

MEASURING THE VIEWS OF GRADE 10-12 GAUTENG SCHOOL LEARNERS ON CHEMISTRY PRACTICALS

by

BRIDGIT HELEN DAVIS

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SUPERVISOR: PROFESSOR E.O. MASHILE

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Summary

The two-part Views on Chemistry Practicals (VOCP) instrument for measuring the views of grade 10 to 12 Physical Science students about the benefits and problems of Chemistry practicals was empirically developed and trialed using six schools in Gauteng. The summary part of the resultant VOCP instrument comprises 24 Likert items and the explanatory part comprises 24 multiple-choice items with 163 options, thus creating a unique current record of a wide range of students' views of chemistry practicals and providing teachers with a tool for improving chemistry practicals. The trial of the instrument with 230 students from three schools indicated that the summary part of the instrument is reliable (Cronbach alpha coefficient) and that a shortened explanatory part of the instrument is reliable (Chi squared values for 17 items with 98 options). The validity of the VOCP instrument was established through the empirical development of the instrument using triangulation of data.

Key terms:

Chemistry practicals; Chemistry laboratories; Science practicals; Science laboratories; Empirical development of instruments; Views on chemistry practicals; Benefits of chemistry practicals; Problems of chemistry practicals; Physical Science students; Action research in chemistry education

Declaration

I declare that

Measuring the views of grade 10-12 Gauteng school learners on chemistry practicals
is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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In developing the instrument I was assisted in the following ways.

The Gauteng Provincial Department of Education granted permission for the research to take place in Tshwane South district. Members of the Tshwane South district office provided necessary information for sampling schools. Principals, teachers and students of six schools of Tshwane South responded to my request for the collection of data in the schools. Without these responses the empirical development of the instrument would not have been possible. Thank you to all concerned.

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The analysis of the data from Questionnaire 2 involved three judges categorizing the data. Dr N. Nkopodi and Prof E.O. Mashile of the Education Faculty at Unisa joined me in this time-consuming and demanding task. The development of the instrument was enriched by the contributions of these two professors. Thank you.

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Chapter 1 Introduction to the development and evaluation of the Views On Chemistry Practicals instrument

Three background points were used to formulate the research problem that there is an absence of a necessary instrument with which South African teachers can find out their students' views of the benefits and problems of chemistry practicals. Existing instruments commonly used in science education research were found to be unsuitable for use in this context. The aim and objectives of the research were developed out of this research problem. The aim was to empirically develop a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools. The literature reviewed in chapter 2 provided support for the development of the Views On Chemistry Practicals (VOCP) instrument and for the method in which the instrument was developed.

The research of designing and developing the VOCP instrument, as described in chapter 3, ensured as much as possible that the English language in the VOCP instrument is understandable to target students, namely Gauteng grade 10 to 12 Physical Science students. The method was therefore informed by the method used to develop the Views on Science Technology Society (VOSTS) instrument (Aikenhead & Ryan 1992: 477-491). In the four stages used to develop and trial the VOCP instrument, data were collected from six Gauteng schools using two questionnaires, interviews and trial use of the instrument, with a different school being sampled for each of the four stages of data collection. The purposive sampling, based on the English language results of the school, was an important attempt at ensuring that the language of students with poor English results was represented in the instrument, but those students with better English results articulated the meaning of the statements made by the first group of students.

As described in chapter 4, the instrument was found to be valid and reliable. The significance of the research is twofold. Firstly the product of the research, that is the VOCP instrument, provides a current record of students' views of chemistry practicals. This record is unique and a result of the empirical development of the VOCP instrument. Secondly, the VOCP instrument is a tool for teachers to use to improve chemistry practicals in South Africa (Gauteng, Tshwane South).

1.1 Background to the research

1.1.1 Benefits and problems as the domains of school science practicals in

South Africa

From 1997 to 2000 the researcher worked in a science center and was thus able to engage science teachers in conversation about science teaching at schools. These informal conversations with many different science teachers started forming a picture of school science practicals as seen by the teachers. The picture was that science practicals benefit the students because practicals lead to understanding, yet practicals are a problem because of, amongst others, lack of equipment. This benefit of understanding and this problem of lacking equipment surfaced in tandem with uncanny frequency.

As recently as 2003, work with in-service science teachers has shown the researcher that teachers continue to see understanding as a benefit of chemistry practicals. The words of one of the teachers supports this claim, “by doing such experiments one is able to understand each aspect of chemistry”. The experiments referred to are the practicals in “every chapter in chemistry”. Work with in-service science teachers in 2002 and 2003 has shown the researcher that some teachers are managing to overcome the problem of lacking equipment (for example by sharing with other schools), but new problems are surfacing. For example, a teacher speaking about the portfolio practicals for the senior certificate has identified the problem that students cannot draw conclusions from their practical work.

So South African teachers (mostly Gauteng and Limpopo teachers in both cases) speaking to the researcher about science and chemistry practicals used the domains of the benefits and the problems of practicals. This is the first important factor in the rationale for the research.

1.1.2 Views of teachers and students

Research often starts with a wondering (Bissex 1987: 3). Prompted by this anecdotal insight into teachers' views on science practicals, the researcher wondered how students viewed chemistry practicals. Research has shown, by comparing teachers' and students' views of the same feature of the classroom environment, that teachers tend to see the classroom environment in a more positive light than their students (Fraser, Giddings & McRobbie 1992: 6). That is, teachers and students see the same feature differently. What if teachers and students don't even “see” the same features of science practicals?

For example, a teacher may view chemistry practicals as beneficial because practicals help students understand chemistry. Yet this teacher's students may see chemistry practicals as beneficial because skills acquired during practicals will help students in future (Hegarty-Hazel 1990d: 5; 15). In such a scenario, the teacher and students may be working at cross purposes. Similarly for problems of practicals. The teacher may focus on the problem that students are not able to draw conclusions, but a different problem may be demanding the students' attention. A postal survey by the researcher of in-service science teachers has shown that in planning and preparing for a chemistry practical, none of the 23 teachers who returned completed questionnaires wrote about their students' views. Therefore these scenarios of teachers being unaware of their students' views are also found amongst South African teachers.

So teachers' and students' views on chemistry practicals are not the same, yet teachers are not considering their students' views. The second important factor in the rationale of this research is that teachers do not often know their students' views about chemistry practicals. Teachers therefore need to be supported in terms of adequate mechanisms of determining students' views about chemistry practicals. It is therefore the aim of this research to develop an instrument that will support teachers in this important teaching and learning function.

1.1.3 Students' views used by teachers to improve school chemistry practicals

In 2002 the researcher attended a seminar presented by Barry Fraser, who has been a prominent player in classroom environment research. Fraser (2001) was also the editor-in-chief of the international journal called *Learning Environments Research*. In the seminar, Fraser showed that students' views of the classroom environment were used successfully by teachers to improve their classroom environments. Classroom environment research literature (for example, see the review by Fraser 1994: 523-531) supported the notion that teachers can use questionnaires to find out their students views, and the findings can be used to improve classroom practice.

Two aspects of South African school science practicals suggested that South African teachers may be needing to improve their own science practicals. Firstly, South African teachers were not familiar with planning and running practicals for their students (Muwanga-Zake 2002: 3). Secondly, from 2001, science practicals were a compulsory part of the school based continuous assessment for the senior certificate (Gauteng 2002: 8). Students' achievement in school science practicals is now integrated in their overall assessment and thus impacts directly on their senior certificate result.

The evidence presented by Barry Fraser and the probable need for South African teachers to have a way to improve their own science practicals were therefore combined to envisage South African teachers using their students' views to build on the perceived benefits and address the perceived problems. So the third and final important factor in the rationale of this research is that, knowing their students' views of specific benefits and problems of chemistry practicals, teachers can improve chemistry practicals.

1.2 The research problem

The three important factors in the rationale for the research combine to form the research problem. Following South African teachers in viewing science practicals in terms of the benefits and the problems of practicals, acknowledging that teachers do not know their students' views about chemistry practicals unless teachers ask students their views, and seeing the potential for South African teachers to use their students' views of the benefits and problems of chemistry practicals to improve chemistry practicals, there is a need for an instrument with which teachers can find out their students' views of the benefits and problems of Chemistry practicals.

Given the need for an instrument on students' views of the benefits and problems of chemistry practicals, no such instrument was found in the literature that would be suitable for South African schools. Such an instrument should incorporate contextual South African factors, including social and linguistic peculiarities. The identified research problem is therefore an absence of an instrument relevant for South African purposes that will determine students' views of the benefits and problems of chemistry practicals.

1.3 Aim of the research

The aim of the research was to empirically develop a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools.

1.3.1 The design and development of a two-part instrument which is both quick to use (summary part) and allows a full range of students' views to be expressed (explanatory part)

The aim was to develop a two-part instrument comprising a summary part and an explanatory part. The summary part was designed to be a single page of questions, answered using a Likert scale, which teachers could use to quickly find out students' views in summary (De Vaus 2002: 102). The explanatory part was designed as a series of multiple-choice items, with each item corresponding to a summary item. The choices for each item offered a range of explanatory views about the stem statement. Teachers could therefore use one or more of the explanatory

items to gain further insight into students' views. The full complement of items from the explanatory part of the instrument was designed to offer as wide a range of students' views on chemistry practicals as possible. The two-part instrument was thus designed to meet the objectives of the instrument being quick to use (summary part) and allowing the full range of students' views to be expressed (explanatory part).

1.3.2 Develop the instrument as a Views On Chemistry Practical (VOCP) questionnaire

Considering a questionnaire as the most convenient instrument for teachers to use, an objective was to develop the instrument as a Views On Chemistry Practical (VOCP) questionnaire.

1.3.3 Use an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument

The aim was to develop an instrument to measure the views held by grade 10 to 12 Physical Science students in Gauteng schools. The instrument was to be in English, but the home language of grade 10 to 12 Physical Science students in Gauteng schools was not necessarily English. Therefore, in order to increase the process validity of the instrument, an objective was to use an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument.

1.3.4 Use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument

Furthermore, in order to increase the validity of the instrument by decreasing the ambiguity of items, an objective was to use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument.

1.3.5 Evaluate the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature.

The empirical process of using Gauteng grade 10 to 12 Physical Science students' input in all the stages of developing the instrument provided the content domain of the instrument. An objective of the research was to evaluate the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature.

1.3.6 Use the developed instrument in schools in Gauteng

In order to evaluate the reliability of the instrument and provide data for evaluating aspects of the validity of the instrument for a group of Grade 10 to 12 Physical Science students in Gauteng schools, a final objective was to use the instrument in schools in Gauteng.

1.3.7 Objectives

A list of the objectives is:

- Design and develop an instrument which is both quick to use (summary part) and allows the full range of students' views to be expressed (explanatory part).
- Develop the instrument as a Views on chemistry Practicals (VOCP) questionnaire.
- Use an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument.
- Use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument.
- Evaluate the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature.
- Use the developed instrument in schools in Gauteng.

1.4 Support from literature for the development of the VOCP instrument

Chapter 2 provides support from literature about aspects of the development of the VOCP instrument.

The nature of chemistry was found to be distinct from the nature of other science disciplines such as physics and biology, thus supporting the focus on developing an instrument to measure the views on chemistry practicals and not science practicals in general. Science education literature, however, does not necessarily make the distinction, so the literature review in Chapter 2 continued by reviewing science practicals in general, and focusing on chemistry if possible.

Science practicals were found to be important as the *sine qua non* of science, as a unique school experience and for their role in improving attitudes to science. Science practicals were also found to be important to students and to curriculum developers and implementers. The demonstrated importance of science practicals supports the development of the VOCP instrument as a contribution to teachers realising the potential of chemistry practicals in South Africa.

The review of the state of science practicals in South African secondary schools focused attention on teachers' perceptions that science practicals lead to understanding and on problems associated with science practicals in Gauteng. Literature thus supported what was described in the background to the research above and thus justified that the benefits and problems of chemistry practicals are used to operationalize views of chemistry practicals in the VOCP instrument. The review of the state of science practicals in South African secondary schools also described the science practical contribution to the continuous assessment for the Senior Certificate, and the South African situation of practicals forming part of a science class and chemistry forming part of the school subject called Physical Science. The development of an instrument measuring the views of Grade 10 to 12 Physical Science students is thus supported.

A description was made of the benefits and the problems of science practicals, as depicted by the science education literature. For various reasons there is a predominance in literature of opinion, and a lack of unequivocal research-based evidence, about the benefits and problems of practicals. The decision to use students' opinions to empirically establish the content domain of the VOCP instrument was thus supported.

Students' views were found to play an important role in the success of teaching, so literature supported the development of an instrument to measure students' views. Further support came from literature which showed that teachers' and students' views differ. This point also supported the use of students' views to establish the domain of the VOCP instrument. Attention was drawn to the wide range of student views about chemistry practicals, thus supporting the objective of developing the explanatory part of the instrument to represent as fully as possible all the views on chemistry practicals. Finally, students' views were shown to be useful to a teacher wanting to improve her (his) teaching, using action research as an example of how teachers could accomplish this improvement. Literature therefore supported the development of the VOCP instrument for improving chemistry practicals in South African (Gauteng) schools.

Existing instruments commonly used in science education research were described and found to be unsuitable for measuring South African students' views about the benefits and problems of chemistry practicals. Literature thus highlighted the need for the development of the VOCP instrument. Chapter 2 provided a rationale for the development of a two-part instrument, designed for use by teachers.

1.5 Research method

English is the language used in the VOCP instrument, but English is not necessarily the home language of students in South African secondary schools. This exacerbates the problem of creating questionnaire items which are understandable to the respondent, and carry the same meaning for researcher and respondent alike (Aikenhead & Ryan 1992: 478). The method used to develop the VOCP instrument was therefore designed to ensure as much as possible that the English language in the VOCP instrument is understandable to target students, namely Gauteng grade 10 to 12 Physical Science students.

The qualitative method was informed by the method used to develop the groundbreaking Views on Science, Technology, Society (VOSTS) instrument (Aikenhead & Ryan 1992: 477-491). In the method used to develop the VOSTS instrument, particular attention was paid to minimising the ambiguity of the items by using students' words and phrases to empirically develop the multiple-choice items (Aikenhead & Ryan 1992: 478-479). The VOSTS instrument consequently has earned itself a reputation for offering greater validity than other instruments (Osborne, Simon & Collins: 2003: 1057). In developing the VOCP instrument, the method used to develop the VOSTS instrument was adapted so that, instead of using literature, South African students' views were used to establish the domain of the instrument. This was necessary as science education literature was not specific to the South African science education tradition and did not provide an unequivocal basis for the content domain of the VOCP instrument.

The process of developing and trialling the VOCP instrument used four stages comprising the use of two questionnaires, interviews and trial use of the instrument. A different school was sampled for each stage of data collection. This purposive sampling, based on the English language results of the school, was an important attempt at ensuring that the language of students with poor English results was represented in the instrument, but those students with better English results articulated the meaning of the statements made by the first group of students. A third school was used for interviews to check the meaning, understandability and completeness of the items. Three more schools participated in the trial use of the instrument. All the schools were in the Tshwane South district of Gauteng province, South Africa. All the students were grade 10 to 12 Physical Science students.

In the first stage of developing the VOCP instrument, a first questionnaire (questionnaire 1) was used to obtain students' lists of the problems and benefits of chemistry practicals. These responses were categorized. The categories established the domain content of the VOCP

instrument. For each category, a representative statement was chosen. The statements were used in a second questionnaire (questionnaire 2). In the second stage, questionnaire 2 was used to obtain students' explanations of the statements. The responses were categorized, and a representative explanation chosen for each category. The statements were used as Likert items for the summary part of the instrument and as the stem for multiple-choice items in the explanation part of the instrument. The explanations from responses to questionnaire 2 were used as options for the multiple-choice items in the explanation part of the instrument.

In the third stage of developing the instrument, interviews were used as a pre-trial of the items. The interviews were used to check the meaning, understandability and completeness of the items. Drafting the instrument primarily relied on the interview responses, but secondarily drew on the responses from questionnaires 1 and 2, and on literature. The instrument was trialed in three schools. The trial use of the instrument provided data for evaluating the reliability of the instrument for the trial group of students. The trial of the instrument also contributed to projections of how teachers could use the instrument in future. The validity of the instrument was evaluated using data from the trial use of the instrument, the projections for future use of the instrument, literature and the method of developing the instrument.

1.5.1 Definition of the term “practicals”

Given that not all schools in Gauteng have laboratories and equipment, and given trends in science education towards learning through activities which may not use formal laboratory equipment, the definition given by Millar, LeMaréchal and Tiberghien (1999: 36) could be suitable for this research: Practical work is “all those teaching and learning activities in science which involve students at some point in handling or observing the objects or materials they are researching”.

On the other hand, the students participating in the research were unlikely to be thinking of practicals in terms of current trends. The data collection tools such as questionnaires and interviews did not spell out a definition of practical work. Therefore, in the absence of an explicit definition, it was likely that respondents implicitly assumed a traditional definition of practicals, such as “doing experiments or practical exercises with scientific apparatus, usually in a science laboratory” (Woolnough 1991c: 3). This traditional definition was used for this research, and verified in the interview stage of research.

1.6 Results and interpretation of results

Chapter 4 shows in detail how the aim and objectives of the research were achieved and the validity of the VOCP instrument evaluated. In summary, empirically developing a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools saw the following objectives being achieved. The process resulted in the:

- Design and development of an instrument which is both quick to use (summary part of the instrument) and allows the full range of students' views to be expressed (explanatory part of the instrument).
- Development of the instrument as a questionnaire (instrument).
- Use of an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument (procedures and sampling results).
- Use of Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument (results of using questionnaire 1, questionnaire 2 and the interviews).
- Evaluation of the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature (face validity).
- Use of the instrument in schools in Gauteng (trial use of the instrument).

The evaluation of the validity was framed by examining the potential of the instrument to express students' views about the benefits and problems of chemistry practicals, and by the potential use by teachers. The instrument was found to be valid for both these aspects for the trial group of Gauteng students. The validity of the instrument was also evaluated by comparing the views expressed in the VOCP instrument with the views in literature. The instrument was found to have face validity in this aspect and the method used to establish the content domain of the instrument was vindicated. The instrument was found to have process validity because of the method used to develop the instrument.

1.7 Significance of the research

The research reported in this dissertation is important for two reasons.

Firstly, the empirical development of the VOCP instrument using students' views as the content domain, and using students to check the completeness of the items, created a record of a range of students' views about chemistry practicals held by grades 10 to 12 Physical Science students

in Gauteng (Tshwane South) from 2002 to 2003. Most of these views have appeared in science education literature at some stage or another and in some context or another, but the combination and chemistry specificity is a unique result of the empirical development of the VOCP instrument.

Secondly, the research is significant because it has produced a valid instrument which can be used by teachers to improve their planning and running of chemistry practicals. The most important factor at work when a teacher is planning specific activities or modifying and implementing the plans in the classroom seems to be the teacher's expectations of students and their abilities, interests and beliefs. (Smith & Lovat 1995: 133; 140-141). As these pivotal teacher expectations of students "are not necessarily accurate" (Smith & Lovat 1995: 140), there is a real need for a tool such as the VOCP instrument with which the teacher can gather accurate information about her (his) students.

1.8 Summary of the following chapters

The literature review in chapter two provides support from literature about aspects of the development of the VOCP instrument. Chapter three shows that the research method is influenced by the South African language situation and consequently by Aikenhead and Ryan's (1992: 478) methodological response to the validity problem of ambiguous items. Chapter four presents the results of the four stages of developing the VOCP instrument and of evaluating the reliability and validity of the instrument. The final chapter reviews the research presented in this dissertation and draws the conclusion that the research is significant, in that the VOCP instrument provides both a current record of students' views of chemistry practicals and a tool for teachers to use to improve chemistry practicals in South Africa (Gauteng, Tshwane South).

Chapter one has provided a broad outline of the research. The following chapters add detail to the outline, starting with a literature review in chapter 2.

Chapter 2 Review of literature related to South African students' views on the benefits and problems of chemistry practicals

The development of the VOCP instrument focuses on views on chemistry practicals, so the literature review begins with a discussion of the nature of chemistry. Chemistry is seen as distinct from other scientific disciplines. The importance of science practicals is then reviewed, showing practical work as the *sine qua non* of science. Science practicals are also important as a unique school experience and for their role in improving attitudes to science. The importance of science practicals for students and for curriculum developers and implementers is considered. Given the importance of science practicals, the development of the VOCP instrument is seen as a contribution to teachers realising the potential of chemistry practicals in South Africa.

