary, moves around to check whether they are recording the results.*

*While learners are busy with the experiment, the **educator draws the table of results**. He asks one group to come and complete the table of results below on the flip-board.*

This is how it was completed.

Number of cells	V	I	V/I
1	1.2	0.1	12
2	2.4	0.2	12

The results for three cells were not indicated.

***The educator asks questions** on the experimental results.*

***Educator**: What happens if we increase the number of cells?*

***Learner**: The potential difference increases.*

***The educator writes down the conclusion** on the flip-board: If the number of cells increases, the potential difference and current increases, which means potential difference increases with increase in current.*

***Educator**: We have direct proportion and inverse proportion. How do you classify the relationship between current and potential difference? Is it inverse or direct proportion?*

***Learner**: It is a direct proportion.*

***The educator writes** $V \alpha I$ on the flip-board.*

***Educator**: If current increases, potential difference increases, if current decreases, the potential difference decreases. This is what is called Ohm's law. One of the variables should be kept constant, what is that variable?*

***Learner**: Temperature.*

***The educator explains**: The ratio of V/I will always give a constant.*

Can anyone state Ohm's law?

***Learner**: The potential difference across the ends of the conductor is directly proportional to the current strength across the ends of the conductor at constant temperature.*

***Educator**: If we plot the graph, what kind of graph are we expecting?*

***Learner**: Straight line graph.*

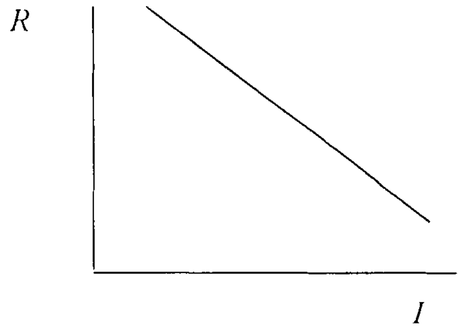
***The educator asks** one learner to come and draw the graph from their set of results.*

***The educator explains** that if the resistor obeys Ohm's law, a straight line is obtained. Anything that does not produce a straight line does not obey Ohm's law.*

***Learner**: How will the graph of resistance versus current look like?*

The educator asks one of the learners to come and draw the graph of R versus I on the flip-board.

This is what the learner drew:



The educator comments by saying: We will confirm this in the next lesson.

The educator then concludes the lesson *by saying: What is important is to state the law. The homework is then given to learners.*

APPENDIX J

MICRO-LESSON PLAN 1

Learning programme: Physical science

Phase organiser: Environment, economy and development

Programme organiser: Ohm's law

Time: 45 minutes

Learning area	SOs	ACs
NS	SO1	
	SO2	
EMS	SO2	
LLC	SO1	AC1
MLMMS	SO5	
TECH	SO1	AC1

Facilitator	**Learners**	**Resources**	**Assessment strategies**
1. Divide learners into two groups.	Learners move to their respective groups and allocate duties to each member.	Tables, chairs, pen and papers	Inspection
2. Ask pre-knowledge questions on electricity.	Learners answer the questions.	Cell, conductors, ammeter, voltmeter, bulb, flip board.	Class assessment
3. Educator assists the learners to connect circuit board.	They follow the instructions of the educator.	1 cell, conductor, ammeter, voltmeter and bulb.	Group assessment
4. Distribute worksheets and graph papers.	Perform the experiment and record the readings.	2 cells and 3 cells as instructed in the distributed worksheets.	Group assessment worksheets

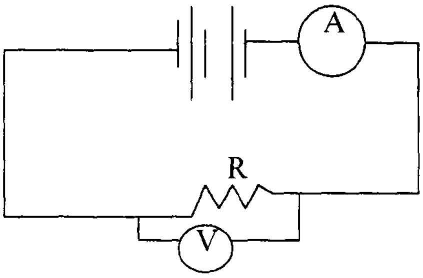
Worksheet

Objectives: To be able to:

- Connect an electrical circuit;
- connect and read ammeter and voltmeter;
- develop means of changing current and potential difference in a circuit;
- draw graphs; and
- deduce Ohm's law from a graph.

Procedure:

- Use a circuit shown below and connect the components as shown in the diagram.



- Record the readings on the voltmeter and ammeter in the table below:

Number of cells	Ammeter reading	Voltmeter reading	V/I
1			
2			
3			

- Repeat the procedure with 2 and 3 cells connected in series and record in the table above.

Analysis of results:

- If we increase the voltage (v) by adding the cell, the current (in A) ------------ (increases or decreases).
- Choose a suitable scale and draw a graph of current on the x-axis and potential difference on the y-axis of your graph paper.
- Is the shape of your graph a straight line or hyperbola shape?
- Use the graph to deduce the relationship between the current and potential difference.
- Is the value of ratio V/I in our graph a constant or does it vary?
- What factor(s) was/were kept constant during the experiment?

Conclusion:

- State Ohm's law.
- Express Ohm's law in mathematical symbols.

APPENDIX K

MICRO-LESSON PLAN 2

Learning programme 1 (one lesson of 45 minutes)

A. Background information for learning programme

Topic of learning programme: Ohm's law **Grade 12**

1 Specific outcomes

1.1 To investigate the relationship between the current in a resistor and the potential difference across its end;

1.2 SO1: to use process skills to investigate phenomena related to the natural sciences;

1.3 SO4: demonstrate an understanding of how scientific knowledge and skills contribute to the management, development and utilisation of natural and other resources.

2 Critical outcomes

2.1 Use science and technology effectively and critically, showing responsibility towards the environment and health of others.

2.2 Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exists in isolation.

3 Assessment criteria

3.1 Learners conduct explorative investigation in which:

a) Phenomena are identified;
b) a plan of action is formulated;
c) data is collected, analysed, evaluated and interpreted; and
d) findings are communicated.

3.2 Learners show work in which:

a) Relevant scientific information is gathered.
b) Observations are made, evidence is collected and recorded.
c) Findings and conclusions are communicated.

4 Range statement

4.1 Learners develop their work by using a wide variety of instruments or devices to collect, measure, analyse and present data and findings.
4.2 Learners evaluate and analyse data in terms of validity and appropriateness of methods and techniques used.
4.3 Learners communicate their findings, decisions and conclusions in a variety of ways, showing a grasp of a relation between various factors that are in context with one another regarding the development, utilisation and management of resources considered.

5 The particular content

Learners would be acquainted with scientific concepts such as current, potential difference and resistance and they will also know (state) the theory of Ohm's law. They will also know how resistors in series and in parallel should be connected.

6 The content/themes/organisers

Ohm's law and resistance.

7 Learning activities that are appropriate

Learners will be conducting an experiment. They would be:

- Connecting three cells, an ammeter, a switch, a rheostat and a length of resistance wire;
- connecting a voltmeter across the ends of the resistance wire;
- adjusting the rheostat to obtain a reasonable value of current and record the corresponding reading on the ammeter;

- recording the readings in a table and plotting the graph of potential difference against current; and
- determining the resistance of the wire from the gradient of the graph.

8 Performance indicators that are relevant

This will be evident when learners:

- Present data in ways that facilitate analysis and interpretation, e.g. a graph that shows relationship; and
- determine the appropriate formulae, graphs and other presenting styles and forms.

9 Teaching methods

Demonstration, experimentation and observation.

10 Teaching materials

Rheostat, 3-cell torch, conductors, voltmeter, ammeter, switch, circuit board and a bulb.

APPENDIX L

MICRO-LESSON PLAN 3

Learning area: Natural science **Grade 12**

Phase organiser: Economic development, personal development.

Programme organiser: Ohm's law.

Outcomes: To be able to:

1. Construct and draw an electric circuit diagram in series connection;
2. identify the relationship between potential difference, current and resistance; and
3. to plot the graph using the data collected from the voltmeter and ammeter.