The state of science practicals in South African secondary schools is then reviewed, with attention paid to teachers' perception that science practicals lead to understanding, to problems associated with science practicals, to the continuous assessment for the Senior Certificate, and to the South African situation of practicals forming part of a science class and chemistry forming part of the school subject called Physical Science.

The development of the VOCP instrument focuses on views of the benefits and problems of chemistry practicals, so the review considers the benefits and the problems of science practicals, as depicted by the science education literature. The discussion turns to the predominance in literature of opinion, and not research-based evidence, about the benefits and problems of science practicals. Reasons for the science education research being equivocal are outlined.

The review turns to important aspects about students' views on science practicals. The significance of students' views in learning is followed by an argument that teachers' and students' views differ. Attention is drawn to the fact that there is a wide range of student views about chemistry practicals. Finally, students' views are shown to be useful to a teacher wanting to improve her (his) teaching. Action research is described as a method for teachers to accomplish this.

Existing instruments commonly used in science education research are described and found to be insufficient for measuring students' views about the benefits and problems of chemistry practicals. Therefore, this literature review chapter ends with a rationale for the development of a two-part instrument, designed for use by teachers.

2.1 The nature of chemistry

Chemistry is the study of matter and the transformations of matter (for example, Suchocki 2001: 2). Chemistry is one of the sciences, but is distinct from other sciences such as physics and biology. As one of the sciences, chemistry seeks explanations of the natural world (Cross & Price 2001:161) as do the other sciences. As a distinct scientific discipline, however, the concepts and methods of chemistry are different from other scientific disciplines.

For example, concepts in chemistry include “how matter is put together, how atoms combine to form molecules, and how the molecules combine to make up the many types of matter around us”, whereas biology “involves matter that is alive” and concepts in physics include “motion, forces, energy, matter, heat, sound, light, and the insides of atoms” (Hewitt 2001: 16). Even when disciplines share the same concept, such as energy, the scientists in different disciplines “hold different ways of viewing phenomena which affect their decisions about how to operate on them” (Herron 1971: 174). For example, “the physicist who is working with high-energy particles and the biologist who is concerned with the flow of energy into and out of an ecological system are interested in vastly different kinds of phenomena” (Herron 1971: 174).

The methods and techniques of the different scientific disciplines also differ. What a Chemist does is different from what a biologist or physicist does. “Chemists make molecules ... they study the properties of these molecules; they analyze ..., they form theories as to why molecules are stable, why they have the shapes or colours that they do; they study mechanisms, trying to find out how molecules react. But at the heart of their science is the molecule that is made, either by a natural process or by a human being” (Hoffmann in Kozma, Chin, Russell & Marx 2000: 117). Students performing a chemistry practical similarly follow these methods and techniques. “In a chemistry laboratory the students 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; but nevertheless they constitute the conceptual basis for understanding what is happening” (Friedler & Tamir 1990: 347).

The disciplinary differences in methods and techniques are also seen in science practicals (Friedler & Tamir 1990: 347). For example, during a chemistry practical students may investigate what is formed when an acid reacts with a base, whereas a biology practical may involve a dissection of what used to be a living organism and during a physics practical students may investigate the motion of an accelerating object. Herron (1971: 174-175) has argued that

“descriptions of biological enquiry in high school biology classes, if they are to be most useful, should differ from their counterparts in chemistry or physics classes”.

So the scientific disciplines, and the science school subjects (Klopfer 1990: 98-99), differ in what is known, e.g. the concepts, and in how the knowledge is achieved, e.g. the methods and techniques (Pickering 1984: 863). Despite the differences, the scientific disciplines are similar in that they all seek knowledge to explain the natural world. Much of science education literature does not focus on disciplinary differences, so both science education and chemistry education literature have been used in this dissertation. Nevertheless, the issue of chemistry as a distinct discipline persists, both because the VOCP instrument describes views on chemistry practicals in particular, and in the review of available instruments. This review shows that students perceive chemistry as different from other school science subjects.

2.2 The importance of science practicals

2.2.1 Practical work as the *sine qua non* of science

Practical work can be seen as a *sine qua non* of science (for example, Hegarty-Hazel 1990d: 16; Pickering 1984: 863) in that practical work is an integral part of science. Without practical work, science would not be what it is. If the science curriculum is meant to mimic science or to give insight into the nature of science, then science practicals are important in school science. This proviso is sometimes dispensed with, turning science practicals into a *sine qua non* of science education. For example, Layton (1990: 55) wrote, “science education without some laboratory experience is unthinkable”.

2.2.2 Science practicals as unique in school experiences

Students’ experiences during science practicals are unique from other experiences in school (Friedler & Tamir 1990: 338; Novak 1990: 66; Van Praagh 1983: 635; White 1996: 761). Science practicals are important because, by being different, they allow teachers to overcome students’ resistance to new ways of learning. For example, science practicals were used to overcome students’ resistance to the hard work of learning metacognitive strategies and thus helped students develop more meaningful learning strategies (Novak 1990: 66).

2.2.3 Science practicals improving attitudes to science

Positive attitudes to science are seen as important for recruiting students to science (Osborne *et al.* 2003: 1049). There are indications that students performing science practicals develop a positive attitude to science (Friedler & Tamir 1990: 339; Gardner & Gauld 1990: 132;

Kimbrough 1995: 172; Soyibo 2002: 33). Therefore, school science practicals could play an important part in ensuring the continued supply of students choosing science careers. Although secondary science teachers and scientists themselves do not necessarily emphasise this aspect of science practicals (Gardner & Gauld 1990: 134-135), there has recently been a call for further research on students' attitudes to science in order to understand the problem of declining numbers of science students (Osborne *et al.* 2003: 1049).

2.2.4 Importance of science practicals for students

School science practicals are important for those students who do pursue careers in science as practicals provide some grounding in practical work. Chemistry practicals in secondary schools were seen to give students insight into the processes of observing, hypothesizing and experimenting, and into the scientific methods leading to the accumulation of chemical knowledge (Gardner & Gauld 1990: 134). School science practicals not only give students an indication of what to expect of science (as discussed above, practical work is a *sine qua non* of science), but also allow students to develop technical skills and manual dexterity needed in the laboratory (Hegarty-Hazel 1990a: 78).

For all students, whether they pursue science careers or not, science practicals are important for developing their scientific literacy. For example, practicals could teach students to use the processes of science to solve problems and make decisions, and could develop students' manipulative skills associated with science and technology (Fensham 1990: 293-294). Another aspect of scientific literacy is having a scientific attitude. Science practicals are again important as practicals do foster scientific attitudes, including habits of mind such as open-mindedness and critical judgement (Gardner & Gauld 1990: 132-133; Friedler & Tamir 1990: 338).

A series of case studies carried out in industry, in community action groups and in personal decision making (Duggan & Gott 2002: 661) showed that "procedural understanding was essential in the higher levels of industry and in interacting with everyday issues, while conceptual understanding was so specific that it was acquired in a need-to-know way". These findings confirmed the importance of science practicals (procedural understanding).

For South African Physical Science students, science practicals are also important because the continuous assessment (CASS) of the practicals contributes to the final senior certificate (Gauteng 2002: 8).

2.2.5 Importance of science practicals as seen by curriculum developers and implementers

Science practicals are seen as important because of positive outcomes of practicals in the cognitive and skills and affective domains (Wellington 1998b: 7-8). For example, cognitive outcomes include improved understanding; skills outcomes in the psychomotor domain include improved manipulative skills; and affective outcomes include positive attitudes to science and increased scientific attitudes (Gardner & Gauld 1990: 133).

Science practicals are particularly important for making science accessible to all students. Fensham (1990: 309) has argued that using science practicals as a vehicle and context for science learning may be the only way to ensure that science education is truly inclusive. Practical work not only offers teachers an opportunity to identify and remediate students' misconceptions, but also offers students concrete experiences to help students comprehend the complex and abstract concepts of science (Friedler & Tamir 1990: 338).

2.2.6 Realising the potential of science practicals

As shown above, science practicals are important in a number of ways. The potential of science practicals can be realized “when curricula and teaching practices are thought through” (Reid & Westbury: 1990: xvi). An underlying assumption of the development of the VOCP instrument is that knowledge of their students' views about chemistry practicals will assist teachers in planning practicals which they have “thought through”, and will thus contribute to realising the potential of chemistry practicals.

2.3 Science practicals in South African secondary schools

2.3.1 Science practicals lead to understanding

Chapter 1 of this dissertation showed that South African teachers talking about practicals tend to see science practicals as leading to understanding. The idea is expressed well in a research monograph from the University of Bophuthatswana as follows.

Practical work if taught effectively contributes to learning by encouraging the growth of knowledge and understanding, regardless of whether or not it is taken to the extreme of discovery learning. Without some tangible verification of the theoretical parts of science courses students are likely to misunderstand many crucial concepts (Humphrey & Taole 1986: np).

This idea that science practicals lead to understanding is not unique to South African teachers. For example, the definition of practical work for the book edited by Hegarty-Hazel (1990d: 4)

included the phrase “to observe and understand phenomena”. Australian undergraduate students have highly rated what they perceive as the links between theoretical work and practicals (Boud, Dunn, Kennedy & Thorley 1980: 415). On the other hand, this perception may be mistaken because during practical work students are engrossed with practical operations to the exclusion of theoretical considerations (Pickering 1987: 521).

For some South African students, reaching understanding of science may be hindered by cultural factors. Lemke (in Osborne *et al.* 2003: 1073) argued that “contemporary science is a product of European cultures, and a middle-class culture at that. For those who lie outside the orbit of such cultures by virtue of their ethnic origin or social status, the nature of what counts as knowledge and what counts as explanation may be startlingly different”. Jegede (1998: 157) explained that the culture of school science is foreign to the African world-view. Since a world-view is the antecedent to cognition, the African world-view “must significantly impact on how both science as school knowledge and science as Western culture are viewed by the African learner” (Jegede 1998: 157). The implication for school science practicals is that obvious causality from the point of view of Western science may conflict with African world-view of causality, and may for example affect what is understood from verification practicals.

So although South African teachers associate practicals with improved understanding, achieving this understanding cannot be taken for granted. The VOCP instrument, which asks students about their views, is intended to be a tool which is useful to teachers addressing this issue.

2.3.2 Science practicals are associated with problems

Chapter 1 of this dissertation showed that South African teachers talking about practicals tend to identify problems associated with running practicals. This is supported by evidence suggesting that some South African teachers are generally not familiar with planning and running practicals for their students (Muwanga-Zake 2002: 3), so problems are to be expected. A possible reason for teachers being unfamiliar with running practicals is that historically in South African colleges of education, “poor lecturers with poor resources and poor students used traditional, teacher-centred methodologies to provide the main corps of teachers for the school system” (Bradley 2000: 2).

Purposive sampling for an anthropological study in South African schools provided insight into the variation of science practical work in 1994 (Lynch 1994a: i) and the following problems surfaced for schools in the Gauteng area (Lynch 1994a: 46-65). The teachers needed training in how to do secondary school practicals and in pedagogical issues, especially for dealing with

overcrowded laboratories, large classes of 50 to 60 plus, and limited equipment. The furniture, equipment and storeroom facilities of the laboratories had degenerated, so the existing laboratories needed refurbishing, restocking and extra security. There was also a need for someone to take responsibility for maintenance and repair in the laboratories. There was enough basic equipment to do some demonstrations but there was not enough basic equipment for students to do group work. The existing laboratories were insufficient for the number of students, especially as some laboratories were not functional due to vandalism or being used as offices or classrooms. Practical work seemed to have been abandoned and blackboard experiments were used to simulate the practical procedures and processes.

General problems affecting schools in the Gauteng area (Lynch 1994a: 46-65), which would also have affected the running of science practicals, included the following. The students spoke different home languages, with up to six African languages offered at the school. Nearby hostels for migrant workers were associated with political conflict causing tensions in the schools. Nearby squatter camps were associated with social problems including graffiti (aggressive, sexual and political), and vandalism and theft, particularly in the school laboratories. Gangs were active in the school. Up to half the students were homeless. Teachers drank alcohol with students and made love to students. Schools were overcrowded and were expected to accept up to 50% more students than the school was designed to accept.

The problems described for 1994 could well be the problems which still beset the schools as indicated by the following regarding crime, insufficient laboratories and overcrowding. Observation by the researcher of a school in Atteridgeville during 2002 showed that vandalism was occurring, that the school was needing to use laboratory facilities as offices and classrooms, and that teachers felt the need for training in running practicals for large classes. In Gauteng in 1999, 55.6% of schools reported criminal incidents such as burglaries, assaults, stabbings, rapes and other serious crimes (Department of Education 2001: 77). In Gauteng in 2000, 83.2% of schools had at least one Physical Science laboratory (Department of Education 2001: 38), but 5.4% of classrooms were used for purposes other than teaching and learning, such as offices, (Department of Education 2001: 27) and 26% of schools needed additional classrooms (Department of Education 2001: 35). The average Gauteng student to teacher ratio increased from 30 in 1996 to 32 in 2000 (Department of Education 2001: 27).

This last statistic shows a discrepancy with the 50 to 60 plus class sizes reported for the Gauteng area in 1994 (Lynch 1994a: 46-65). The Department of Education statistic was for the whole of

Gauteng so schools with a large proportion of governing body-appointed teachers may have decreased the student to teacher ratio, compared with the 1994 township schools in Lynch's study. Either way, there are problems associated with trying to do practicals with large classes. According to teachers in Nigeria (Onwu 1998: 125-126) teaching large classes makes it difficult to do practical work and to do practical work frequently, and there is minimal class control and supervision.

In the above review, findings for the Gauteng province were chosen out of findings for the whole country because the Pretoria (Tshwane South) area used in developing the VOCP instrument falls in this area and because the provinces differed in profiles. Nevertheless, there are other problems associated with science practicals which are likely to be common to teachers throughout South Africa. A study of the context and practice of science teaching in secondary schools in KwaZulu-Natal (Jita 1998: 46-47) showed that most teachers teach grades 8 to 12, so teachers at some stage would find themselves teaching the general education and training (GET) outcomes based curriculum as well as the further education and training (FET) traditional curriculum. As the teachers rely on syllabus documents, textbooks and their own experience when planning instruction (such as a chemistry practical), the teachers need material resources, and training to widen their experience, to help them change from traditional to outcomes based instruction.

In conclusion, a number of problems beset secondary schools in South Africa, so teachers' association of problems with science practicals is substantiated. The VOCP instrument is a tool which teachers can use to discover what problems their own students perceive, and thus address the problems in an informed manner, to improve chemistry practicals in their schools.

2.3.3 Continuous assessment

Recent changes in South African education policy have introduced school based continuous assessment (CASS) as a component of the Senior Certificate. For the time being, 25% of the Senior Certificate is CASS, with the examination forming the rest of the result. For Gauteng province half of the CASS mark comprises the mark for portfolio practicals (Gauteng 2002: 8).

The change in education policy means that Grade 12 Physical Science students in Gauteng province are required to perform chemistry portfolio practicals for their Senior Certificate. The other grades at senior school are also affected. Practical work should be performed by students on a continuous basis from Grade 8 so that students have opportunities to develop the

knowledge and skills they need to perform the portfolio practicals when they are in grade 12 (Gauteng 2002: 6).

The training the province provides for teachers to become au fait with the new system is important, but experience throughout Africa has shown that “too often teacher development programmes involve ‘topping up’ teachers with content, and when this proves unsatisfactory, even more is provided” (Fabiano 1998: 143). The rationale of the development of the VOCP instrument is that alongside the training provided by Gauteng education department, teachers will have a tool to use in action research so they actively can take part in improving the way they run practicals.

2.3.4 Practical as part of the science classes

In South Africa, practicals are part of the science course. Schools do not form a separate practical class doing a free-standing practical course. The science class does practicals as part of the complete set of course activities. According to South African secondary school teachers surveyed by the researcher in 2002 and 2003, the science textbook guides the teacher as to which practicals to conduct and provides the procedures for a particular practical, so in effect the practicals are part of, not separate from, the theoretical component of the course. The implication for the development of the VOCP instrument is that the Science Laboratory Environment Inventory cannot be used in South African schools as the use of this instrument is restricted to separate practical courses (Fraser *et al.* 1992: 2).

There are also implications for the learning of science in general. Johnstone and Letton (1989: 192) have made a strong case for science practicals to be a free standing course independent of the theoretical teaching. On the other hand, McRobbie and Fraser (1993: 84) found that cognitive and attitudinal outcomes of chemistry students were enhanced when the practical courses were integrated with non-practical courses. So the South African practice may compromise the science practical component of the science course, but may enhance the cognitive learning and improve the attitudes of the school students doing science.

2.3.5 Chemistry as part of Physical Science

The subject Physical Science in South Africa comprises physics and chemistry. Therefore Physical Science students had to be used in sampling chemistry students in South Africa. Section 2.1 above showed that chemistry is a separate discipline of science. Therefore the development of the VOCP instrument focused on chemistry only and did not adjust to the South African school subject of Physical Science comprising chemistry and physics.

2.4 The benefits of science practicals

The assumed benefits of science practicals are found in the purposes, outcomes, goals and aims expressed for practical curricula. The three main purposes of practicals are to allow students to learn science, to learn about science and to learn to do science (Hodson 1996: 756).

Layton (1990: 55) summed up possible learning outcomes of science practicals as “a familiarity with materials and natural events, the enhancement of motivation to learn, the acquisition of laboratory skills, understanding of the scientific processes by which scientific knowledge has been acquired, or understanding of an important scientific idea”.

Additional goals for practicals, suggested by Hegarty-Hazel (1990d: 15) after reviewing comparative learning studies, include designing and executing experiments; generating, analysing and interpreting data; developing resourcefulness and creativity; introducing a new discipline; providing for individual differences; providing concrete learning experiences; and fostering an attitude of success, motivation and control in science.

These outcomes and goals for science practicals combine practical benefits (e.g. acquiring laboratory skills) with science education benefits (e.g. understanding an important scientific idea) and general education benefits (e.g. developing resourcefulness and creativity). By contrast, the exclusively practical aims favoured by practicing scientists and graduate students are “the acquisition of practical skills, equipment familiarity, observational skills, interpretation of data and a critical approach to experimentation” (Boud *et al.* 1980: 415). There are also purposes linked specifically to the school science system, such as fitting the requirements of practical examination regulations and verifying facts and principles already taught (Kerr 1963: 21). Although the latter were identified in the 1960’s, they are still a part of science practicals today, as shown by the CASS portfolio practicals and school textbook practicals.

2.5 The problems of science practicals

The benefits of practicals have been discussed above in terms of the planned outcomes, the goals and the aims of practicals. One of the biggest problems with practicals is that practicals are not efficient in achieving these planned benefits (Tobin 1990: 403). So, for example, there is a lack of discovery, a lack of learning and a lack of thinking by students (Johnstone & Letton 1989: 190). Teachers face the problem of being expected to use practicals to achieve a multitude of benefits, and achieve them simultaneously (White 1996: 762; Jenkins 1999: 27). Other problems which have been discovered in science practicals relate to students, in that students do not

understand fundamental concepts, students' knowledge is deficient, students make misleading associations, students are not able to link theoretical knowledge to observed phenomena, and students cannot distinguish between the relevant and the irrelevant in the practical (Friedler & Tamir 1990: 346). The practical problems experienced by South African teachers have been detailed in section 2.3 above.

2.6 Opinions and research-based evidence about science practicals

An issue that surfaced when reviewing literature about science practicals is that claims are largely unsubstantiated although commonly believed. The trend in literature is that authors acknowledge commonly accepted beliefs about the benefits of practical work, point out the problems in achieving these benefits and bemoan the paucity of research-based evidence for and against practical work in science education. The following paragraphs illustrate this trend.

Reviews of literature, and reviews of literature reviews, make frequent mention of the common belief that school science practicals are beneficial in various ways. For example, Nakhleh, Polles and Malina wrote (2003: 72), "to this day, the laboratory experience has been almost universally regarded as desirable, if not essential". Their review of literature included Thomas (1972), who "referred to laboratory work as a fundamental belief" and Blossner (1980, 1983) who "reported that the science education community had a strong belief in the inherent value of laboratory work." (Nakhleh *et al.* 2003: 72).

Other writers have also noted this belief. For example, "there is a clear commitment by science teachers to the value of practical as a central part of a scientific education" (Woolnough and Allsop 1985: 2). More recently, Jenkins (2000: 212) wrote, "practical work conducted in a laboratory remains an important feature of current attempts to improve science teaching", thus implying that practicals are still seen as a way of improving science education.

On the other hand, Watson (2000: 57) acknowledged the common belief about the benefit of science practicals, but he queried the reasons for these beliefs with, "many scientists and science educators are convinced that practical work must play an important role in learning science, but the reasons for its prominence are less clear." Similarly, the authors quoted above also questioned the rosy picture of school science practicals.

Nakhleh *et al.* (2003: 74) went back to a 1978 review of science practicals and noted that Bates' comments were positive but Bates is best remembered for concluding with the question, "what

does the laboratory accomplish that could not be accomplished as well by less expensive and less time-consuming alternatives?" (Bates in Nakhleh *et al.* 2003: 74).

Referring to Woolnough and Allsop (1985) and to Hodson (1996), Leach and Paulsen (1999: 7) claimed that, "much literature coming out of countries with a strong tradition of school science practical work concentrates on questioning the limitations of practical work as a vehicle for a number of ambitious aims". Jenkins (2000: 212) added his voice with, "there is no shortage of criticism of the role that the science teaching laboratory has come to play in school science teaching".

So there are discrepancies in reviews of literature and of literature reviews: practicals are seen as both beneficial and problematic. At times this duality has been seen as "either/or". For example, using numerous sources, Nakhleh *et al.* (2003: 77-78) have identified a spectrum of reasoning about school practicals. At one extreme, the problems of science practicals have prompted arguments for the elimination of science practicals. At the other extreme, the belief that practicals are beneficial persists. The onus is therefore on science education practitioners to find a way to unlock the benefits.

The development of the VOCP instrument falls into this end of the spectrum as the researcher intends that the instrument be made available for teachers to improve their chemistry practicals. However, an either/or approach of practicals either being beneficial or practicals being problematic is not supported. Suffice to note that both benefits and problems exist and to develop an instrument that encourages respondents to express views of both benefits and problems. Both are potentially useful to teachers and, as described in chapter 1, the formulation of the research problem had its origin in teachers pairing a benefit with a problem of science practicals.

As illustrated above using a small section of the voluminous literature about science practicals, the trend is that, both in opinion and in research reports, there is no consensus about the benefits and problems of science practicals. Jenkins (1999: 21) also drew attention to the lack of research-based evidence about science practicals with, "conclusions tend to be asserted, not arrived at". The review by Nakhleh *et al.* (2003: 76) made this point for particular aspects of science practicals, such as learning during science practicals, with "the research focus on learning in the teaching laboratory has continued, and that research is still characterised by mixed results and lack of general agreement on outcomes".

2.6.1 Reasons for equivocal research

There are a number of reasons why science education research has not produced unequivocal research based evidence about science practicals. Science practicals are complex and therefore difficult to research (Lazarowitz & Tamir 1994: 94-95; McComas 1997: 15). For example, there have been conflicting results from replicated studies (Jenkins 1999: 28).

Teaching methods cannot always be classified as purely science practicals (Boud, Dunn and Kennedy 1980: 456). The definition of practical work varies (Garrett & Roberts 1982: 109) and the definition is sometimes too specific and other times too loose (Hegarty-Hazel 1990d: 4). The definitional problem is compounded by different instructional concepts of practical work (Hodson 1996: 756). For example, a teacher or researcher may see practical work as a complex instructional strategy, or a tactic or a simple technique (Garrett & Roberts 1982: 110; Hegarty-Hazel 1990d: 4). Accurate distinction between tactics and strategies is important as observable measurable changes are only expected for changes in teaching strategies, not tactics (Garrett & Roberts 1982: 139). Seemingly conflicting research findings may be an artifact of assuming that there is only one method of running science practicals (Jenkins 1999: 28; Watson 2000: 57) and because researchers do not fully describe the practical and the context of the practical (Atkinson 1990: 123-124). Findings are limited by researchers who disregard subjective and anecdotal data because of a preoccupation with quantitative and objective data (Garrett & Roberts 1982: 139).

Assumptions made by researchers may have caused findings to be confusing. For example, a researcher may mistakenly assume that doing a practical ensures the intended learning has occurred (Psillos & Niedderer 2002b: 2) or that a student who performs a practical will definitely remember and refer to the practical when the learning outcomes of the practical are assessed (Atkinson 1990: 124). What is being measured should be clarified (Häussler 1987: 79) and care should be taken to measure relevant variables, such as group effects not individual effects, and to analyze data effectively (Keeves 1998: 1133). More sensitive science education research instruments are needed and researchers should attend to the characteristics of samples more carefully (Garrett & Roberts 1982: 119; Lazarowitz & Tamir 1994: 94-95). The variety of research methods adds to the confusion in science education literature (Jenkins 1999: 28).

Science education researchers generally have not asked research questions which appropriately focus their research (Garrett & Roberts 1982: 110; Tobin 1990: 404). Furthermore, researchers have used different foci to the extent that direct comparisons of findings are often impossible. For example, researchers have focused on issues of gender differentiation, motivation, skills,

cognition and attitudes (Jenkins 1999: 28). For a particular focus, researchers have not comprehensively researched the issue and have thus not obtained sufficient data to confirm or reject opinion-based claims made in literature (Nakhleh *et al.* 2003: 72).

Neglecting to apply the psychology of learning to science practicals has further confounded science education research. Johnstone and Letton (1989: 190) have explained that many of the problems besetting research on science practicals are perfectly understandable if the psychology of learning is applied to the practicals. Nakhleh *et al.* (2003: 89-90) have similarly pointed out that top-down research needs re-examination, and have therefore advocated a research focus on the laboratory as a learning environment and “the students’ perspectives of the laboratory”. The VOCP instrument falls in this area of research.

2.6.2 Implications of equivocal research about the benefits and problems of science practicals

As literature does not present an unequivocal and research-based picture of the benefits and problems of science practicals, the content domain of the VOCP instrument was empirically derived, instead of being derived from literature and then developed empirically.

2.7 The significance of students’ views

Hegarty-Hazel (1990a: 80) described an instructional strategy for the special case of teaching technical skills in science practicals. The first stage was, “teachers should provide for students a satisfying rationale (e.g. in terms of future learning or use in society)”. The development of the VOCP instrument contributes to teachers being able to find out students’ views so that teachers can structure practicals using a rationale that is truly satisfying to their students. In the context of compulsory practicals which contribute to the final senior certificate, the instrument could be seen as an important needs-assessment (Anderson, Herr and Nihlen 1994: 128) used to inform the design and running of the practicals (Hancock & Mansfield 2002: 183-184). Increasingly, knowing students’ views is seen as important in understanding teaching (McCallum, Hargreaves & Gipps 2000: 276).

Much of what students learn in class is not subject matter but “what will please teachers and gain high grades” (Ramsden 1988b: 23). Students have personal agendas and orientations which affect their motivation and persistence in tasks in science education (Lee & Anderson in Dos Santos & Mortimer 2003: 1096). Generally in education, teachers may end up competing with students’ own ideas, interests and intentions so teachers need to find out students’ agendas (Drew 2001: 328) and negotiate the curriculum with their students in order to engage students in

learning what must be learned (Boomer: 1987: 11; Tobin, Tippins & Gallard 1994: 50). Students' views, which form part of an "underground curriculum" (Atwell: 1987: 178), can thus be acknowledged and incorporated into the curriculum, to improve the success of the formal curriculum.

Substantiation for the coupling of students' views with the success of the chemistry curriculum is provided by Zusho, Pintrich and Cuppola (2003: 1081-1092), who found that task value reported by introductory chemistry students is a strong predictor of final course performance for these students. Zusho *et al.* (2003: 1093) concluded that it is "vital for chemistry instructors to focus on task value in their pedagogy and explanations of course materials". In other words, task value or "students' beliefs about the utility and benefits of a course" (Zusho *et al.* 2003: 1083) cannot be ignored when planning a chemistry curriculum.

2.8 Teachers' and students' views differ

As outlined in chapter 1, it is important for teachers to find out their students' views instead of relying on their own views because teachers' views are not necessarily the same as their students' views. Teachers have found that they do not really know what is going on in their students' minds (Goswami & Stillman: 1987: 4). There are two different worlds in one school – the students' world and the adults' world (Anderson *et al.* 1994: 96). Teachers tend to view the classroom environment more favourably than their students (McRobbie & Fraser 1993: 78).

For science practicals, evidence has been obtained from a study of grade 11 biology students and teachers in Australia, that

both students and teachers value laboratory work, but that perhaps they do so for different reasons. Students apparently appreciate the 'hands-on' experience itself. Teachers seem to place less value on this; rather the laboratory work would seem to be regarded as psychomotor means towards more purely cognitive ends (Gardner & Gauld 1990: 138).

Although there may be agreement between the attitudes of teachers and students about chemistry practicals (Okebukola 1986: 531), research has found that students performing science practicals do not perceive the same purpose and outcomes for the practical as the teachers (Watson 2000: 66), and this is one of the reasons students retain their intuitive views (Friedler & Tamir 1990: 348-350).

So it is important for teachers to provide a rationale that is satisfying for students, to assess the needs of the students and to use students' views to improve the formal curriculum, but teachers

cannot assume the teachers' view represents students' views. Although teachers and students may hold the same attitudes about science practicals, teachers still need to find out their students' views, and use these views in planning more effective science practicals.

2.9 Wide range of students' views on science practicals

Students in a single class are by no means identical in their views of what happens in class (Perry 1988: 145-161). Similarly, students in a single class are by no means identical in their views on science practicals (Hegarty-Hazel 1990d: 9-10). Research has shown "that often only able students appear to strongly link the appropriate scientific knowledge with the laboratory experiment". (Hegarty-Hazel 1990d: 18). The varied ability of students could therefore contribute to creating a wide variety of views in a single class, with able students viewing science practicals as helping them understand science but less able students seeing a different benefit in science practicals. Differences in students' personalities also introduce varied views on science practicals. For example, research has shown that science practicals are "more likely to appeal to students who like to think and who are willing to work hard in order to succeed" (Gardner & Gauld 1990: 136). Further variety in students' views on science practicals probably arises from students in the same group experiencing the same practical differently (Atkinson 1990: 124). A single student may hold different views from practical to practical (Hodson 1998: 59). A single student may hold different views about the same practical, such as enjoying practicals but finding certain aspects of the practical unsatisfying (Gardner & Gauld 1990: 139).

In summary, different students hold different views on science practicals, and each student may hold a range of positive and negative views of practicals. The development of an instrument for describing students' views should therefore allow a wide range of views to be expressed by students, and these views should include the benefits and the problems that students perceive. The VOCP instrument has done this.

2.10 Student views used to improve teaching

The rationale for the development of the VOCP instrument is that, knowing students' views on chemistry practicals, the teacher will be able to improve the planning and running of chemistry practicals (Drew 2001: 328). This is an echo of the general idea expressed by Simpson, Koballa, Oliver and Crawley (1994: 211) as follows.

Those who teach science have come to a universal observation: Students' behavior is influenced by the values they hold, the motivation they possess, the beliefs they bring from home to the classroom, and the myriad attitudes they have formulated about school, science and life in general. The key to success

in education often depends on how a student feels toward home, self and school.

Although for much education “the views of students have rarely been solicited to inform educational practice and reform” (Anderson *et al.* 1994: 61), there are specific examples of the use of student views to improve teaching. The literature review by White and Tisher (1986: 881) showed a variety of sometimes conflicting student views about the value of practical work. They pointed out that opinions depend on local conditions so a variety of opinions is to be expected. Furthermore, they suggested the opinions be used “for determining local action”, not as a contribution to theory.

A possible local action could be for teachers to fine-tune a curriculum. For example, there has been a proposal by the Project Synthesis working group that teachers stop expecting all students to attain all scientific enquiry outcomes equally, and instead differentiate outcomes according to “known differences in students’ intellectual ability, predilections and personal goals” (Klopper 1990: 115).

A common local action for improving a curriculum is to gather feedback from students in order to improve specific instructional strategies (Leckey & Neill 2001: 23). Methods for gathering feedback include questionnaires, journals, interviews, debriefings, focus groups and student-staff committees (Kimbrough 1995: 157; Leckey & Neill 2001: 23). Examples of studies relevant to improving chemistry practicals include inquiry into students’ views of small-group learning in chemistry (Towns, Kreke & Fields 2000: 113, 115), of chemistry topics and how the topics are taught (Kennedy 1996: 53), of laboratory work and practicals (Bliss 1990: 383), of project oriented chemistry laboratory work (Knipe 1975: 606), of student preparation for chemistry practicals (Rollnick, Zwane, Staskun, Lotz & Green 2001: 1069 - 1070), and of qualitative analysis chemistry practicals (Tan, Goh, Chia & Treagust 2001: 232-233). None of these studies asked for students’ views of the benefits and problems of chemistry practicals.

The above examples are laudable in that students’ views were solicited and could be used directly for improving instruction. The researchers in question have been sensitive to students “who are relatively powerless organizational members” but are “experts” about their own experiences and needs’ (Anderson *et al.* 1994: 43). Students’ views have been used to involve students in improving their learning (Anderson *et al.* 1994: 47), but the focus of the development of the VOCP instrument was to provide teachers with an instrument to improve teaching.

Despite the “comfortable assumption” (Goswami & Stillman 1987: 68) that improvements merely require students to change (Boud 1973: 82; Van den Akker 1998: 433), it is also necessary for teachers themselves to change (Goswami & Stillman: 1987: 68; Johnstone & Letton 1989: 192; Van den Akker 1998: 442). The role of students is to inform teachers about students’ views, so teachers can take action to improve the courses (Boud *et al.* 1980: 415).

For improving chemistry practicals based on knowledge of students’ views of the benefits and problems of chemistry practicals, teachers can seek to increase the consonance elements (i.e. the benefits) and decrease the dissonance elements (i.e. the problems) (Simpson *et al.* 1994: 220). Alternatively, the teacher may be working with the goals of the students. Goals in this context are what students would like to happen (i.e. the benefits) and what students would avoid (i.e. the problems) (Schutz & DeCuir 2002: 127). The importance of teachers working with students’ goals lies in the influence of an individual’s goals on thinking, interpreting, remembering, behaving and feeling shame, anxiety, hope or pride (Schutz & DeCuir 2002: 127).

Critics may shortsightedly claim that taking account of students’ views compromises education, but this claim is not valid (Alsop & Watts 2003: 1046). The point that students’ views can be used to improve teaching is logically argued by Winitzky and Kauchak (1997: 77) as follows.

The crux of successful teaching is its impact on students, so students should represent the most powerful feedback source for [teachers] from which they can refine their productions of teaching.

Winitzky and Kauchak (1997: 77) went on to substantiate their argument with an example from constructivist teacher education. “Morine –Dershimer and her colleagues ... have found that candidates who think about their students are better teachers. Morine –Dershimer has also developed strategies for encouraging candidates to attend more to their students.”

Using the VOCP questionnaire about how students view chemistry practicals is also a strategy for teachers to attend to their students and consequently refine and improve their teaching.

2.10.1 Action research to improve practice

Using a questionnaire to systematically gather data for improving teaching is one way for teachers to perform action research. Action research is a process of change entered into by a practitioner, such as a teacher, who wants to improve and understand her (his) practice (Smith & Lovat 1995: 221). The importance of action research is that, compared with the usual academic

channels of research and dissemination or implementation of findings, relatively immediate action is possible for improving teaching practice (Feldman & Minstrell 2000: 429). Situating the VOCP instrument as a tool for teachers' action research creates the expectation of action by the teacher to improve chemistry practicals based on the use of the questionnaire (Feldman & Minstrell 2000: 431-432; Leckey & Neill 2001: 25-29; Tobin 1990: 412). This naturalistic approach is more likely to bring about change in practice than dissemination of external research results and information (Anderson *et al.* 1994: 34-35; Confrey & Lachance 2000: 262-263; Van den Akker 1998: 443). As research linked to action for changing educational practice, the validity of teachers using the VOCP instrument can be judged according to the following validity criteria (Anderson *et al.* 1994: 30-33):

1. Democratic validity, e.g. students are seen as insiders in the research
2. Outcome validity, e.g. successfully completing an action research spiral of problem solving
3. Process validity, e.g. using a variety of research methods to guard against acquiring a simplistic view of events
4. Catalytic validity, e.g. deeper understanding provided by the research prompts the practitioner to change practice

The benefits will be immediate for those involved in a successful action research cycle. That is, the students who fill in the questionnaire are the students who will benefit from the research (Leckey & Neill 2001: 28). For the teacher engaged in action research, the VOCP instrument will also perform the important roles of adding to the teacher's knowledge base in a way which is needed for the teacher to improve the planning and running of chemistry practicals (Keeves 1998: 1140), of allowing the teacher to see the changes taking place, indicating success in a spiral of action research (Goswami & Stillman: 1987: 4), and of providing an opportunity for personal growth and empowerment through examination of her (his) own practice (Bell 1998: 685; Feldman & Minstrell 2000: 434; Osborne & Monk 2000: 3).

2.11 Existing instruments for describing students' views of the benefits and problems of chemistry practicals

In this section the description and analysis of commonly used science education instruments show that these existing instruments are useful research tools but are not suitable for describing students' views of the benefits and problems of chemistry practicals.

2.11.1 Learning environments

In discussing the paucity of contemporary science education research into affect, Alsop and Watts (2003: 1044) explained that one of the reasons might be the “archetypal image of science itself”. Emotions and values are not seen as important as reason, truth and objectivity. Science education itself has traditionally emphasised the cognitive domain of education (Alsop & Watts 2003: 1044). White (1996: 767) also noted that there are many more studies about the effect of practicals on achievement than on attitude and motivation, and suggested the reason may be that researchers see achievement as all-important. Nevertheless, there has been some research into students’ perceptions of science learning environments.

Anderson (in Hofstein, Gluzman, Ben-Zvi & Samuel 1980: 548) defined learning environment as “the interpersonal relationship among pupils, relationships between pupils and their teachers, relationships between pupils and both the subject matter studied and the method of learning and, finally, pupils’ perception of the structure characteristics of the class”. One aspect from this definition may be seen as relevant to the development of the VOCP instrument, namely the relationship between students and the subject matter and the method of learning. Chemistry practicals are the method of learning and the subject matter itself (see 2.1 above – Chemistry practicals are a *sine qua non* of school chemistry), and a student’s relationship with chemistry practicals is investigated by the VOCP instrument asking what are the student’s views about the benefits and problems of chemistry practicals.

2.11.2 Learning Environment Inventory (LEI)

A Learning Environment Inventory (LEI) was developed and validated for physics learning environments in the 1960’s and 70’s in order to measure the components of the learning environment (Hofstein *et al.* 1980: 548). Two out of fifteen scales in the LEI are possibly relevant to the development of the VOCP instrument as they deal with the relationship between students and the subject matter and the method of learning. One of these scales “demonstrates whether the student considers the subject matter difficult” and the other scale “indicates whether individuals within the class feel no affinity with class activities” (Hofstein *et al.* 1980: 548). The social classroom interactions between individuals in the classroom are prominent in LEI. Therefore, even when the LEI is modified to use the word, “chemistry” (Hofstein *et al.* 1980: 550), the LEI does not deal in detail with a range of the benefits and problems of chemistry practicals, but gives insight into all fifteen components of the chemistry learning environment. The LEI is therefore not perfectly relevant to the development of the VOCP instrument.

Furthermore, there is a value problem when interpreting LEI results as good or bad (Tamir & Caridin 1993: 12).

The LEI has, however, been useful in a number of studies. Comparisons between students' preferred and perceived learning environments have shown that achievement is improved when students' preferred environments are congruent with their perceived environments, and teachers have systematically tried to improve teaching by decreasing the discrepancies between preferred and perceived environments (McRobbie & Fraser 1993: 78-79).

Examples of findings from using the LEI in chemistry education research include the following. Students perceive chemistry learning environments differently from the way they perceive physics and biology learning environments (Lawrenz 1976: 321). Jewish students perceive chemistry learning environments differently from biology learning environments, but Arab students do not (Tamir & Caridin 1993: 12). Instructional methods affect students' perceptions of the chemistry laboratory environment when the instructional methods differ for high school and vocational groups of students (Hofstein *et al.* 1980: 551), and for chemistry and biology students (Hofstein & Lazarowitz 1986: 189). Some of the components of the classroom environment (half the LEI scales) can predict students' attitudes to chemistry (Hofstein, Gluzman, Ben-Zvi & Samuel 1979: 235).