Teacher activities	Learner activities	Classroom props	Assessment	Estimated time
1. Divide learners into pairs	Learners sit in pairs	-	-	2 minutes
2. Educator asks the following questions: 2.1 Name appliances that you use at home. 2.2 What would happen when you load many appliances at the same time? 2.3 What would happen to the value of current and voltage is measured in a circuit as the number of cells increases?	Learners give verbal answers.	Flip-board	Individual assessment	5 minutes
3. Educator issues worksheets and explain the procedure of an experiment to be carried out. The facilitator facilitates as learners conduct the experiment.	Listens and thereafter perform the experiment, explain and record the results.	Worksheets Apparatus	Group assessment	20 minutes
4. Draw the graph expected on the flip-board and explains Ohm's law by means of the graph	Listen and brainstorm the ideas	Flip-board	-	9 minutes
5. Interpretation of the graph by using the formula and relationships	Listen and brainstorm the ideas	Flip-board	-	9 minutes

Worksheet

Aim:

In this experiment we want to verify Ohm's law by determining the ratio between the potential difference across the resistor and the current passing through the resistor.

Prediction:

What would happen to the value of current and the voltage measured in a circuit as the number of cells increases?

Procedure:

1. Set up a circuit consisting of the following components:
    - One cell
    - An ammeter
    - One resistor
    - A voltmeter (across the resistor)
    - A switch
2. Record the current flowing through the resistor and the voltage across the resistor.
3. Add a second cell and record the voltage and current again.
4. Continue to add cells to give as many readings as you can.

Observations:

- What happens to the voltage drops across the resistor as the number of cells increases?
- What happens to the current through a resistor as the number of cells increases?

Recording your observation as results:

- Record what you have observed during the experiment.
- For each resistor you investigated, record the values you measured for voltage and current in the table with headings such as the one below.

Number of cells	**Potential difference V (v)**	**Current A**	**V/I**
1			
2			
3			

Interpreting the results:

- What can you say about the ratio V/I for each of the resistors?
- How do the values you obtained compare to the resistors you tested?
- Draw a graph of V versus I.
- What type of relationship does this graph represent?
- What is the value of the slope of the graph you have drawn?
- From this graph can you say that the resistors obey Ohm's law? Why?

Drawing conclusions:

- Explain in your own words what you have discovered about the relationship between voltage and current in this experiment.
- Explain what you understand by Ohm's law.

APPENDIX M

MICRO-LESSON PLAN 4

Topic: Ohm's law **Grade: 12**

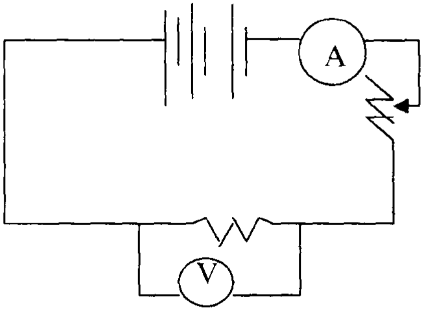
Outcomes: Learners should be able to:

1. Apply Ohm's law by solving practical problems;
2. complete an electric circuit for determining V/I; and
3. draw a graph showing the relationship V/I and determine the resistance of a circuit.

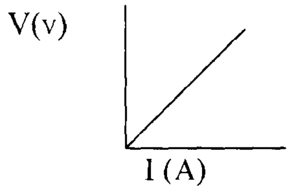
Educators' activity	Learners' activity	Resources	Assessment	Estimated time
Activity 1 1.1 Discuss Ohm's law and specify the usefulness of the law	Listens, answer questions	Hand outs	Worksheet	45 minutes
1.2 Giving learners practical problems to solve by using Ohm's law.	Solving problems by using a worksheet.	Worksheets	Individual assessment	80 minutes
Activity 2 Grouping learners into small groups to perform an experiment to verify Ohm's law.	Perform an experiment to verify Ohm's law using a worksheet.	Circuit board, ammeter, voltmeter, cell holders, and cells, resistors, leads and a switch	Worksheet Rubric Group assessment	90 minutes

Notes given to learners (handout):

1. The current in a conductor is directly proportional to the potential difference across it, provided the temperature remains constant.
2. Circuit for verifying Ohm's law.



3. Graph obtained in verifying the law:



4. Relationship for Ohm's law:
   $V \propto I$

   Equation for Ohm's law:

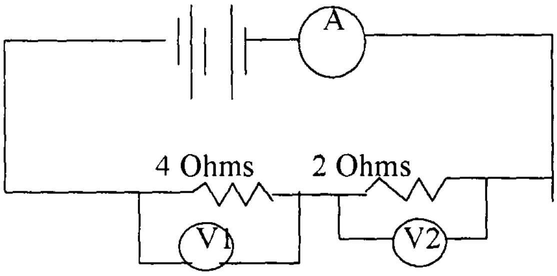
   $$\frac{V}{I} = \text{Constant}$$

5. Ohm's law applies for metal conductors.
6. Application equation for Ohm's law:

$$R = \frac{V}{I}$$

Example: Refer to the circuit diagram below and apply Ohm's law to find the readings on the:

a) Ammeter;
b) voltmeter v1; and
c) voltmeter v2 .



Worksheet

Aim: To verify Ohm's law

Apparatus:

- Circuit board
- Cells and cell holder
- Voltmeter
- Ammeter
- Leads

Method:

1. Connect three cells in series with an ammeter, a rheostat, a resistor and a switch.
2. Connect a voltmeter across the resistor.
3. Set the rheostat at maximum resistance.
4. Close the circuit and adjust the rheostat to get suitable readings on the ammeter and voltmeter.
5. Repeat for more sets of readings, leaving a couple of minutes for each set, only allowing the current to flow for short periods each time (so as to minimise the increase in temperature of the resistor).
6. The readings should be recorded in a table with the headings V, I and V/I.
7. A graph of I versus V will reveal the relationship that exists between I and V in the resistor (as should a glance at the values in the V/I column).

Results:

Complete the table:

Current I A	**Potential difference V (v)**	**R = V/I**	**R**
1			
2			
3			
Average			

1 What quantity is given by ratio V/I?
2 Give Ohm's law
2.1 As an equation
2.2 In words
3 Draw a circuit with 4 cells, ammeter, voltmeter, switch and resistor.
4 Complete the table above.
5 Draw a graph of I versus V.

APPENDIX N

MICRO-LESSON PLAN 5

Learning area: Natural science **Grade: 12**

Phase organiser: Economic development, personal development

Programme organiser: Ohm's law

Critical outcomes:

- Collect, analyse, organise and critically evaluate information.
- Communicate effectively by using mathematical and language skills in modes of written presentation.

Specific outcomes:

- Learners should be able to measure potential difference and current and work efficiently and safely; and
- should be able to measure and calculate resistance and research factors.

Skills:

- Communicating, listening, observing, recording, interpreting data and drawing conclusions.

Educators' activity	**Learners' activity**	**Classroom props**	**Assessment**	**Estimated time**
1. Educator divides learners into two groups with groups of 3 and 4 members each.	Learners divide themselves into groups of seven	Learners	-	-
2. The educator introduces a topic by using questions on electrical quantities and a flip-board.	They listen, respond and ask questions.	Flip-board, pens.	Educator assessment	-
3. Distributes handouts and worksheets to the learners and also explains to them by using a flip-board.	Listens, ask questions.	Handouts, worksheets, flip-board and learners.	Educator assessment	-
4. The educator gives learners all relevant apparatus and instructs them to follow the procedure to experiment and facilitates where possible.	Listen, ask questions and start the experiment.	Worksheets.	-	-
5. The educator instructs learners to record their observations on the worksheets.	Learners record the results.	Worksheets.	-	-
6. He asks the learners to explain their observations.	They explain what they have observed.	Worksheets.	Educator assessment	-
7. He asks learners to communicate the different skills they have learnt.	Learners give skills they have developed.	Learners.	Educator assessment	-

Worksheet

Aim: To investigate the ratio V/I for various potential difference.

Apparatus:
- Circuit board
- Cells
- Switch
- Voltmeter
- Ammeter
- Resistor

Method:
- Connect a circuit as instructed, using one cell;
- Close switch and record readings on ammeter and voltmeter;
- Connect a second cell in series, close switch and record readings on ammeter and voltmeter;
- Connect the third cell in series to the second cell, close the switch and record readings on ammeter and voltmeter; and
- Note the results as indicated in the table; calculate the ratio V/I for each case and draw the graph of V versus I.