These examples show that the LEI can be used for research into chemistry learning environments, albeit not for describing students' views of the benefits and problems of chemistry practicals. A different inventory, the Science Laboratory Environment Inventory (SLEI), has been used for research into science laboratory learning environments.

2.11.3 Science Laboratory Environment Inventory (SLEI)

Compared with the LEI's 15 scales (Hofstein *et al.* 1980: 549), SLEI has five scales as the SLEI was deliberately designed to have a small number of scales (McRobbie & Fraser 1993: 79). Two of the SLEI scales are not found in LEI as they are specific to the practical side of science education. These are the open-endedness of the practical activities, and the integration of the practical activities with other activities and theory classes (McRobbie & Fraser 1993: 79). Two of the SLEI scales are permutations of LEI scales, namely student cohesiveness (intimacy between students in LEI and help and supportiveness between students in SLEI) and material environment (physical environment in LEI and adequacy of laboratory equipment and materials in SLEI) scales (Hofstein *et al.* 1980: 549; McRobbie & Fraser 1993: 79). The fifth and final SLEI scale is identical to the LEI scale, although SLEI applies to laboratory environment and

LEI applies to classroom environment. This scale is the extent to which behaviour is guided by formal rules (Hofstein *et al.* 1980: 549; McRobbie & Fraser 1993: 79).

All of these SLEI scales do not describe students' views of the benefits and problems of practicals – they describe students' perceptions of the existing or preferred laboratory environments. The value problem when interpreting LEI results as good or bad (Tamir & Caridin 1993: 12) exists for SLEI too. For example, consider the scale of open-endedness of practicals. Open-ended practicals could be interpreted as a benefit or as a problem, depending on the specific circumstances of the students' learning (Johnstone & Letton 1989: 192). So the SLEI is not perfectly matched to the development of the VOCP instrument. Furthermore, the Science Laboratory Environment Inventory cannot be used in South African schools as the use of this instrument is restricted to separate practical courses (Fraser, Giddings & McRobbie 1992: 2), which South African schools do not have.

Nevertheless, the SLEI has been useful in a number of studies. Examples of findings relevant to chemistry practicals include the following. Fisher, Harrison, Henderson and Hofstein (1998: 353) compared Australian students' views on chemistry, physics and biology practicals, and found that SLEI differentiated between the three subject area practicals. Similarly, Hofstein and Cohen (1996: 103) found that SLEI differentiated between Israeli students' views on chemistry and biology practicals. McRobbie and Fraser (1993: 83) found that the cognitive and attitudinal outcomes of a sample of Australian senior high school chemistry students correlated with their perceptions of the laboratory environment, irrespective of student ability and of the unit of analysis being the individual or the class. The SLEI was modified to form the chemistry Laboratory Environment Inventory (CLEI), which was used in a study revealing significant associations between the nature of the chemistry laboratory environment and Singaporean chemistry students' attitudinal outcomes (Wong and Fraser 1996: 91; Wong, Young and Fraser 1997: 449).

2.11.4 Views on Science Technology Society (VOSTS)

The LEI, SLEI and CLEI discussed above were useful for measuring students' attitudes to the psychosocial learning environment, but they were not suitable for describing a wide range of student views.

The prototype of an instrument measuring a range of views was the Views on Science Technology Society (VOSTS) instrument. VOSTS was developed over six years in a large-scale empirical study in Canada (Aikenhead & Ryan 1992: 486). Special methodological attention

was paid to using students' views to develop the items, thus keeping ambiguity as low as possible (Aikenhead & Ryan 1992: 480-486). This method has earned the VOSTS instrument a reputation for being particularly valid (Osborne *et al.* 2003: 1057). The instrument is a 114 statement multiple-choice questionnaire, with between five and 13 choices for each statement (Aikenhead & Ryan 1992: 484). Its sheer size is a consequence of expressing a wide range of student views on Science-Technology-Society (STS) matters.

It is common practice for users of the VOSTS instrument to select and use a portion of multiple-choice statements (and choices) relevant to their study. For example, Zoller, Dunn, Wild and Beckett (in Tobin *et al.* 1994: 63) used six statements from VOSTS to investigate student and teacher STS beliefs, and Mbajjorgu and Iloputaife (2001: 55-58) used ten statements to investigate pre-service science teachers' views of scientists.

Other researchers have used the methods of developing the VOSTS instrument as a foundation for the empirical development of their own instruments. For example, Bennett, Green, Rollnick and White (2001: 1-12) developed an instrument to measure South African (Wits University) undergraduate students' views about studying chemistry. This instrument was then used to develop profiles of undergraduate chemistry students' views about studying chemistry (Rollnick, Green, White, Mumba & Bennett 2001: 13-28). One out of six dimensions (12 items) in the instrument dealt with chemistry practicals (Bennett *et al.* 2001: 9). The 12 items for this dimension were mixed between what may be seen as benefits (e.g. practical work makes chemistry more interesting), problems (e.g. chemistry practicals are challenging) and organisational (e.g. pre-laboratory discussions for chemistry practicals are important) (Rollnick *et al.* 2001: 19). So this instrument is by no means dedicated to describing a wide range of students' views of the benefits and problems of chemistry practicals.

2.11.5 Possible methods for measuring students' views on chemistry practicals

The above description and analysis of commonly used science education instruments show that these existing instruments are useful research tools but are not suitable for describing students' views of the benefits and problems of chemistry practicals. Other methods that have been used in science education attitudinal research, and could possibly be applied to measuring students' views on chemistry practicals, include subject preference studies, attitude scales, interest inventories, subject enrolments and qualitative methodologies (Osborne *et al.* 2003: 1055-1059).

Research methods for investigating science practicals have included interaction analyses (e.g. analyzing teacher and student behaviour), naturalistic descriptions of practicals (e.g. a case study

using observations and interviews), and learning environment inventories (Hegarty-Hazel 1990b: 359-362).

Bearing in mind that the intention is that teachers measure their own students' views of the benefits and problems of chemistry practicals, the most suitable instrument out of all the options offered above is a questionnaire designed specifically for teachers' use. Therefore, the VOCP instrument takes the form of a questionnaire.

2.12 Rationale for a two-part instrument, designed for use by teachers

The significance of this research is seen as the future use of the instrument in schools. As part of an action research cycle, it is important that students' views are obtained effectively and efficiently (Leckey & Neill 2001: 25). Students must be able to express their own views, not just rely on what the teacher thinks is important (Leckey & Neill 2001: 25). For ease and brevity of use, the best option is a summary Likert part in the single-page format of the SLEI instrument. Gillham (2000: 32), however, pointed out the weaknesses of Likert responses. One weakness is that whatever response is chosen, the researcher does not know why that response was chosen. A different format, such as a detailed VOSTS-style multiple-choice part, used in conjunction with the summary part, would offer the teacher more insight into the students' views than using the summary part in isolation. Therefore a two-part instrument, comprising a summary part and an explanatory part, is the most suitable instrument for teachers to use.

2.13 Interpretative summary of chapter 2

The literature reviewed in this chapter has provided support for the development of the VOCP instrument and for aspects of the method in which the instrument was developed.

Chapter one argued that there is a need for an instrument to measure the views of students on chemistry practicals. In chapter 2, it was argued that practicals in chemistry are different from those of other science disciplines and that a separate instrument is required to help teachers plan their teaching. Furthermore it was shown that practical work is important in science education and, as such, that the development of the VOCP instrument is a worthy contribution to teachers realizing the potential of chemistry practicals in South Africa.

As it is, practicals in South African secondary schools are associated with certain benefits and problems. This justifies the emphasis on benefits and problems in the VOCP instrument. In South Africa, science practicals contribute to the continuous assessment for the senior certificate, science practicals form part of a science class and chemistry forms part of the

Physical Science. The development of an instrument measuring the views of Grade 10 to 12 Physical Science students is thus supported.

For various reasons there is a predominance in literature of opinion, and a lack of unequivocal research-based evidence, about the benefits and problems of practicals. Therefore the method of using students' opinions to empirically establish the content domain of the VOCP instrument is supported. Students' views play an important role in the success of teaching, but teachers' and students' views differ, so there is a need for the VOCP instrument to allow teachers to measure students' views on chemistry practicals. As there is a wide range of student views on chemistry practicals the explanatory part of the instrument is necessary to represent as fully as possible all the views on chemistry practicals.

The underlying assumption of developing the VOCP instrument as a tool for teachers to use to improve chemistry practicals is supported by literature showing that students' views can be used by a teacher wanting to improve her (his) teaching. Action research is an example of how teachers could accomplish this improvement. Literature therefore supported the development of the VOCP instrument for improving chemistry practicals in South African (Gauteng) schools, especially because existing instruments commonly used in science education research are insufficient for measuring students' views about the benefits and problems of chemistry practicals. Finally, the rationale was presented for the development of a two-part instrument for measuring students' views about the benefits and problems of chemistry practicals.

Chapter two has thus supported the development of the VOCP instrument in its particular form. Chapter three documents the method in which the instrument was developed and evaluated for validity.

Chapter 3 The research method used to develop and evaluate the Views On Chemistry Practicals instrument

Figure 1 shows in outline that the process of developing the Views on Chemistry Practicals (VOCP) instrument used two questionnaires, interviews and trial use of the instrument. The process is described briefly in the following three paragraphs. A different group of respondents was sampled for each stage of data collection.

Questionnaire 1 asked respondents to list problems and benefits of chemistry practicals. These responses were then used to develop categories of the benefits and the problems of chemistry practicals. For each category, a typical statement was chosen from the responses to questionnaire 1, and used in questionnaire 2. This second questionnaire asked respondents to explain the statements. The explanation responses were used to form subcategories of each category of the benefits and problems of chemistry practicals, and a representative explanation was chosen from the responses to questionnaire 2 for each subcategory.

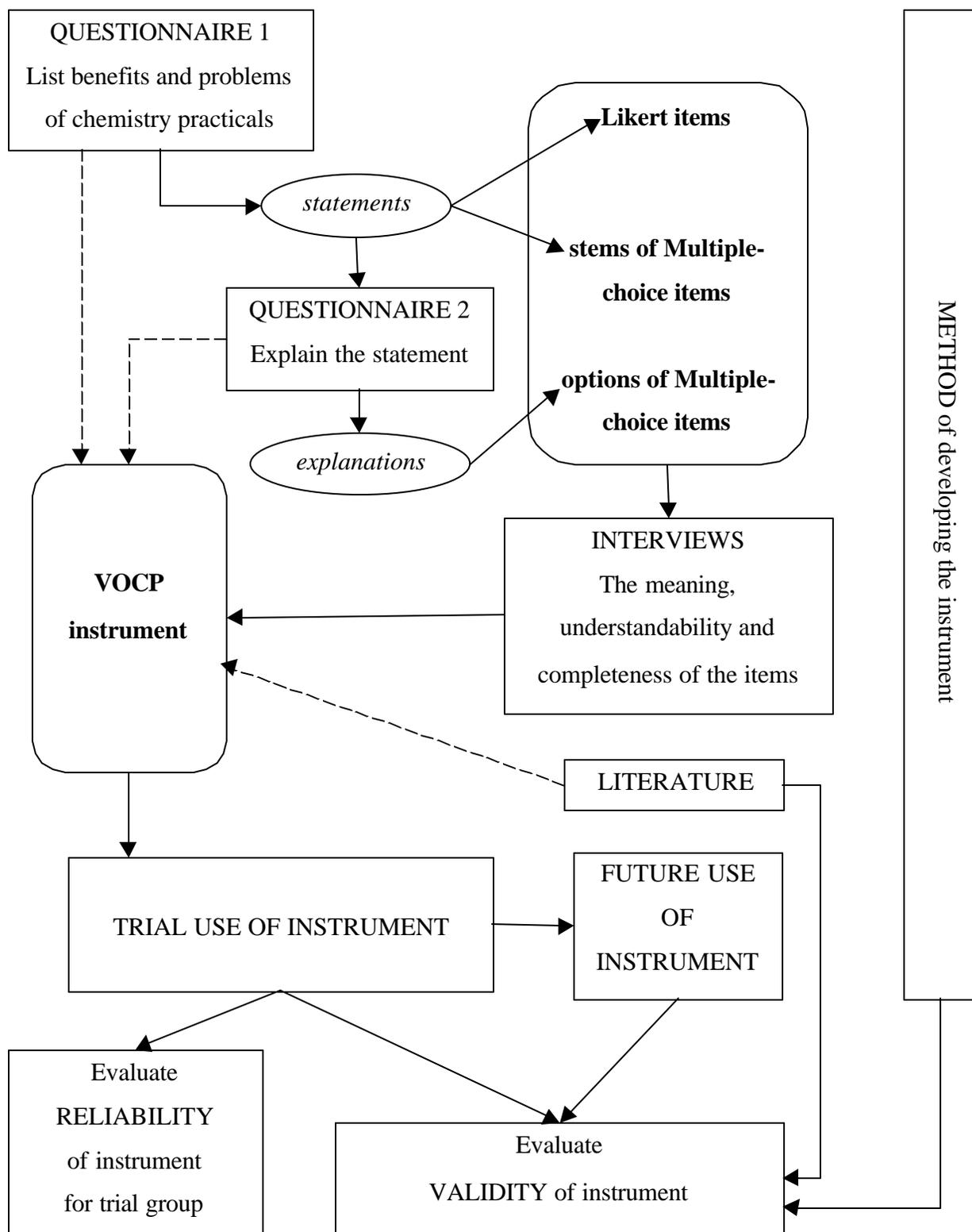
The statements were used as Likert items for the summary part of the instrument and as the stem for multiple-choice items in the explanation part of the instrument. The explanations were used as options for the multiple-choice items in the explanation part of the instrument. Interviews were used as a pre-trial of the items. The interviews were used to check the meaning, understandability and completeness of the items.

Drafting the instrument primarily relied on the interview responses, but secondarily drew on the responses from questionnaires 1 and 2, and on literature. The instrument was trialed in three schools. The trial use of the instrument provided data for evaluating the reliability of the instrument. The trial of the instrument also contributed to projections of how teachers could use the instrument in future. The validity of the instrument was evaluated using data from the trial use of the instrument, the projections for future use of the instrument, literature and the method of developing the instrument.

The rest of chapter 3 deals with research design and methods used. Firstly, the research design section describes where the research fits into the spectrum of education research. Secondly, a rationale is provided for the research design. Thirdly, the sampling procedures are described. Finally, the procedures used in each stage of the research process are described in detail.

Figure 1: Overview of the method used to develop the instrument

The dashed arrows indicate the input is secondary to the input of the solid arrow.



3.1 Research design

The most general meaning of research design is whether the researcher chose the quantitative or qualitative research tradition. The development of the VOCP instrument used both quantitative and qualitative traditions (Tobin & Fraser 1998: 639), with triangulation of data collected by various methods being a key feature of the strength of the research (Arksey & Knight 1999: 21-31).

The development of the VOCP instrument was predominantly qualitative and the research displayed the following characteristics of qualitative research (Creswell 1998: 15-16). There was a focus on participants' perspectives and their meaning. The researcher went to the natural setting to collect data. The data were collected as words, with the researcher a key instrument of data collection in the interview stage of research. The analysis was inductive and paid attention to particulars. The researcher built a complex and holistic picture to address the research problem.

Quantitatively, the development of the VOCP instrument focused on an empirical trial of the instrument. The VOCP instrument was administered to a sample of students and the data analyzed statistically.

The intended use of the instrument is in action research by teachers in their classrooms. This practitioner research is a paradigm of research, which "uses elements of the qualitative and quantitative research paradigms, as well as ways to conduct research in concrete settings and theoretical contexts" (Anderson *et al.* 1994: 107). Other possible uses of the instrument could be as one of the data collection methods in case studies, i.e. in qualitative research, or as an indicator of a variable in an experiment, i.e. in quantitative research design (McRobbie & Fraser 1993: 78).

Essentially the development of the VOCP instrument was the development of an instrument that could in future be used in the research paradigms of action research, qualitative research or quantitative research.

3.2 Rationale for the research design

3.2.1 Demands of the South African situation

As shown in chapter 2, schools in South Africa may offer as many as six languages. The interpretation is that not all students are first language English speakers. Care must therefore be taken with the English language of the instrument to ensure as much as possible that the language is understandable to first and second English language speakers alike. This is ambitious and for logistical reasons has been modified to trying to ensure that the language in the VOCP instrument is understandable to target students, namely Gauteng grade 10 to 12 Physical Science students.

Making the instrument as understandable as possible in South African schools has been conceptualized as a question of instrument validity, with steps taken to ensure that the meaning of questions is the same for the researcher and the respondents. As mentioned in chapter 2, the VOSTS instrument has earned itself a reputation for this issue of validity. The empirical method for developing the VOSTS instrument resulted from an investigation by Aikenhead into the ambiguity of the language used in instruments (Aikenhead & Ryan 1992: 477-491). Ambiguity in this context means that the meaning of the items is not the same for the researcher and the respondents. Aikenhead had found ambiguity levels of:

- 80% for Likert items,
- 35% to 50% for paragraph-response items,
- 5% for semi-structured interviews, and
- 15 to 20% for empirically developed multiple-choice items.

Instruments in the format of semi-structured interviews required too much time for data collection and analysis, so empirical development of a multiple-choice instrument was preferred. Unlike most explanatory tests that yield numerical scores, the VOSTS multiple-choice instrument describes students' ideas.

The VOSTS method used different groups of students in a number of stages of writing and refining the instrument, and retained the students' phrasing as much as possible. The VOSTS method also paid particular attention to using students' input to reduce the ambiguity of items. These aspects of retaining students' phrasing and using students' input to reduce ambiguity were taken as the most feasible way to address the English language aspect of developing the VOCP instrument in Gauteng, South Africa.

3.2.2 The research design of the VOCP instrument informed by methods used to develop existing instruments

Chapter 2 shows that the VOSTS instrument is in common use today and is seen to be particularly valid. The method used to develop the VOSTS instrument therefore serves as a suitable guide to developing a valid instrument.

The empirical development of the VOSTS instrument (Aikenhead & Ryan 1992: 477-491) started with theory from past instruments and recent literature to establish the content domain of the instrument and to write the stem multiple-choice statements. Students wrote paragraphs explaining why they agreed with, disagreed with or could not decide about the statements. The development of the VOCP instrument differed from the VOSTS method by using Questionnaire 1 to establish the content domain of the instrument and thus to write the statements using students' opinions and not opinions from literature. The VOCP method then used Questionnaire 2 to get a group of students to write explanations of the statements. In this way the VOCP method followed the VOSTS method. Both VOSTS and VOCP methods involved three researchers in categorizing students' explanatory views, and retained the students' words and phrases as much as possible in writing the explanatory multiple-choices for each statement stem.

The development of the VOSTS instrument then used a new group of students to probe how well the items captured the views of students, involving a combination of paragraph writing and semi-structured interviews based on the paragraphs. A last group of students expressed their thoughts aloud as they worked through items, allowing the researcher to look for discrepancies between the meaning found by the students and by the researcher (i.e. looking for ambiguity). The development of the VOCP instrument, by contrast, used one interview process to probe how well the items captured the views of students and to look for discrepancies between the meaning found by the students and by the researcher (i.e. looking for ambiguity). In both VOSTS and VOCP methods, responses to the instrument were gathered in order to fine-tune the instrument.

The validity of both the VOSTS and the VOCP instruments is anchored in the process used to develop the instrument. This empirical process for addressing the validity of the instrument is in contrast with the process used to develop other instruments. Chapter 2 shows that the SLEI is in common use today and has been adapted for specific uses such as providing a Chemistry Laboratory Inventory. The SLEI therefore serves as an example of another way in which instruments in common use are developed.

The development of SLEI firstly involved a literature review to identify the important dimensions to include in the questionnaire. This first stage was guided by looking for dimensions of the unique environment of a science laboratory course, of existing classroom environment instruments and of all human environments (McRobbie & Fraser 1993: 79). Sets of items were drafted. Senior secondary school and University science teachers and students commented on these draft versions of the instrument in an attempt to “ensure that the SLEI’s dimensions and individual items were considered salient by teachers and students” (McRobbie & Fraser 1993: 79). So the development of SLEI items was based on a literature review. The role of students was to comment on the relevance of these items, not to provide their opinions as content of the items.

The validity of the SLEI instrument was provided by three steps taken in developing the instrument (Fraser *et al.* 1992: 5). Firstly, the items were successively revised based on reactions of colleagues with expertise in questionnaire construction and science teaching. Secondly, attention was paid to making the items suitable for measuring what they were meant to measure. Finally, a series of item and factor analyses was used to improve a draft questionnaire and finalize the questionnaire. The SLEI therefore lacked the greater validity provided by the VOSTS process of using students’ views in the instrument (Osborne *et al.* 2003: 1057).

On the other hand, the instrument design of SLEI provided the inspiration for the summary part of the VOCP instrument. The SLEI instrument was designed to allow teachers to “obtain a quick and easy assessment of their students’ perceptions of their science laboratory classroom environment” (Fraser *et al.* 1992: 1). Two design features of the SLEI were thus copied in the design of the summary part of the VOCP instrument. Firstly, the five-point Likert scale is easy for hand scoring by the teacher. Secondly, the summary form fits onto a single A4 page, so “printing and collation costs are minimized” (Fraser *et al.* 1992: 5).

3.2.3 The need to adapt existing methods of developing an instrument

Although the instrument design of SLEI has been used for the summary part of the VOCP instrument, the discussion above shows that the process of developing the SLEI was not suitable for the language ambiguity demands of the South African situation. Instead, the VOSTS method for developing an instrument informed the development of the VOCP instrument. The VOSTS method was, however, adapted to suit the South African situation. The VOSTS method used literature to establish the content domain of the instrument, before turning to students to develop the content of the items. The VOCP method, on the other hand, used students’ opinions to establish the content domain of the instrument, and then compared this empirically derived

domain with literature as part of evaluating the validity of the instrument. It was necessary to turn to South African students' opinions from the start for two reasons.

Firstly, chapter 2 shows that science education literature about the benefits and problems of practicals is largely a matter of opinion, not of research-based evidence. Furthermore, opinion in literature is divided about the benefits and problems of science practicals. Therefore, science education literature does not provide a strong unequivocal basis for the content domain of the instrument.

The second reason is the main reason for turning to South African students' opinions from the start of developing the instrument. There is not enough literature about the benefits and problems of chemistry practicals in South Africa to establish the content domain of the instrument (Laugksch 2003: 480). The alternative literature from countries such as the United States of America (USA) and the United Kingdom (UK) would not be suitable as these countries have over a century of science practicals in schools (DeBoer 1991: 230; Gott & Duggan 1996: 791; Lunetta 1998: 249), and the schools in South Africa do not necessarily have this long tradition. South African students' perceptions of the benefits and problems of chemistry practicals may therefore contain unique elements, and the relative importance of common benefits and problems may be different in South Africa.

3.3 Sampling

3.3.1 Purposive sampling

In purposive sampling the sample is deliberately chosen to yield as much useful information as possible, thus meeting a specific purpose. The choice of schools was purposive to include the views of students from schools with low and with high senior certificate results for English. Responses from a school with low English language results were used to derive student statements about the benefits and problems of chemistry practicals. Responses from a school with high English language results were used to derive student explanations about typical statements of benefits and problems of chemistry practicals.

This purposive sampling, based on the English language results of the school, was an important attempt at ensuring that the language of students with poor English results was represented in the instrument, but those students with better English results articulated the meaning of the statements made by the first group of respondents.

3.3.2 Tshwane South

For each stage of the empirical development of the instrument, a different group of Tshwane South (Gauteng) grade 10 to 12 Physical Science school students was used. The Gauteng Department of Education granted permission for the research to be carried out in schools in Tshwane South. The letter granting permission is shown in Appendix A.

3.3.3 Canvassing volunteers

Gillham (2000: 10) discussed the problem of motivating respondents and noted that “few people are strongly motivated by questionnaires *unless* they can see it as having personal relevance”. Therefore the relevance of possible improvement in chemistry practicals was mentioned in the letters to schools and to parents canvassing volunteers and support for the project.

Procedures used in each stage of the research

3.4 Questionnaire 1 to derive statements

The first questionnaire asked grade 10 to 12 Physical Science students to list benefits and problems of chemistry practicals. Appendix B provides the actual wording of the questions.

The questionnaires were administered by the teachers to 117 grades 10, 11 and 12 Physical Science students in a school that achieved low results for English in the 2002 senior certificate examinations. The responses were categorized following a method similar to the method of Gillham (2000). The benefits and problems were categorized separately.

For benefits, the responses were first considered in turn to compile a list of words and phrases from the data. During the process of working through each list of benefits, a note was made of possible categories suggested by the data. These categories were then adjusted based on seeing whether the words and phrases could be placed in the categories. Further minor adjustments were made to the categories based on the process of placing in a category each benefit statement from the responses to the questionnaire. For example, the initial category of “knowledge” was adjusted to “information” when the words and phrases were placed in the categories. This change was made as the words and phrases in that category seemed to fit “information” better than “knowledge”. During the process of categorizing each benefit statement it was discovered, however, that the complete benefit statements seemed to fit “knowledge” better than “information”. The category label was therefore changed back to “knowledge”.

For problems, the responses were not as complex nor as numerous as the benefits. The stages involving words and phrases were therefore not necessary. Instead, tentative categories were derived from reading through a portion of the responses. The remaining responses were then placed in these categories, showing that the responses did all fit into the tentative categories. The tentative categories were, however, refined into more discriminating categories during this process. For example, one of the tentative categories was “practical”, meaning that in essence the practical itself is intrinsically a problem. This category was refined into three categories dealing with the intrinsically problematic nature of practicals, namely that some practicals don’t work; that theoretical background is lacking for a practical; and that the expected skills cannot be developed for a practical.

For each benefit and problem category, a typical statement in students’ words was chosen to represent the category. The choices for benefit categories were made by comparing all the statements or a portion of the statements, depending on the perceived stability of the category. The meaning of a stable category was clear, without nuance and repetitions between respondents, so a portion of statements was thus sufficient for comparison to choose the typical representative statement. An unstable category comprised a number of similar but slightly different views, and thus required comparison of all the statements in that category for the choice and rationalization of a typical representative statement. The choices for problem categories were made by comparing all the statements in the categories. Through these comparisons of benefit or problem statements within a category, a shortlist of statements was made for further comparison to rationalize the final choice of a typical statement. This part of the research resulted in final adjustment of the categories.

The chosen statements were written as full sentences which emphasized the beneficial or problematic nature of chemistry practicals, and which retained the phrasing of the students as far as possible. These statements were submitted to the Gauteng Education Department for approval for use in Tshwane South schools in Questionnaire 2, interviews and trialling the instrument. Approval was granted, so the research continued.

3.4.1 Categorization

The categorization process described above is a central part of content analysis of responses -“a practical activity but an intellectually demanding one: translating your material into a manageable and comprehensible form” (Gillham 2000: 66). The intellectual demand of the process is to be expected as, according to Dey (1999: 49), a category is always conceptual. A category may be defined as a “class or division; one of a set of classes among which things are

distributed” (Dey 1999: 49). The process of categorization therefore involves “classifying things into categories through comparison, involving relations of inclusion and exclusion” (Dey 1999: 55).

Questionnaire 1 and the resultant categories were important because the categories formed the content domain of the instrument, with an example of a statement from each category forming the items of the summary part of the instrument and the stem of the multiple-choice explanatory part of the instrument.

3.5 Questionnaire 2 to derive explanations

The second questionnaire asked students to explain the statements of benefits and problems of chemistry practicals. The 28 statements derived from the first phase were divided so each respondent was asked to explain two benefits and one problem of chemistry practicals.

Appendix C shows the statements and the wording of the question.

Grade 10 and 11 Physical Science students from a school with high English results for the 2002 senior certificate examination filled in questionnaire 2. Although a letter asking for written parental consent was attached to each questionnaire, the school decided to stand *in loco parentis* and gave consent for this stage of the research to be conducted at the school. A return rate of 1 in 3 was expected and 100 completed questionnaires were needed, so 300 questionnaires were administered. The teachers handed out the questionnaires and collected questionnaires that were returned.

The explanations were used to form subcategories for each statement in turn. The number of responses for each statement was small enough to form subcategories by inspection of a set of explanations. No attempt was made to limit the number of subcategories as the intention was to capture as complete a range of views as possible.

The subcategories for each statement were used by the researcher and two science education experts (three judges) to categorize the explanations for each statement. Judges were invited to suggest new subcategories if an explanation did not fit into any of the supplied subcategories.

The judges’ responses were used to finalize the subcategories for each statement as follows:

1. New subcategories were created.

2. Subcategories were deleted if only one judge used that subcategory only once, including the newly created subcategories.
3. The subcategories of Not Applicable, Agree and Disagree were deleted.
4. Subcategories were renamed.

The extent of agreement between the judges was used in choosing a representative explanation for each subcategory of explanations as follows:

1. An explanation placed in the subcategory by three judges was chosen in preference to an explanation placed in the subcategory by two judges or one judge.

Retaining the phrasing of the students as far as possible, the representative explanations were written as sentences agreeing or disagreeing with the statement. The processes of finalizing the subcategories and choosing the representative explanations prompted slight rewording of some of the statements. These modifications to the statements, and deviations from the described procedure of finalizing the subcategories and choosing representative explanations were discussed until consensus was reached by two of the judges before being implemented in the next stage of the research.

Questionnaire 2 and the subcategories derived from responses were important because the process allowed for many views to be expressed in the instrument as explanations of the statements. The summary part of the instrument could therefore be complemented by the explanatory part. A teacher using the instrument could therefore look for an explanation of any problem she (he) diagnosed using the summary part of the instrument.

3.6 Interviews to probe the meaning, understandability and completeness of the items

The statements derived from Questionnaire 1 were used as Likert items in the summary part of the instrument and as the stems of multiple-choice items in the explanatory part of the instrument. The explanations derived from Questionnaire 2 were used as options to choose from in the multiple-choice items. These items, shown in appendix D, formed the prompts for semi-structured interviews. (Note that interviewees saw only the statements and explanations. The categories and subcategories also shown in appendix D were used for analysis of the interview data.) The interviews focused on the explanations in the explanatory items.

Written parental consent was obtained for interviews with grade 11 and 12 Physical Science students from a school with high English results for the 2002 senior certificate examination. Four interviews were conducted in a classroom at the school after school hours.

Interviewees were informed that they were helping with the development of the instrument. Permission was obtained from the students to record the interview on cassette. The researcher also made notes by hand during the interview. The interviews were scheduled to last for two hours and interviewees were asked approximately every half hour whether they would like to take a break. Short conversations about science, school science, interviewees' career aspirations, learning styles, etc. set the tone of the interviews as relaxed and flexible.

The interviews were structured as follows:

1. To familiarize the respondent with the full range of statements, the respondent read the statements silently and wrote SA (Strongly Agree), A (Agree), N (Neutral), D (Disagree) or SD (Strongly Disagree) next to each statement according to her view of chemistry practicals.
2. For each Explanatory item,
 - a. To familiarize the respondent with all the explanations of the statement, the respondent read the statement and options silently and circled any option she agreed with.
 - b. The respondent read aloud then explained the meaning of each option in turn. When appropriate, the respondent was reminded to explain the meaning of the words, not her opinion. This was probing the **meaning of the items**.
 - c. The respondent was asked whether anything in the item was worded strangely or was difficult to understand. This was probing the **understandability of the items**.
 - d. The respondent was asked whether she had any explanations to add to the set of explanations. This was probing the **completeness of the items**.
3. The researcher interrupted the flow of the interview at times to seek clarification about certain points such as what was being said or the items in general.

After two interviews the following changes were made:

1. The options of learning how to observe, measure and classify were added to the skills options. These aspects of skills in chemistry practicals were frequently mentioned in responses from Questionnaire 1 and never mentioned in responses from Questionnaire 2.

2. The explanatory items were dealt with in reverse order. All the items were not necessarily dealt with in each interview, so the reverse order ensured that all the items were dealt with in one interview or another.

The cassette recordings were transcribed and used for analysis of the interviews. The notes made by hand during the interview were used for parts of the interviews that were inaudible if there were not three transcribed responses from other interviews.

There were three to four responses for each item by the end of the interviews, except for two responses for the options that were added after the second interview. The data were analyzed by:

1. comparing each response to the subcategory it was probing (shown in appendix D) thus analyzing the **meaning of the items**.
2. noting which explanations were identified by respondents as difficult to understand, thus analyzing the **understandability of the items**.
3. noting new subcategories of explanations suggested by respondents thus analyzing the **completeness of the items**.

To simplify this analysis, the data were coded as follows:

0. response does not fit in the explanation subcategory
1. response fits in the explanation subcategory
2. unusable data e.g.
 - a. missing (two not three responses for that option);
 - b. opinion (not the meaning of the option);
 - c. obvious (interviewee could not explain the meaning as it was so self explanatory);
 - d. not statement (interviewee did not link the explanation option to the statement stem)
3. interviewee found the wording strange or difficult to understand
4. interviewee added this as an option to the set of options for the statement paraphrase

The suffix paraphrase was added to codes 0, 1 and mostly 2, when the response was merely paraphrasing the words of the option. In these cases, the response was a restatement and not an explanation of the option. Therefore the coding certainty decreased as the interviewee's understanding of the option was not clear. Comparison of a paraphrasing with the subcategory was little better than comparison of the option with the subcategory.

During the analysis and coding, notes arising from the data and analysis were made about:

1. the options (called explanations notes)
2. the stems (called statements notes)
3. the subcategory the explanation fitted into (called subcategory notes)
4. the category the statement fitted into (called category notes)
5. suggested changes to items in general (general notes)

The interviews and analysis of the interview data were important because of the research emphasis on minimising the ambiguity of the items. Items were reworded based on the interview data and analysis. A secondary research emphasis on expressing the views of South African students as widely as possible was also served by collecting additional views on chemistry practicals from interviewees who spent two hours focused on thinking and talking about chemistry practicals.

3.7 Writing the VOCP instrument

The coding and notes obtained during analysis of interview data were used in the following order to make decisions in writing the items for the instrument.

1. For each option in turn, the explanations notes were considered in conjunction with the following steps using the codes of responses.
2. Two to four codes of 1 lead to keeping the option as it was (code 1 = the interview response fitted the explanation subcategory).
3. One code of 1 lead to rewording or deleting the option:
 - a. rewording was allowed if support was found from any interviewee having circled the explanation as an explanation she agreed with; and/or from questionnaire 1 data and/or from questionnaire 2 data and/or interview notes and/or literature.
 - b. the rewording was done using the explanations notes and/or students' phrases from questionnaires 1 and 2 and/or literature.
 - c. if no support was found then the option was deleted.
4. Exceptions were made to the step above (step 3) when support was found to keep the option as it was, instead of rewording the option, given that the responses happened to involve codes of 2 which may very well have been codes of 1 in their own right if the data collection had been more sensitive.
5. Codes of 4 (new option added by interviewee) were equivalent to step 3 above because the creation of a new option in a new subcategory meant there was only one response

fitting that subcategory. So the code of 4 lead to looking for support for the new option or subcategory. This was done:

- a. by checking whether the option/ subcategory was somewhere else (under a different statement stem) in the group of items; if not, then
 - b. by looking for support from questionnaire 1 data, questionnaire 2 data and literature. If support was found, then the new option/ subcategory was added.
6. No codes of 1 (that is, codes of 0, 2 and 3 indicated lack of meaning, unusable data and lack of understanding respectively) lead to the deletion of the option.
 7. Exceptions to the step above (step 6) were made if support was found to keep the option as it was or to reword it, instead of deleting the option, given that the responses happened to involve codes of 2 which may very well have been codes of 1 in their own right if the data collection had been more sensitive.
 8. The statements notes were considered and appropriate changes made.
 9. The subcategory notes were considered. Responses that would be coded as 1 if compared with the option, but were coded as 0 because they were compared with the subcategory, prompted consideration of subcategory change to match the option.
 10. The category notes were considered with a view to:
 - a. changing the category to better match the statement stem, and
 - b. joining tautomeric statements.
 11. The general notes were considered and appropriate changes made to item layout, sentence structure, pronouns, grammar and repetitive phrasing.

The Likert items were written with a five point Likert scale. A five-point scale was preferred to a seven-point scale because deciding between five points is less of a load for respondents than deciding between seven points (Gillham 2000: 32).

The option "None of these show what I think about chemistry practicals" was added as the last option for each set of multiple-choice options. The reasons were that people often do not have a developed opinion (Gillham 2000: 26) and because incomplete responses cannot be dealt with in the same way that complete responses are dealt with for finding a Cronbach alpha coefficient.

The drafting of the instrument was accomplished using all the above procedures and avoiding common faults in questionnaire design, such as response overlap, imprecise questions, long questions, complex questions, awkward phrasing, negative questions, leading questions, prestige bias, over precise questions, ambiguous questions, dangling alternatives and composite

questions (Cox 1996: 9-11; De Vaus 2002: 97-99; Scott & Usher 1999: 68). Points about the closed format of the questions and the order of questions are elaborated below.

3.7.1 Closed questions

Given the intended use of the instrument by teacher in schools, it was decided to develop a questionnaire comprising entirely of closed questions. A closed question is taken as “one where possible answers are predetermined” (Gillham 2000: 5). The VOCP instrument therefore reaps the following benefits of questionnaires and of using closed questions (De Vaus 2002: 99-100; Gillham 2000: 6-8). Collecting data from many people quickly is easier using a questionnaire than another instrument such as an interview. Answers to closed questions are relatively straightforward to analyse. Respondents’ anonymity can be preserved.

A weakness of questionnaires is the sometimes faulty assumption that the opinion being measured actually exists (De Vaus 2002: 99; Gillham 2000: 12). Respondents to the VOCP questionnaire were offered the choice of “Neutral” in the summary part of the instrument and “None of these show what I think about chemistry practicals” in the explanation part of the instrument, so respondents were able to express that they had no opinion for any item.

3.7.2 The order of questions

It seems that "there are almost no experimentally based general rules to order questions." Question order sometimes affects the response, but numerous studies have shown that question order does not always affect the response. Even when the order is shown to have an effect, "it is frequently unclear that one order is better than another. Instead, each order may reveal a different facet of the issue being studied." (Converse & Presser 1986: 41). More recent references offer advice about question order without substantiating assumptions with research-based evidence (e.g. De Vaus 2002: 110-111). For the VOCP, the order of questions follows the order in which the categories and subcategories suggested themselves to the researcher during analysis of data from questionnaire 1, questionnaire 2 and the interviews.

3.8 Trial use of the instrument

The instrument was trialed in three schools. Two of the schools had probable low results for English in the 2002 senior certificate examination. The data to ascertain the results were unavailable, but the researcher observed the students filling in the questionnaire and thought their English achievement probably low because the students mouthed the words as they read them and the students took at least three times longer to fill in the questionnaire than students at a school with high English results. The third school had high results for English in the 2002

senior certificate examination. With the teachers' help, written consent was obtained from parents before the instrument was administered. Teachers also helped the researcher to hand out and collect the questionnaire. The respondents were grade 10 and 11 Physical Science students.

The data from the trial use of the instrument were used to evaluate the reliability of the instrument for the trial group of three schools. A Cronbach alpha coefficient was used to evaluate the reliability of the summary part of the instrument. The Cronbach alpha coefficient was calculated using the Statistical Package for the Social Scientist (SPSS) computer software. Chi squared values were used to interpret the reliability and validity of the Explanatory part of the instrument. A Unisa statistics consultant using Statistical Analysis Systems (SAS) software conducted this analysis. For this analysis the explanatory data were split into either the last option (None of these) was chosen or one of the other options were chosen. That is, the analysis focused on choice or not from the options and did not focus on which particular explanations were chosen.

For both the Alpha coefficient and the Chi squared analyses, discrepant responses were excluded. A response of more than one position chosen for a summary item, e.g. Agree and Disagree chosen for one statement, was taken as discrepant. In the explanatory part of the instrument, a choice of more than one option for a stem was acceptable, unless the last option (none of these) was chosen in addition to one of the other options. These responses were considered discrepant.

The trial use of the instrument was important as it provided data to evaluate the reliability of the instrument for that group of respondents. The trial use of the instrument furthermore provided data with which to evaluate the validity of the instrument.

3.9 Evaluating the validity of the instrument

3.9.1 Development and trial use of the instrument

The method used in the empirical development of the instrument formed the primary procedure for trying to ensure the validity of the instrument. An evaluation of the method therefore provided an evaluation of this aspect of validity.

3.9.2 Validity framed as the potential for the instrument to express the views of students

To gauge the success of the method, the data from the trial use of the instrument were used to evaluate the validity of the instrument for the trial group. Validity in this procedure was seen as the potential of the instrument for allowing students to express their views on chemistry practicals.