Observation:
- What is the reading of the ammeter as the number of cells increases? State the relationship between an increase in number of cells and the current should be established in simple words.
- How is the voltmeter reading affected as the number of cells is increased?
- A relationship between the voltmeter reading and the ammeter reading is established.
- A new resistor with a different value should is connected in order to verify whether the relationship between the voltmeter and ammeter above still holds.

Cells	**Potential difference (v) across the resistor**	**Current (I) through the resistor**	**Relationship between V and I**
1			
2			
3			

Questions:

- What is the value of V/I for each of the resistor?
- Draw a graph of current and potential difference on the same set of axis.
- What meaning does the slope convey?

APPENDIX O

MICRO-LESSON PLAN 6

Topic: Ohm's law **Grade 12**

Outcomes: To be able to:

- Collect and record data;
- interpret data; and
- draw a graph

Educators' actions	Learners' activities	Resources	Assessment	Estimated time
1. Introduces the lesson by asking questions about previous knowledge	Listen carefully, ask questions, answer questions	Flip board	Asking questions verbally	3 minutes
2. Instructs learners to sit in groups.	Execute the instructions	Chairs and tables		2 minutes
3. Issues worksheets and explains procedure of how to conduct the experiment.	Learners set up the apparatus and carry out the experiment and complete the worksheet.	Circuit board, cells, voltmeter, ammeter, connecting wires and bulbs	Educator completes group evaluation tool.	25 minutes
Homework	Write down five factors that affect the resistance of a resistor.			

APPENDIX P

EVALUATION OF MICRO-LESSONS

1. The structure of the lesson
2. How were the lessons introduced?
Elaborate
3. Comment on the outcomes specified.
Elaborate
4. What pre-knowledge was probed?
Elaborate
5. Comment on the questions asked by the educator.
Elaborate and give examples thereof.

6. If learners were involved, how were they involved?
Elaborate
7. Does the lesson emphasise theory or practical, or both?
Elaborate
9. Comment on the worksheets used during the lesson.
Elaborate
10. Misconceptions identified during the lesson?
10. Is the structure of the lesson OBE or traditional, or both?
Elaborate

APPENDIX Q

QUESTIONNAIRE ON VIDEO-TAPED MICRO-TEACHING

Dear respondent

We are interested in your opinion on using video-taped micro-lessons as a teaching strategy in subject didactics of science. You are requested to answer the following questions. No marks are given. Give you fair comment or response. You may remain anonymous if you wish.

Number of years teaching physics:..............................

Highest qualifications:..

Province: ....

Were you a member of the group who presented the last micro-lesson?

YES	NO

1 Do you think that the teaching strategy using video-taped micro-lessons will help to improve your approach to OBE lessons in physics?

YES	NO

Elaborate

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....

2 Do you think video-taped micro-lessons can aid in the training of educators?

YES	NO

3 Do you have a better understanding of how to approach practical work after this project?

YES	NO

4 Did the micro-lessons change your ideas about the role of the educator as facilitator?

YES	NO

Elaborate:

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5 Were the discussions held after viewing the video-taped micro-lessons helpful?

YES	NO

6 Do you need more knowledge on how to conduct OBE lessons in physics?

YES	NO

Elaborate

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7 Is practical work necessary in OBE lessons in physics?

YES	NO

8 Do you have apparatus in your school to do practical work in physics?

YES	NO

9 I need more knowledge on how to plan and execute an OBE lesson in physics.

YES	NO

10 What did **you like** about the following aspects of the micro-lessons?

(a) Preparations: ....

....

....

....

(b) Presentation: ....

....

....

....

(c) Discussions / Feedback: ....

....

....

....

11 What did **you not like** about the following aspects of the micro-lessons?

(a) Preparations: ....

....

....

....

(b) Presentation: ....

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....

(c) Discussions / Feedback: ....

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12 Video-taped micro-lessons can help in addressing misconceptions in physics.