To this end, the data were examined by asking:

1. Was the position of “Neutral” for the summary part of the instrument chosen more than the positions of Strongly agree, Agree, Disagree and Strongly disagree?
2. Was the last option of “None of these” for the explanatory part of the instrument chosen more than the other options were chosen?
3. What views did this group of students express?

The first two questions were answered by seeing whether “Neutral” or “None of these” were more than 50% of the responses for each item of the summary or explanatory parts of the instrument. The third question was answered by looking at the frequency of choices made for the summary and explanatory parts of the instrument. For the summary part of the instrument, data were sorted to show which items generated the most agreement (Strongly agree and Agree combined) or the most disagreement (Disagree and Strongly disagree combined), depending on which was in the majority. This provided an outline, in the categories of the instrument, of the views of this group of students. A more detailed description, in the subcategories of the instrument, of the views of this group of students was obtained by sorting the multiple-choice data to show which explanations were chosen most frequently. Throughout this procedure, the number of usable responses for the items differed as missing and discrepant responses were excluded. Therefore percentages (not frequency counts) were used to allow comparison of items.

3.9.3 Face validity: Views in the instrument compared with views in literature

Additionally, an indication of the face validity of the instrument in a broader context than Gauteng, South Africa, was obtained by comparing the empirically derived views expressed in the instrument with views expressed in literature from countries such as the USA and the UK. This comparison was made by looking in literature for examples of the view expressed by students in the instrument. As discussed in chapter 2, the literature is largely a matter of opinion so this procedure was essentially a comparison of literature opinion with opinions of the Tshwane South students involved in the development of the instrument.

3.9.4 Validity framed as potential use of instrument by teachers

Finally, validity was framed as the potential use of the instrument by teachers. The rationale for this originated in seeing the instrument as a way for teachers to assess their students' views to inform the teachers' planning and running of chemistry practicals. Linn and Gronlund (1995: 49) highlighted that validity of a test includes an evaluative judgment about the interpretation and use of test results. This aspect of validity was evaluated using the question,

1. Can the instrument provide results which can be interpreted and used to inform the planning and running of chemistry practicals?

Examples of how data could be interpreted and used to inform the planning of chemistry practicals were given using the data from the trial use of the instrument.

3.10 Summary of Chapter 3

The research design triangulated the qualitative and quantitative paradigms of research. The language demands of the South African situation necessitated that the method attempted to ensure as much as possible that the English language in the VOCP instrument is understandable to target students, namely Gauteng grade 10 to 12 Physical Science students. The method was therefore informed by the method used to develop the VOSTS instrument. In developing the VOCP instrument, the method used to develop the VOSTS instrument was adapted so that, instead of using literature, South African students' views were used to establish the domain of the instrument. This was necessary as science education literature was not specific to the South African science education tradition and did not provide an unequivocal basis for the content domain of the VOCP instrument.

The process of developing and trialling the VOCP instrument used four stages comprising the use of two questionnaires, interviews and trial use of the instrument. A different school was sampled for each stage of data collection. This purposive sampling, based on the English language results of the school, was an important attempt at ensuring that the language of students with poor English results was represented in the instrument, but those students with better English results articulated the meaning of the statements made by the first group of students. A third school was used for interviews to check the meaning, understandability and completeness of the items. Three more schools participated in the trial use of the instrument. All the schools were in the Tshwane South district of Gauteng province, South Africa. All the students were grade 10 to 12 Physical Science students.

In the first stage of developing the VOCP instrument, questionnaire 1 was used to obtain students' lists of the problems and benefits of chemistry practicals. These responses were categorized. The categories established the domain content of the VOCP instrument. For each category, a representative statement was chosen. The statements were used in questionnaire 2. In the second stage, questionnaire 2 was used to obtain students' explanations of the statements. The responses were categorized, and a representative explanation chosen for each category. The statements were used as Likert items for the summary part of the instrument and as the stem for multiple-choice items in the explanation part of the instrument. The explanations from responses to questionnaire 2 were used as options for the multiple-choice items in the explanation part of the instrument.

In the third stage of developing the instrument, interviews were used as a pre-trial of the items. The interviews were used to check the meaning, understandability and completeness of the items. Drafting the instrument primarily relied on the interview responses, but secondarily drew on the responses from questionnaires 1 and 2, and on literature. The instrument was trialed in three schools. The trial use of the instrument provided data for evaluating the reliability of the instrument for the trial group of students. The trial of the instrument also contributed to projections of how teachers could use the instrument in future. The validity of the instrument was evaluated using data from the trial use of the instrument, the projections for future use of the instrument, literature and the method of developing the instrument.

The method of developing and evaluating the validity of the VOCP instrument was described in detail in this chapter. Chapter four shows the results of each stage of the described research method.

Chapter 4 Results and interpretation of the empirical development of the two-part Views On Chemistry Practicals instrument

The aim of the research was to empirically develop a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools.

Chapter 4 presents the results of the process of achieving the aim of the research and of evaluating the validity of the VOCP instrument.

Results are presented and interpreted for sampling; for each stage of the research process, namely using questionnaire 1 to derive statements, using questionnaire 2 to derive explanations, using interviews as a pre-trial check of the meaning, understandability and completeness of items, and drafting and use of the instrument; and for evaluating the instrument.

The interpretation of results is presented in each section of results and is framed by the objectives of the research. These were to:

- Design and develop an instrument which is both quick to use (summary part) and allows the full range of students' views to be expressed (explanatory part).
- Develop the instrument as a Views On Chemistry Practicals (VOCP) questionnaire.
- Use an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument.
- Use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument.
- Evaluate the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature.
- Use the instrument in schools in Gauteng.

In particular, the objectives of obtaining students' input at each stage of the development of the instrument, and of using students' words and phrases as much as possible in the instrument, were the defining features of ensuring the research produced an instrument which is valid in the South African (Gauteng, Tshwane South) situation, and thus played a prominent role for interpreting results.

4.1 The samples obtained for the stages of the research

4.1.1 Purposive sampling

The sampling was purposive so that phrasing and views from schools with low and with high English language results could contribute to the development of the instrument. The English language senior certificate results for 2002 were used. Low achievement in English was taken as an average of less than 50% for second language English (higher grade). High achievement was taken as more than 50% for first language English (higher grade).

The statements were derived from students at a school with low achievement in English in the 2002 senior certificate (average of 48% for second language higher grade English). The explanations were derived from students at a school with high achievement in English in the 2002 senior certificate (average of 67% for first language higher grade English). The purposive sampling was therefore successful in ensuring that the instrument contains views and phrases of both groups of students.

All the schools used in the development of the instrument were in the Tshwane South district of Gauteng. This limited sampling was convenient, but created the drawback that further research, such as the interview stage already completed, must be repeated in future to check that the instrument is valid for the whole of Gauteng and for South Africa, if the VOCP instrument is to be used outside the Tshwane South district.

4.1.2 Canvassing volunteers

The students had a choice to respond or not and were thus volunteers. They gave up their time during break or after school or between exams. Taking this into consideration, a 100% return rate was not expected. An estimate return rate on the number of students who could respond in the school was balanced against the target number of responses. The target number of responses were 70 for questionnaire 1; 100 for questionnaire 2; five for the interviews; and 50 from each of three schools for trialling the instrument. The return rates from grade 10 to 12 Physical Science students were sufficient to meet the targets satisfactorily.

Some of the return rates were higher than expected (89% to 100%) so the number of responses achieved were in excess of the targeted numbers. On the other hand, moderate return rates (36% and 39%) resulted in the target number of responses barely being met, thus vindicating the low estimations of return rate. These low estimations resulted in the sampling targets being met for

the questionnaire stages because enough questionnaires were distributed. The integrity of the research was thus conserved.

The return rate from some of the schools substantially exceeded the expected return rate, so the research benefited from the analysis of far more responses than was strictly necessary. On the other hand, excessive return rates may be an indication that one of the dangers of using volunteers was coming into play, namely that results ended up skewed towards positive attitudes because volunteers tended to be those who have experienced chemistry practicals in a positive way (Borg & Gall 1989: 443). Two possible sources of this volunteer artifact could have affected the development of the instrument.

Firstly, the teachers who volunteered their classes for research could have been more confident in running chemistry practicals than the teachers who did not volunteer their classes. The students may therefore have been accustomed to well-run practicals, and may therefore have a more positive view of chemistry practicals than the whole possible group of grade 10 to 12 Physical Science students whose teachers were canvassed for volunteering.

Secondly, within the classes whose teachers volunteered, the students had a choice to volunteer or not. Those who did respond are likely to have been more positive about chemistry practicals than those who did not respond. An alternative explanation for the high return rate at some of the schools is that the students were captive volunteers, i.e. their teachers gave them no choice. If so, this second possible source of volunteer artifact is eliminated.

In all of the stages of research, the respondents expressed both positive and negative views so the instrument does contain negative views, albeit fewer negative than positive views. Knowing that students were likely to express negative views less than positive views, the wording of questionnaire 1 was a deliberate attempt to support the students in listing the problems they have experienced in chemistry practicals (see appendix B).

The target number of usable responses was not met for the interview stage of research, although actual responses exceeded the target number. The data from the interviews turned out to be sufficient for the research, especially because other sources of information complemented the interview data in the process of producing the instrument.

The Gauteng Physical Science students used in developing the instrument were in grades 10-12 for deriving the statements, grades 10-11 for deriving the explanations, grades 11 to 12 for the interviews and grades 10-11 for trialling the instrument. Therefore, the objective of obtaining input from Gauteng grade 10 to 12 students was met overall, although in some stages the grade 12 students were unavailable because of study commitments.

4.1.3 Quality of responses

Having a high return rate and meeting the target number of responses did not necessarily ensure that the sampling had served the purpose of the research. Another aspect was the quality of responses, i.e. How usable was the response?

The responses to questionnaire 1 contained answers copied from one to the next respondent, so the data could not be used to count the frequency of response in each category. As the frequencies were not to be used in the development of the instrument (e.g. there was no intention to exclude views with a low frequency of expression) this copying did not matter. The danger from the copying was that the expression of views would be limited, so the instrument would end up not giving a complete description of the views held by grade 10 –12 Physical Science students. Fortunately the high return rate (100%) balanced the copying so the data from this stage of the research seemed saturated.

Steps were taken to decrease copying in the following stage of the research (questionnaire 2), to minimise the danger of developing an incomplete instrument. Only one instance of copying was detected in the 321 explanations considered from 108 respondents. The quality of these responses allowed a range of subcategories (explanations) to be developed for each category (statement), so the purpose of this stage of the research was adequately served by the responses.

Similarly, the interview responses allowed the meaning, understandability and completeness of the items to be checked, so the purpose of this stage of the research was served. The responses to the trial use of the instrument were of high quality, with more than 220 out of the 230 responses being usable for each item.

4.1.4 Sampling conclusion

On the whole, the purposive sampling allowed the development of an instrument according to the objective to use an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the VOCP instrument. A possible problem was that using volunteers may have caused the items to be more positive than would be expected

from a non-volunteer sample. The responses also included negative views. So although the instrument may have been loaded with positive views, the instrument does allow expression of negative views about chemistry practicals. Responses to the different stages of the research were of high enough quality to serve the purposes of the research.

Results of procedures used in each stage of the research

4.2 Results of using questionnaire 1 to derive statements

4.2.1 Categorizing questionnaire 1 data

The process of developing and using categories reduced a large volume of data to a manageable size. For the benefits, analysis started with a total of 1050 benefits listed by 117 respondents. Each response was worked through in turn to compile a list of words and phrases from the data. The results were 194 unique words and phrases, and 26 categories of data. The categories were adjusted by fitting words and phrases into the categories, resulting in 30 categories. The final stage of choosing typical statements resulted in 19 categories of benefits (see table 4.1), derived from the questionnaire 1 data.

Table 4.1 Categories of benefits derived from analysis of questionnaire 1 data

skill	chemicals	curiosity	social	experiment
knowledge	future	opportunity	reasoning	record
evidence	nature of	required	apply chemistry	creative
apparatus	chemistry	understand	safety	motivational

For the problems, analysis started with a total of 147 problems listed by 117 respondents. All this data resulted in six initial categories being formed. Choosing typical statements for these categories saw the number of categories increasing to nine categories of problems (see table 4.2), derived from the questionnaire 1 data.

Table 4.2 Categories of problems derived by analysis of questionnaire 1 data

physically lacking time	practical without theoretical background	learner limitations
physically lacking equipment and chemicals	practical without being able to develop the expected skills	environment
practical not working	learner behaviour	teacher

During the process of developing the categories from the data, the number of categories changed as shown above. An example is that the initial problem category of the practical itself, that is the *intrinsic nature of practicals is problematic*, became three problem categories of the *practical not working*, of doing a *practical without theoretical background* and of doing a *practical without being able to develop the expected skills*. Other categories were merged during the process of developing categories, thus decreasing the number of categories. For example, the benefit category of *rhetoric*, that is that the student is expressing a rhetoric and not a personal statement of benefits, was merged with the benefit category of *required*, that is the student is expressing what is required of a student and a *practical*. These were merged to form the *required* category as *rhetoric* and *required* seemed to express how practicals and students doing practicals ought to be (are required to be).

For other categories, the nature of the category was adjusted as the label of the category changed during the process. For example, one of the benefit categories was initially *proof*. In fitting words and phrases into the categories, this category was labeled *evidence* and indicated that the concepts of *proof, evidence, data and verification of theory* were included. As a final category, all these concepts were subsumed under the simple label of *evidence*. Another example of adjustment to the nature of the category itself was that the category labeled *knowledge* changed from *knowledge* to *information* and back to *knowledge* during the process of developing the categories from the data.

So the categories changed in number and nature during the categorization process. These changes are perfectly acceptable as the typical stages in a categorization process involve such actions as reviewing the categories with a view to combining or splitting or adapting as necessary, and modifying the categories so they match the statements better than before (Gillham 2000: 66-69).

The resultant number and nature of categories support the concern discussed in the sampling section, namely that the responses and ultimately the items of the instrument may be loaded with positive views. The 117 respondents listed a total of 1050 benefits and 147 problems of chemistry practicals. The process of developing categories from these resulted in 19 categories of benefits and 9 categories of problems from this stage of the research. Ultimately, the categories corresponded to the items in each of the summary and the explanatory parts of the instrument so, although during further stages of research the number of categories changed, the

instrument ended up loaded with positive items. A possible explanation is simply that students express more positive views than negative views about chemistry practicals. The following stage of research (Questionnaire 2) alleviated the positive loading to some extent by introducing positive and negative subcategories for positive categories.

4.2.2 Selecting and writing the statements typical of each category

During the categorization process it became apparent that a large number of responses were copied between respondents, so frequency counts of responses in the different categories were meaningless. For example, there were from 11 to 188 statements per category, with replicas between respondents for the categories with a large number of statements. This did not compromise the research, as the purpose of this stage of the research was to derive typical statements to use in questionnaire 2, not to measure the extent with which the group of students held these views.

In the process for deriving a typical statement for each category, statements were considered and a sample of available statements was considered for stable categories, i.e. for categories with clear meaning. For all the categories, a shortlist of statements, which conveyed different ideas within the category, was considered to rationalize the final choice of a typical statement for the category. Using the shortlist, a typical statement was chosen for each category and some categories were adjusted. The idea of a “typical statement” uncovered a characteristic of the categories, namely the stability of the category. A stable category had a clear meaning. Any statement in the category was more or less as typical of the category as any other statement in the category. On the other hand, the statements in an unstable category all fell in the overriding concept of the category, but there were differences in meaning between the different statements in the category. Therefore, to choose a typical statement, care was taken to consider each statement with its nuance of meaning.

The students’ original phrasing was retained as much as possible in writing the typical statements as full sentences highlighting the beneficial or problematic nature of chemistry practicals. An example of using students’ words in writing a typical statement is the popular (188 responses) statement about developing skills. The student response, “to develop skills”, was written as “A benefit (good thing) of chemistry practicals is to develop skills”, thus creating a full sentence highlighting the beneficial nature of chemistry practicals yet retaining the students’ words and phrasing.

Another example of writing a selected typical statement shows that there was sometimes a slight shift in wording, not a simple transposition of the student's words into the full sentence frame. The student's words, "to avoid accidents" became a matter of learning to avoid accidents in, "A benefit (good thing) of chemistry practicals is to learn to avoid accidents."

Not all of the typical statement sentences used the words "benefit" or "problem". For example, in response to the question asking for benefits of chemistry practicals, a student's response was, "to make the subject more interesting". This was written as the typical benefit statement, "Chemistry practicals make the subject more interesting".

Given the discussion in chapter 2 of chemistry as a distinct discipline, the frame used for most of the typical statements used the words, "chemistry practicals", and the word, "chemistry", was inserted into the student's phrase if necessary. For example, the student's statement, "It is easy to learn with practical work" was rewritten as "It is easy to learn with chemistry practical work."

Overall, the typical statements were rewritten for the research ensuring that the phrasing of the students was retained as far as possible. This approach was drawn from the VOSTS method described in Chapter 2 and satisfied for this stage of the research one of the objectives of the research, namely to use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the VOCP instrument. The purpose was to contribute to the validity of the instrument by making the items as understandable as possible to Gauteng grade 10 to 12 Physical Science students. The typical statements derived from Questionnaire 1 were central to the next stage of developing the instrument and provided the items for the instrument.

4.2.3 Questionnaire 1 conclusion

In a deliberate departure from the typical procedure for developing an instrument, questionnaire 1 was used to solicit students' views about the benefits and problems of chemistry practicals at the start of the research process, without first turning to literature to set the content domain of the instrument. In the process of categorizing statements, the categories naturally changed in number and nature, and ultimately the VOCP instrument was loaded with positive items derived from this stage of research. In the process of choosing typical statements for each category, the stability of the categories had to be considered. In meeting one of the objectives of the research, rewriting the typical statements took care to retain the phrasing of the students as far as possible, in order to increase the understandability of the items.

4.3 Results of using Questionnaire 2 to derive explanations

4.3.1 As many subcategories as possible

The categorization process for Questionnaire 2 was used to derive as wide a range of explanations of each statement as possible. In total, 321 explanations were considered and 225 subcategories were initially derived from these explanations of the statements. Gillham (2000: 64) recommended that the researcher who is categorizing responses asks "what categories are going to be useful or necessary for your research purposes?" For the development of the VOCP instrument, all categories and subcategories were considered useful and necessary. The purpose of the research was developing an instrument capable of describing the views in all their diversity. Therefore, the development of the instrument emphasized the creation of as many categories (statements from Questionnaire 1) as necessary and as many subcategories (explanations from Questionnaire 2) as possible. A consequence was that generally there were only one or two responses in each subcategory.

The subcategories could have been forced into a more compact set, with more responses per subcategory, but this would have been alien to the spirit of the process of developing the VOCP instrument. The categorization of explanations into as many subcategories as possible met the objective of research to design an instrument that allows the full range of students' views to be expressed (explanatory part of the instrument).

4.3.2 Three judges categorized the explanations obtained using questionnaire 2

Three judges categorized the explanation data into the initial 225 subcategories. Judges were invited to create additional subcategories if necessary. In assigning subcategories to an explanation or part of an explanation, all three judges assigned the same subcategory 44% of the time, two of the three judges assigned the same subcategory 48% of the time and none of the judges assigned the same subcategory 8% of the time. The number of judges assigning the same subcategory to an explanation or part of an explanation was taken as an indication of the extent of agreement between the judges about categorizing that particular explanation or part of the explanation.

The as-many-categories-as-possible approach hindered the analysis of interjudge reliability. A Kappa coefficient was considered as an indicator of interjudge reliability (see for example Neale, Rokkas and McClure 2003: 39-40), but because the analysis of questionnaire 2 data had created many subcategories with few counts for each subcategory, the data was unsuitable for

calculating a Kappa coefficient. Ultimately, the lack of a Kappa coefficient did not matter for the research because the extent of agreement between judges was used on an explanation-by-explanation basis, not as general statistic.

Although the judges were unanimous only 44% of the time, the judges' responses to the data proved to be fruitful firstly in shaping the subcategories and two of the statements. Secondly, the extent of agreement between the judges informed the choice of explanations representative of each subcategory.

4.3.3 Extent of agreement between judges used to adjust the subcategories

The extent of agreement between the judges was used in adjusting the initial 225 subcategories of explanations. For example, 22 subcategories were deleted as each of these subcategories was used only once by one judge out of all the explanations for that statement. A judge's new subcategory suggestion was immediately deleted because, by the nature of the process, only one judge had used that subcategory. This happened 17 times. Only one new subcategory was made as a result of all three judges suggested the same subcategory, but seven categories were split into new categories at the suggestion of the judges. Renaming a subcategory happened six times as a result of a suggestion from a judge. The categories of "not applicable" and of "agree" or "disagree" were deleted. The 225 subcategories assigned originally thus decreased to 185 subcategories.

4.3.4 Extent of agreement between judges used to select a representative explanation for each subcategory

The extent of agreement between the judges was secondly used in choosing a representative explanation for each subcategory of explanations. The extent of agreement between the judges was seen as an indicator of the clarity of the explanation under consideration. An explanation that all three judges placed in the same subcategory was seen as conveying the underlying concept (subcategory) with more clarity than an explanation that the three judges placed in three different subcategories. The explanations that, for the judges, had the most clarity were chosen as typical explanations for the subcategories in the instrument in order to decrease the ambiguity of the explanations in the items of the VOCP instrument.

Unlike the complex iterative process of choosing typical statements for each category, the choice of a representative explanation for each subcategory was a straightforward process. The process was simplified by the small number of explanations to consider in each subcategory and

by using the extent of agreement between judges as a guide to which explanation ostensibly represented the subcategory with the most clarity.

The resultant representative explanations differed from statement to statement in number and nature. There were from four to ten explanations per statement. There were both negative and positive explanations for a particular statement. There was some overlap of subcategory from category to category. In these cases the difference between the category to which the subcategory referred differentiated between the overlapping subcategories. Having a range of explanations for each statement was suitable for the development of the VOCP instrument as one objective of the research was to develop an instrument that allows the full range of students' views to be expressed.

4.3.5 Two judges reached consensus about variations

Modifications to the statements, and deviations from the described procedure of finalizing the subcategories and choosing representative explanations were discussed until consensus was reached by two of the judges. As a result, two of the statements were reworded. Eleven subcategories were retained even though they should have been deleted as they were used only once by one judge out of all the explanations for that statement. Four subcategories were retained even though they should have been deleted, as they were simply “agree or disagree” with the statement. Twice the explanation chosen as representative of the subcategory was not the explanation indicated by judge agreement.

4.3.6 Researcher bias

The lack of complete unanimity about questionnaire 2 data and the large influence of the judges' input on the development of the instrument, raise a concern about the use of questionnaire 1 data. With hindsight, the development of the instrument could have benefited from scrutiny by one or more other judges of the decisions made by the researcher as sole judge in the first stage of the research. In developing the instrument as a whole, reasoning and decision-making were carried out continuously by the researcher during analysis of empirical data and development of the instrument. Therefore the instrument inevitably carried the stamp of the researcher.

Converse and Presser (1986: 58-59) have pointed out that “investigators are rather prone to forgetting that not everyone brings the same fervent interest to their topic that they do.” These words were written about the length of questionnaires, but seem to apply to the subcategories initially created by the researcher, with minuscule variations in meanings accommodated by the researcher. Fortunately the process of developing the instrument allowed the judges' (and

interviewees') input to temper the level of detail in the instrument. Sometimes, however, the researcher relied on her intuition based on her involvement from the start of the research (i.e. her tacit knowledge of all the responses from the start of the research) to motivate some deviations from following the majority opinion of judges. Overall, the researcher used one of the objectives of the research as the adjudicator between the researcher's opinion, the opinions in the data and external judges' opinions. The objective was to design and develop an instrument that allows the full range of students' views to be expressed (explanatory part).

4.3.7 Writing the representative explanation of each statement

Retaining the phrasing of the students as far as possible, the chosen representative explanations were written as sentences agreeing or disagreeing with the statement, for use in the next stage of the research. Retaining the phrasing of students was drawn from the method used to develop the VOSTS instrument and achieved the objective of the research to use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument. That is, by using students' language an attempt was made to ensure the items would be understandable to Gauteng grade 10 to 12 Physical Science students.

4.3.8 Questionnaire 2 conclusion

The data from Questionnaire 2 were used to make as many subcategories as possible for each category. This suited the purpose of the research to develop an instrument capable of describing the views in all their diversity. Three judges categorized the data, and the extent of agreement between the judges was an important guide in adjusting the subcategories and statements, and in choosing typical explanations for each subcategory. The judges' influence on shaping the subcategories, statements and explanations of the instrument, and the lack of complete unanimity between the judges, supported the use of other sources of opinion such as judges and interviewees to complement the researcher's opinion to develop a valid and reliable instrument.

By the end of this stage of research, a suitable range of subcategories had been developed, and the typical explanations for each subcategory had been rewritten retaining the original student phrasing as far as possible. The use of agreement between judges and the phrasing of students had maximized the understandability of the items as much as possible at this stage. The interview stage which followed was crucial for checking that items were not only understandable, but also carried the same meaning for researcher and student alike (no ambiguity). The interviews also probed whether the items were complete in describing the range of views held by Gauteng grade 10 to 12 Physical Science students.

4.4 Results of using interviews to probe the meaning, understandability and completeness of the items

Four students were interviewed and the data were analyzed as described in chapter 3. In short, interviewees explained the meaning of the multiple-choice options, and each response was compared with the subcategory label to check that the option conveyed a clear meaning to the respondent. Clear meaning of an option was indicated if the response fitted the subcategory of the explanation. Probing the meaning of options was in effect probing the ambiguity defined as a difference between the researcher's meaning and the student's meaning for an option. The subcategory label captured the researcher's meaning. Responses either fitted the relevant subcategory (meaning is clear) or did not fit the subcategory (meaning is not clear). Out of all 515 interview responses explaining the multiple-choice options, 82% showed that the meaning of the option was clear and 18% showed the meaning of the option was not clear.

Interviewees were also asked to identify words and phrases that they found difficult to understand. There were 45 responses from the four interviewees identifying trouble with the understandability of specific parts of certain items. A further 22 suggestions from interviewees helped to identify additional views which could be added to the existing views in the instrument, to improve the completeness of the items.

The interviews thus provided data to improve the options with unclear meaning and items that were found not to be understandable. This part of the research process involved modification of the original wording of students, but still achieved the objective to use Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument. Retaining the wording without adjustment in the face of the interview data was not possible, as it would have compromised the validity of the VOCP instrument.

4.4.1 The interviews as a first pretest

The interview phase of the research can be considered as the first pretest of the instrument. Converse and Presser (1986) reviewed literature and expert opinion about developing standardized survey questionnaires. Even in this well-established field, the authors found that for pretests,

There are no general principles of good pretesting, no systematization of practice, no consensus about expectations, and we rarely leave records for each other. How a pretest was conducted, what investigators learned from it, how they redesigned their questionnaire on the basis of it - these matters are reported only sketchily in research reports, if at all. Not surprisingly, the power

of pretests is sometimes exaggerated and their potential often unrealized (Converse and Presser 1986: 52).

Bearing these points in mind, care has been taken in this dissertation to report explicitly (Darlington & Scott 2002: 142-143) how the interviews were conducted (chapter 3), what was learned from the interviews (see below), and how the questionnaire was redesigned on the basis of the interviews (chapter 3). The data obtained in the interviews were used to structure the redesign of the questionnaire to such an extent that the power of this phase of the research cannot be exaggerated. Converse and Presser (1986) described strategies, purposes and phases for the design and use of pretests. The following points drawn from these authors emphasize why the potential of the interviews as a pretest of the instrument was realised.

The interviews were used as a participating (not an undeclared) pretest. Therefore during the interviews, detailed probes could be (and were) asked about the questions, the phrases and some of the words of the questionnaire (Converse and Presser 1986: 52). An example of probing the questions is that interviewees were asked whether they had anything to add to the set of explanations for each statement they responded to during the interview. An example of probing the phrases is that interviewees were asked whether they found any of the explanations "difficult to understand" or "strangely worded". An example of probing specific words is that the interviewer pointed out the use of "you", "I" and "one" as the pronouns in the instrument and asked the interviewee which worked best. Interviewees' responses had a big impact in the final stage of redesigning the instrument as "I" was used throughout.

The interviewees were volunteers from a school with high English results for the senior certificate. Therefore the interviewees were "sensitive to nuances of language" (Converse and Presser 1986: 53).

The interviews were devoted to testing the questions for meaning, thus serving the purpose Converse and Presser (1986: 55) identified as the most important pretesting purpose. Interviewees identified VOCP items, and phrases and words in items as not conveying clear meaning. For example, the item that there are problems in chemistry practicals *if the learners don't know how to develop skills* carried no meaning for interviewees who could not see how anybody cannot develop skills. This category statement was therefore changed to one of the explanation subcategories of the skills category statement, so the view was not lost but was no longer of prominent statement importance. Similarly, interviewees expressed the opinion that the phrase *thinking makes me interested* carries no meaning. This view was deleted.

Interviewees also did not know the meaning of certain words such as *hands-on*. This word was not used in the VOCP instrument.

The importance of this phase of the research was not only because it did identify problem areas, but also because the nature of questionnaires is such that bad questions would probably not be diagnosed through simple use of the instrument. The reason given by Converse and Presser (1986: 56-57) is that respondents answer most questions, even when they have to “*transform* obscure questions into ones that seem sensible from their standpoint as they strain for meaning”. Similarly, Houtkoop-Seenstra (2000: vii) observed respondents answering questions without being sure of what the question meant.

The interviews were no longer than 2 hours, which is the maximum length identified by Converse and Presser (1986: 68). The interviewees were from grade 11 to 12 Physical Science classes in a Gauteng school, and thus resembled the target population (Converse and Presser 1986: 68) of grade 10 to 12 Gauteng Physical Science students.

4.4.2 Responses in the interviews

The interviews were unexpectedly enlightening for the researcher. Having used Questionnaires 1 and 2 to write the items in students’ words and phrases, the researcher was pleased to find that on the whole the items were meaningful to the interviewees. The researcher is in agreement with Gillham (2000: 82):

If you want to convey a picture of the reality of people’s lives and, more importantly, what their questionnaire responses might mean, then a face-to-face interview is without parallel as a method. In other words, it doesn’t just *illustrate*, it also *illuminates*.

A satisfying 82% of the interview responses indicated the meaning of an item was clear. The remaining 18% of the responses indicating that the meaning was not clear were used, with the responses identifying words and phrases which were difficult to understand, to improve the items of the VOCP instrument. For example, the option *for an average student it takes longer to complete a practical than for a student with more science ability* was changed to *some learners take longer to complete a practical than other learners*. Other options were added, such as the subcategory of students feeling that proving a theory was a benefit because putting it into their own language made the theory more accessible than in textbook language. The interviews thus complemented questionnaires 1 and 2 to ensure the validity of the VOCP instrument by increasing the meaning, understandability and completeness of items.

4.4.3 The definition of practicals and experiments

Chapter 1 gave two definitions of practicals, and motivated that in the absence of an explicit definition, it is likely that respondents implicitly assume a traditional definition of practicals, such as “doing experiments or practical exercises with scientific apparatus, usually in a science laboratory” (Woolnough 1991c: 3). This definition of practicals was therefore used for this research. The interviews indicated that the traditional definition was a reasonable assumption.

Interviewees were also asked whether there is a difference between a practical and an experiment at school, and if there was a difference, to explain the difference. The responses not only gave insight into the meaning of the word practical as understood by the interviewees, but showed that the notion of experimenting carried four different meanings for four different interviewees from the same school. For example, one interviewee saw *experiment* differing from *practical* as verbs and nouns in that “you can experiment doing an experiment but you can’t practical doing a practical”. Another interviewee saw practicals and experiments as “the same thing”. A third interviewee described an experiment as creating and investigating questions from observations, but explained that in a practical a theory or conclusion is proved. By contrast, the fourth interviewee saw proving something by doing it as an experiment. The experiment involved following the instructions in a book whereas a practical was writing it up. Given the differences in meaning, the item about experimenting was eliminated from the VOCP instrument.

4.4.4 Interviews conclusion

The interviews were successfully used as a pretest to provide data identifying a few problem areas in the instrument. The success arose from the interviews (pretest) providing detailed probes about the wording of items, from the use of suitable interviewees with language sensitivity, from rigorous testing of the items for meaning, and from using interviews lasting for a suitable length of time. The bulk of the responses indicated that items carried clear meaning, but some of the responses provided information allowing the items to be rewritten for greater clarity (meaning) and understandability, and new items to be written to complement existing items. The interviews also provided information confirming the choice of definition of practicals and even, with extreme lack of consensus about the meaning of the word experiment, prompting the elimination of an item from the instrument.

4.4.5 The instrument

As explained above, the interview data prompted changes to previous drafts of items. The changes were made if there was support from other sources such as data from questionnaire 1

and 2, and literature. An example of a change prompted by the interview data and supported by data from questionnaire 1 and 2 and by literature is that in explaining *a benefit of chemistry practicals is to investigate*, the option *because you should always be asking yourself “why”* was changed to *because investigating lets me find out why something is happening*. Likewise, the responses identifying additional views were used as described in chapter 3 with support from literature and data from questionnaires 1 and 2 to improve the VOCP instrument. For example, in explaining that practicals are a benefit when the student interprets results, the new option *if I interpret the results before I am given the explanation* was added.

Writing the VOCP instrument was completed when *None of these show what I think about chemistry practicals* was added as a last option for each item in the explanatory part of the instrument, categories were renamed, statements were adjusted, and tautomeric categories were joined.

The changes made in creating the instrument were the result of a complex interplay of procedure, data, advice from literature and judgement. The result of this process was a set of 24 items for the summary part of the instrument, the same 24 items used as the stems for the explanatory part of the instrument and a set of options for each of the explanatory stems. In total there were 163 options for the 24 stems in the explanatory part of the VOCP instrument. The number of options per stem ranged from four to 13. The objective of developing the instrument as a Views On Chemistry Practicals (VOCP) questionnaire (as opposed to some other instrument such as an interview protocol) was thus achieved. Using the statements to create a Likert summary part of the instrument and using the statements as stems and explanations as options in a multiple-choice explanation part of the instrument achieved the research objective to design and develop an instrument which is both quick to use (summary part) and allows the full range of students' views to be expressed (explanatory part).

4.4.6 Students' words and phrases

Gillham (2000: 21) suggested that obtaining the phrasing of questions from potential respondents may be more respondent-friendly than writing the questions ab initio. This approach, drawing on the method used to develop the VOSTS instrument, was central to the development of the VOCP instrument. Students' words and phrases were obtained and retained as far as possible.

Given that students do not express themselves with perfect language, that non-standard language can distract attention from the meaning of the language, and that the focus of the instrument had

to be maintained, the following changes to students' words and phrases were necessary at various stages of developing the instrument.

Spelling and grammar were corrected. Responses to the first questionnaire were mostly phrases so these phrases were turned into full sentences highlighting that a benefit or problem of chemistry practicals was being considered. Responses to the second questionnaire were generally paragraphs containing more than one idea so key phrases were extracted from the paragraphs and turned into full sentences. The interviews resulted in a number of changes being made, such as avoiding repetition of phrases within a set of explanations, using the pronoun "I" instead of "you" or "one", making the link between the explanation and the statement more obvious in the explanation, changing all the explanations into the same format, and so on.

By the end of all these changes the instrument items were not written purely in students' words. The views expressed by the instrument were, however, still the views of the students, and the views were expressed in the students' words unless there were indications (spelling, grammar, focus of the instrument, interview data) that the meaning of the question was at risk through rigid retention of students' words. In this way, every effort was made to optimize the understandability and respondent-friendliness of the items of the instrument, and to minimize the ambiguity of the items. A larger research than the one reported here could include another semi-structured interview stage to check the success of these efforts.

4.4.7 The personal form of the instrument

Interview responses indicated that the personal pronoun "I" be used in preference to "you" or "one". This was implemented in writing the instrument, with the result that the instrument took the personal form and not a class form of instrument. Fraser (1998: 539) described research that "justifies the decision to evolve separate class and personal forms because they appear to measure different, albeit overlapping, aspects of the science laboratory classroom environment". As the aim was to develop an instrument concerned with students' personal views, the personal form of the instrument was appropriate.

4.4.8 Instrument conclusion

The items of the instrument were written following a rigorous procedure and implementing identified principles of writing questions for questionnaires. Although the development of the instrument utilized open questions, the instrument consisted entirely of closed questions, which suits the intended use of the instrument in schools. Although the instrument items were not written purely in students' words, the views expressed in the instrument were the empirically

derived views of students and the phrasing of the students were retained as much as possible. Steps had therefore been taken to optimize the understandability and minimize the ambiguity of the items of the instrument. The personal form of the instrument was appropriate for the aim of this research.

Overall, the instrument achieved the research objective of developing the VOCP instrument as a questionnaire as opposed to some other research instrument. The research objective to design and develop an instrument that is both quick to use (summary part) and allows the full range of students' views to be expressed (explanatory part) was also achieved. Appendix E contains the VOCP instrument.

4.5 Results of trial use of the instrument: Fine tune the VOCP instrument

The trial use of the instrument achieved another research objective, namely to use the instrument in schools in Gauteng. The trial use of the instrument not only provided a few final insights for the development of the VOCP instrument but also provided data for the evaluation of the reliability and the validity of the VOCP instrument.

4.5.1 The trial use of the instrument as the second pretest

Converse and Presser (1986: 74-75) describe the second pretest as a “polishing” pretest. In other words, the test should be as close to the final format as possible; neither for exploration nor repairing gross errors; rather for “cutting, trimming, splicing, rearranging, and ... formatting for clarity”; given to colleagues for criticism (as a smaller imposition than previous drafts of the questionnaire would have been); an undeclared pretest; and evaluated with a high barrier to the addition of new questions. The VOCP instrument was trialed in this spirit. Nevertheless, a few issues emerged, as discussed in the following sections.

4.5.2 The design of the VOCP instrument

Gillham (2000: 37) pointed out that design involves not only how things look but also how things work, and that this "functional aspect of design is critical: whether it really works or whether it goes wrong". In short, does the instrument do what it is supposed to do? The VOCP instrument included instructions and examples about how to fill in the questionnaire. There are indications that the design of the instrument was successful in getting the respondents to fill in the questionnaire as requested. For example, administration of the instrument in three schools yielded a low proportion of missing responses in the summary and the explanatory parts of the instrument; a low proportion of more than two responses per summary item; and a low

proportion of the explanatory option "none of these show what I think about chemistry practicals" chosen when another option had already been chosen from the set of options.

The design of the instrument also involved aiming for "a clean uncluttered look" (Gillham 2000: 39). Therefore, summary items in the VOCP were blocked in groups of five and each explanatory set of options was blocked to avoid a cluttering line leading the respondent from each item or option to the place to make the response. This aspect of the design may have compromised the functionality of the design for the low proportion of respondents who did not respond as required. For example, one respondent had a double choice in the summary item below an item where the choice was missing. One of the double choices may have been intended for the item above (Cox 1996: 15). The final VOCP instrument in appendices E and F therefore included guiding lines for all summary items and explanatory options.

Another aspect of aiming for an uncluttered look in the instrument was cutting down on the number of columns in the instrument. It is common to have a coding column "for research use only" next to the response column (Gillham 2000: 40). In the instrument, the unique answer numbers, which would usually be found in the "research" column, were the numbers of the item for the summary part of the instrument and the numbers of the explanatory option for the explanatory part of the instrument. The explanatory option numbers were used as the response column on the right of the page. This saving of space precluded the use of Unisa services for typing the responses, yet served the purpose of saving space and allowing respondents to respond in an understandable way. As teachers will have to process the data by hand without the help of Unisa services, the format remains advantageous enough to be used in the final instrument.

Another aspect about the functional design of the instrument is whether the instrument was able to fulfill its purpose by measuring the views of students about chemistry practicals. This is discussed below when the validity of the instrument is evaluated.

4.5.3 Communicating with respondents in the trial use of the instrument

According to Gillham (2000: 13), good questionnaire construction is incomplete without making clear "*why* the information is being collected and what *use* it will be put to". For the instrument, students took home a letter to their parents explaining these points and asking parents to sign a consent form. It was felt that students would know from this process the reason and use for the information being collected. Given the length of the instrument, there was a need to reduce the reading load so a cover explanatory page was not used for the instrument. Instead the header of

the document asked, “What do **you** think of chemistry practicals?” Future use of the instrument would require a cover page such as the one in Appendix E, as there will be no covering letter to parents explaining the reason and use of the information.