YES	NO

13 Mention major problems that you encounter at school regarding the teaching of physics, especially practical work.

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14 Did the micro-lessons represent (model) a realistic class situation?

YES	NO

Elaborate:

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....

15 Have you presented micro-lessons before during your training as an educator?

YES	NO

If yes, in which ways did these micro-lessons differ from your previous experience?

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16 Please write down any other comments

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APPENDIX R

"MODEL" MICRO-LESSON PLAN

Investigation of Ohm's law

Outcomes:

- ✓ Expand the concept of resistance.
- ✓ Obtain accurate measurements
- ✓ Record information obtained in scientific format.
- ✓ Draw, analyse and interpret the graph.

Guidelines:

- ✓ Formulate an action plan to determine the resistance of the unknown resistor.
- ✓ Choose/select appropriate apparatus.
- ✓ Use apparatus and take measurements to obtain data.
- ✓ Manipulate data to determine the required resistance.

Procedures:

I What is resistance?

II Is it possible to predict the value of a resistor (e.g. bulb or wire) by just looking at it? Explain your answer.

III State your plan of action to determine the physical properties of the bulb or wire and name the apparatus you would need. Also draw an appropriate diagram.

List of apparatus	**Circuit diagram**

Plan of action (method):

IV Put your plan of action to test. Set up the apparatus you have chosen and take the measurements and readings required.

V Record your results and design/complete a suitable table to record them in a way to depict the relationships involved.

Table:

Number of cells	Voltmeter reading (V)	Ammeter reading (I)	V/I
1			
2			
3			

VI Interpret the readings, results and calculations and also illustrate the relationship involved using a graph

VII Which factors could have been responsible for any deviation in your results? Explain your answer.

VIII Formulate your conclusions, including:

a) The interpretation of the relationship between the current and potential difference.
b) Proportionality
c) Gradient of the graph
d) Meaning of resistance
e) Establish Ohm's law
f) Unit of resistance

Look at other groups' value of V/I and record it in the table below.

Number of cells	Group 1 (V/I)	Group 2 (V/I)	Group 3 (V/I)
1			
2			
3			

IX What do you think makes your answers different. Discuss your answers in groups.

APPENDIX S

TRANSCRIPT OF THE "MODEL" MICRO-LESSON

The educator starts the lesson by asking learners. *What is resistance?*

The educator gives learners the apparatus *to inquire experimentally about the concept of resistance.*

Educator: *You are going to make connections.*

Learners take out apparatus *from the box and start experimenting.*

Educator: *We are going to start with one cell. The circuit diagram is drawn by the educator and learners are asked to refer to it when making connections.*

Educator: *Record your readings in the worksheets given.*

Learner: *I do not know how to adjust the multi-meter.*

Educator: *How do we connect the ammeter in the circuit?*

Learner: *In series*

Educator: *How do we connect the voltmeter in the circuit?*

Learners: *In parallel.*

The educator moves between groups *to see if they are making correct connections.*

The educator divides learners into two groups. *One group seems to be struggling with the connections. The other group is not having problems.*

Comment of the educator: *Your group seems to have so many problems.*

The educator tries to guide them *but they do not follow. The educator spends more time guiding and monitoring progress in this group. (The problem seems to be mainly with the connection of the multi-meter).*

The educator rearranges the groups.

Educator: *Are you winning?.*

Educator: *There you go, after a long time.*

Educator: *Take the readings from the other group and compare your results.*

Comment by educator: *Make sure you plot the graph.*

After 40 minutes:

Educator: *Let's discuss what your results.*

Educator: *What can you deduce from the relationship between V and I?*

Learner: *If V increases, then I also increases (v is directly proportional to I).*

The educator uses the concept of gradient to discuss the results.

Educator: *What do we call the ratio of V and I?*

Learners: *Resistance*

Educator: *Finally let's put it in a scientific way. This is called Ohm's law.*

The law is stated.

Educator *explains the mathematical application. If you want to calculate any one of the variables R, V and I you can use the equation V= IR.*

Educator: *We have come to the end of the lesson.*