Gillham (2000: 13) also pointed out that a consequence of our information-conscious age is that people feel that even anonymous information may be stored and identified as information about a particular individual. At the start of filling in the VOCP instrument, one respondent asked what was going to happen to the questionnaires, and many of the respondents asked where to fill in their names. So, on the one hand the respondent may have been exhibiting this uncertainty about what happens to the information he supplies. On the other hand, some respondents seemed unconcerned about anonymity.

These questions from respondents helped to identify an inconsistency in the instrument. The header and the spoken introduction told respondents that the individual’s opinion is important, yet the questionnaire neglected to ask for the individual’s name. This omission trivializes the message that the individual’s opinion is important. In future use of the instrument by teachers, it would be appropriate for the teacher to decide whether the responses are anonymous or named.

Using anonymous responses may invite candid responses, and the information obtained could be used to plan a response implemented in the whole class. Using named responses may allow a teacher to respond to individual differences between students. This alternative was suggested by one of the teachers helping with the administration of the instrument. She told her students to write their names on their questionnaires, and asked that these questionnaires be returned to her so that she could know what each student was thinking and respond appropriately. She preferred knowledge of the individual student’s views rather than a summary of the whole class’ views. (She could only be given a summary as the respondents had been told their responses were anonymous prior to the teacher telling them to write their names on their questionnaires. The teacher gave this instruction while the researcher was with the second class of respondents in a different classroom.)

4.5.4 The length of the instrument

The research method started with a questionnaire of open questions. During the following stages of the research, the questions became more and more closed, ending with a questionnaire consisting entirely of closed questions. This is typical practice in the development of a questionnaire. Closed questions are, however, normally used when the answers are factual or predictable. When answers are opinions, beliefs or judgments, the small number of answers

offered in a questionnaire is unlikely to represent the full range of opinion (Gillham 2000: 5). The VOSTS research developed an example of an instrument used for views, and this instrument is exceptionally long. Similarly, the VOCP instrument was designed to describe views and was long, with 24 summary items, and a total of 163 answers to choose from in the explanatory part of the instrument. The number of pages exceeded the maximum of four to six pages recommended by Gillham (2000: 10, 39). This length is a result of trying to represent the full range of views grade 10 to 12 Physical Science students may hold about chemistry practicals. What are the possible consequences of the length of the instrument?

Converse and Presser (1986: 58-59) described a paper and pen questionnaire in which as many as 23 items were grouped together in the same format, with choices ranging from Strongly Agree to Strongly Disagree. There was evidence of respondent fatigue or boredom towards the end of such a group of items. The described format is almost identical to the 24 item summary part of the VOCP instrument. Therefore, the concern is raised that respondent fatigue can affect responses towards the end of the summary part of the instrument.

On the other hand, classroom environment questionnaires routinely have more than 24 items without losing reliability. For example, the SLEI has 52 items and reliability coefficients ranging from 0.61 to 0.91, with most of the coefficients above 0.7, for groups of students from the USA (Fraser 1994: 501). Although this example is comforting, it may be providing a false sense of security. A different group of respondents, such as students with poor English proficiency, could experience considerably more fatigue or boredom than those who are proficient at English. The SLEI reliability coefficients for groups of students from Nigeria ranged from 0.43 to 0.76, with the bulk of coefficients below 0.7 (Fraser 1994: 501).

Respondent fatigue or boredom in answering the summary part of the VOCP instrument thus remains a possibility.

The sheer length and repetitiveness of the explanatory part of the instrument may compound respondent fatigue or boredom caused by the summary part of the instrument. Fortunately the intended use of the instrument by teachers alleviates this problem.

The intended use of the instrument sees the less onerous summary part of the instrument being used more frequently than the explanatory part of the instrument. The explanatory part of the instrument is intended firstly to give a more intermittent and a more detailed overview of students' views about chemistry practicals than the summary part of the instrument. For

example, using the explanatory part of the instrument at the beginning of the year can give the teacher insight into the views behind the summary scores. A second use for the explanatory part of the instrument is to select and use a single item or a small set of items to probe a particular problem area or potential benefit. This idea of using a portion of the instrument is based on the use of the VOSTS instrument. For example, see Mbajjorgu and Iloputaife (2001: 58). The instrument can thus be used in ways that alleviate the length of the instrument.

4.5.5 Conclusion of the trial use of the instrument to fine tune the VOCP instrument

The design of the instrument included a functional design which elicited usable responses in a high rate, and which achieved an uncluttered look, needing only slight modification in future instruments. The final instrument includes guiding lines for all summary items and explanatory options. A cover page is provided to explain the reason for filling in the questionnaire and the intended use of the information. Teachers can decide whether to ask for students' names or not. The length of the instrument caused concern, but the intended use of the instrument will alleviate this potential problem.

4.6 Results of trial use of the instrument: Reliability

4.6.1 The reliability of the summary part of the VOCP instrument

The Cronbach alpha coefficient was used to evaluate the reliability of the summary part of the instrument for the trial of the instrument in three schools. For a total of 183 cases and 24 items the Cronbach alpha coefficient calculated using SPSS software was 0.7672.

The Cronbach alpha coefficient for the summary part of the instrument was higher than the 0.7 widely taken as an acceptable cut off (Hatcher 1994). So for the trial group of students, the reliability of the summary part of the instrument was acceptable. This means that the internal consistency of the set of results is acceptable as more than 70% of the variance is systematic (Pedhazur & Pedhazur Schmelkin 1991: 92-97).

4.6.2 The reliability of the explanation part of the VOCP instrument

The explanatory part of the instrument allowed more than one explanation option to be chosen for each stem statement, and the number of options differed from statement to statement. In the absence of a routine test of reliability for such a multiple-choice instrument, Chi squared values gave an indication of the reliability of the trial group's response to the explanatory part of the instrument. The focus was whether respondents chose the last option (None of these) or any of

the other options for each item (not looking at the specific options), in the same way. Two tests were conducted. The first test used data from the full set of items, and the second test used data from a reduced set of items. The set of items was reduced from 24 items to 17 items by eliminating the items with the last option (None of these) chosen the most frequently (20 or more times out of 230 responses). These results and information about the data are shown in table 4.3.

Table 4.3: Two Chi squared tests to probe the reliability of the explanatory part of the VOCP instrument

	Full set of 24 items	Reduced set of 17 items
Degrees of freedom	23	16
Chi-Square value	98.6525	22.3652
Probability	0.0001	0.1318
Total sample size	5505	3902
Total frequency of last option	331 (i.e. 6%)	165 (i.e. 4%)
Total frequency of other option	5174 (i.e. 94%)	3737 (i.e. 96%)

Chi square tests deal with categorical data (Gillham 2000: 71), and were thus an appropriate choice to probe the reliability of the explanatory part of the instrument. The Chi square test compares the obtained frequency with the expected frequency of a response (Gillham 2000: 73). According to the Unisa statistics consultant who performed the Chi squared analyses of the data, the highly significant Chi squared value for the full data set indicates that the students did not respond in the same way to the statements, i.e. the full set of items cannot be seen as reliable. On the other hand, the reduced set of data gave a Chi squared value that was not significant. Therefore the responses to these statements were more or less equal and the statements can be seen as equally reliable as a measuring instrument (Müller 2003: personal communication). Appendix F contains the shortened reliable explanatory part of the instrument based on the reduced set of 17 multiple-choice items.

4.6.3 Conclusion of reliability results from the trial use of the VOCP instrument

The results for the trial group of students showed that the summary part of the instrument was reliable, but for students' choice of the "none of these" option the reliability of the explanatory part of the instrument was improved by using a reduced set of items.

Results for evaluating the validity of the instrument

The emphasis of the research was on the validity of the instrument, so validity was evaluated in a number of ways.

4.7 Validity framed as the potential for the instrument to express the views of students

The first aspect of the validity of the instrument is to what extent the instrument expresses the views of students. One way to consider this is to ask whether the instrument failed to allow the trial group of students to express their views. In other words, how often did respondents choose “Neutral” in the summary part of the instrument and how often did respondents choose “None of these show what I think of chemistry practicals” for the explanatory part of the instrument?

For the summary part of the instrument, there were from 221 to 229 usable responses for each item, and the proportion of times Neutral was chosen ranged from 1% to 32%. For the explanatory part of the instrument, there were from 225 to 230 usable responses for each item, and the proportion of times “None of these shows what I think of chemistry practicals” was chosen ranged from 2% to 12%. Thus the option of Neutral for the summary part of the instrument was not chosen more than the set of Strongly agree, Agree, Disagree and Strongly disagree. Similarly, the last option for the explanatory part of the instrument was not chosen more than the other options were chosen from the set of options for an explanatory item. Therefore, in considering to what extent the instrument expresses the views of students, it seems that the instrument did allow the trial group of students to express their views as the group did not predominantly choose the “Neutral” and “None of these” options. These results are interpreted as students being able to express their views.

Another way to consider this aspect of validity is to ask whether the trial group of students were able to express their views at all. Looking at each statement or option in turn for levels of agreement with the views expressed in the items shows that by choosing their responses the students were able to express the views they chose. For example, using the summary part of the instrument, the group of trial students has shown that most agree (strongly or otherwise) that a benefit of chemistry practicals is to develop skills. Most agree (strongly or otherwise) that a benefit of chemistry practicals is to gain more knowledge, and so on. In other words, the students have been able to express their views.

The data from the summary part of the interview were sorted to show from most to least which statements the students agreed with (Strongly agree and Agree combined). The result was the following order of categories, with the percentage agreement shown in parentheses: chemicals react (93.4%); help understanding (90.1%); knowledge (87.6%); skill (87.2%); creative (82.4%); nature of chemistry (79.6%); curiosity makes me investigate (73.4%); record/report (70.7%); required (69.9%); apply chemistry (69.9%); lack equipment/ chemicals (68.3%); safety (67.9%); motivate (67.3%); limits to understanding (63.8%); apparatus (62.9%); evidence (60.6%); lack time (60.4%); learner behaviour (57.7%); practical not working (53.1%); reasoning (51.4%); group work (49.5%); teacher (46.5%); theoretical background (46.2%); physical environment (41.5%).

So this group of students agreed more with the statements about chemicals reacting, and practicals helping them understand and gain knowledge and skills, than with the statements about group work, teachers, theoretical background and physical environment in practicals. It is now easier to see what the views are that this group of students have expressed about the benefits and problems of chemistry practicals. The explanations of each statement in the explanatory part of the instrument were similarly sorted to show in greater detail what this group of students' views were about each statement. Four examples follow, with the percentage of students who chose the explanation given in parentheses. As students were allowed to choose more than one option, the total for each statement is more than 100% of students.

The first example shows students' views about the category labeled "chemicals react". Students chose the subcategories to the following extent: understand (68.6%); useful knowledge (40.3%); safety proviso (27.9%); useless (12.4%); None of these (5.8%).

The second example shows students' views about the category labeled "safety". Students chose the subcategories to the following extent: learn to work with dangerous substances (66.8%); learn to work carefully (50.7%); accidents teach (36.2%); None of these (7%).

The third example shows students' views about the category labeled "help understanding". Students chose the subcategories to the following extent: order/priority (48.2%); experience (47.8%); positive attitude (47.4%); sometimes not (7.9%); not school chemistry (7.5%); None of these (4.4%).

The final example shows students' views about the category labeled "environment". Students chose the subcategories to the following extent: safety (52.0%); onus on teacher (38.2%); effect on results (29.3%); None of these (12.0%).

So considering whether the VOCP instrument allowed this group of students to express their views of chemistry practicals, the examples have illustrated that for each statement some options were chosen more than others as showing what the students thought of chemistry practicals. This group of students did therefore express their views. The individual student's views would be obtainable from that individual's completed summary (Bohner & Wänke 2002: 28) and explanation parts of the instrument. Overall, these results demonstrate that the VOCP instrument has both functional and face validity for Gauteng grade 10 to 12 Physical Science students expressing their views about the benefits and problems of chemistry practicals.

4.8 Views in the instrument compared with views in literature

The above section has shown that the VOCP instrument can be used to express the views of grade 10 to 12 Gauteng Physical Science students. The views are derived from the input of various groups of grade 10 to 12 Gauteng Physical Science students. Therefore, the VOCP instrument provides face validity for grade 10 to 12 Gauteng Physical Science students. But what about other people looking at the VOCP instrument? What about those familiar with science education literature? In a broader context than Gauteng, an indication of the face validity of the instrument was found by comparing the empirically derived views expressed in the instrument with views expressed in literature from countries such as the USA, the UK, Australia and European countries.

A comparison of the views expressed in the VOCP instrument with views about science practicals found in literature (Ainley 1990; Atkinson 1990; Baird 1990; Beane 1990; Bennett & Holman 2003; Bliss 1990; De Vos *et al.* 2003; DeBoer 1991; Dombrowski & Hagelberg 1985; Erduran & Scerri 2003; Fairbrother 2000; Friedler & Tamir 1990; Gardner & Gauld 1990; Head 1982; Hegarty-Hazel 1990; Howard & Boone 1997; Jenkins 1999; Jenkins 2000; Kimbrough 1995; Layton 1990; Leach & Paulsen 1999; Manana 1994; Millar *et al.* 1999; Molyneux-Hodgson *et al.* 1999; Monk & Dillon 2000; Nagel 1981; Nakhleh *et al.* 2003; Ntombela 1999; Osborne 2000; Pickering 1987: 521; Solomon 1980; Solomon 1999; Tiberghien 1999; Tobin *et al.* 1994; Van Praagh 1983; Watson 2000; Welzel *et al.* 1999; White & Tisher 1986; White 1996; Woolnough & Allsop 1985; Woolnough 1991a) showed that only fourteen views out of 163 views expressed in the explanation part of the instrument were not found in the reviewed

literature. Overall the face validity of the VOCP instrument should therefore be acceptable to someone familiar with science education literature. Furthermore, some of the fourteen views may be of interest to those involved in science and chemistry education.

4.8.1 Views not found in the reviewed literature

The fourteen views (see table 4.4 below) included some views specific to schools, such as the amount of time spent on practicals and having enough equipment. These views are probably too specific to schools to be mentioned in the reviewed literature, yet they are views held by students. Other views are too risqué to appear in literature. For example, the view that small accidents help students learn how practicals should be done, and the view that a student should suffer the consequences of inattention, are not likely to be published in literature. Yet these are empirically derived views of students and should be seen as part of what may be happening during chemistry practicals. The personal student views, such as the student being motivated by chemistry because the future may be barren of chemistry practicals, add further new insights into the dynamics of chemistry practicals. The empirical development of the VOCP instrument has thus made an important contribution to knowledge of students' views of chemistry practicals.

Table 4.4 Empirically derived explanations not found in literature, with the corresponding statements provided *in italics* for clarity

<i>Statement</i>	Empirically derived view not found in literature
<i>I benefit when I learn to avoid accidents during Chemistry practicals.</i>	Yes, but small accidents help me remember how it should be done.
<i>I benefit from recording and reporting the Chemistry practicals we do.</i>	Yes, I benefit because when I want to remember something, I check my record.
<i>Chemistry practicals motivate me</i>	Yes, especially because later in life I may not have the chance to do Chemistry practicals.
<i>A problem of Chemistry practicals is we do not have much time to do practical work.</i>	No, we do a lot of Chemistry practicals.
	No, we have more than enough time to get through each practical we do.
	Yes, time is a problem because by the time we get all the equipment ready, the period is already half over.
<i>A problem of Chemistry practicals is we don't have enough equipment and chemicals for all the experiments that we need to do.</i>	No, we have all the equipment we need.
	Yes, and because of this problem sometimes some chemicals are not available and we cannot see certain reactions.
<i>A problem of Chemistry practicals is sometimes the practicals do not go well, or as planned.</i>	Yes, but I must do the practical properly so that it goes according to plan.
	Yes, but it depends on the resources of the laboratory.
<i>A learner who is not co-operative is a problem in Chemistry practicals.</i>	Yes, because I can't work when someone is fooling around.

	Yes, and this learner won't know what happened in the practical.
<i>A problem is doing Chemistry practicals in an environment not suitable for practicals.</i>	Yes, because practicals done in an unsuitable environment can be inaccurate or may not work.
<i>A problem of Chemistry practicals is teachers expect learners to do things themselves while the learners don't understand.</i>	Yes, but if the teacher did explain and the learner wasn't listening then the learner should suffer the consequences.

4.8.2 Using student views to establish the content domain of the VOCP instrument

The method used to develop the VOCP instrument turned to students' views to establish the content domain of the instrument. This was a departure from the norm of using literature to establish the content domain of an instrument. The appearance of most of the VOCP instrument views in literature may seem to show that the literature would have sufficed to establish the content domain of the instrument, but this is not so. The literature was reviewed with the VOCP instrument in hand, so views in literature corresponding with the view expressed by students in the VOCP instrument could be drawn out of the plethora of views in literature. The VOCP instrument would not have had the same content domain if the vast and unspecific literature had been used to set the content domain of the instrument. The departure from the norm of using literature, in favour of a completely empirical approach, is thus vindicated.

4.9 Validity framed as potential use of instrument by teachers

The instrument is not valid if it is unusable. Another evaluation of the validity of the instrument is therefore to give an example of how data could be interpreted and used to inform the planning of chemistry practicals, using data from the trial use of the instrument. Box 1 shows how the data could be used.

Box 1: An example of how a teacher could use data from the VOCP instrument to improve teaching

The highest percentage agreement on the summary part of the instrument was agreeing that a benefit of chemistry practicals is to know how chemicals react. In the explanatory part of the instrument, almost 70% of the students expressed the view that this benefit derives from the practical helping them to understand the specific reaction of the practical. The teacher could utilize this view of this group of students by planning mini-practicals to demonstrate specific reactions as part of the general scheme of teaching and learning. A practical demonstration by the teacher or by a student of a reaction could thus contribute to the group's feeling of understanding the reaction.

Reactions aside, the second highest level of agreement was agreeing with the more general view that chemistry practicals help the student understand chemistry. In the explanatory part of the instrument, three explanations seemed equally popular and were chosen by just under half the students each. Topping the list was the view that the students understand more clearly if they learn about the chemistry and then do the practical. The teacher could therefore check what the other half of the group feel – no preference or prefer to do the practical before learning the chemistry – and plan the sequence of activities accordingly. The next explanation chosen by about half the students was that understanding chemistry comes from actually working with the materials. The teacher would therefore not rely entirely on the practical demonstrations discussed in the first paragraph of this box, but would also plan practicals which students perform themselves. The last explanation chosen by about half the students was that understanding chemistry comes from being shown the work in a fun atmosphere. The teacher could therefore deliberately encourage positive attitudes during practicals, both demonstration and student practicals. For example, encourage the feeling that this is fun, interesting, amazing, cool, etc. and planning when to interject with greatest effect.

For the trial group of students, the smallest percentage agreement was with the statement that doing practicals in an environment not suitable for practicals is problematic. Although this garnered the least agreement out of all the statements, over 40% of students did agree with this statement. The teacher could therefore attend to this aspect of practicals. According to the Explanatory responses, safety was the major concern about the physical environment of practicals (approximately 50% of students chose this view), with the onus being placed on the teacher to take appropriate action (just under 40% of students chose this view). The teacher could therefore plan that practicals are not conducted unless the physical environment is safe enough for the particular practical and that the physical environment of the practical (classroom or laboratory or outside) be made as safe as possible. Examples of safety measures are a safety screen for a reaction which may explode, ventilation for reactions using or producing toxic substances, a fire extinguisher and/or sand bucket for fires.

The teacher could also include the students in the safety measures, by making sure students know what to do in an emergency and how to behave safely during practicals in general. Including students in the safety measures is supported by the data from the trial use of the instrument. Close to 70% of the trial group of students agreed that they benefit from chemistry practicals when they learn to avoid accidents during chemistry practicals. In the explanatory

part, 67% of the group thought that they benefit because they learn how to handle different dangerous substances. Making use of the students' apparent willingness to take responsibility for their safety, the teacher could therefore plan to teach the learners the safe way to behave using specific chemicals. The range of practical work available to the group of students could be increased by training the students in safe behaviour. This therefore opens up future planning of practicals for the group of students.

The box has given a few examples, but the teacher could interpret and use the data for all the statements in a similar manner. In other words, the instrument can provide results which can be interpreted and used to inform the planning and running of chemistry practicals. If this happens with the final VOCP instrument, the instrument will then have both outcome validity in a successful completion of an action research spiral of problem solving, and catalytic validity in that deeper understanding provided by the research prompts the practitioner to change practice (Anderson *et al.* 1994: 30-33).

4.10 Process validity in the development of the VOCP instrument

The method used in the empirical development of the instrument formed the primary procedure for trying to ensure the validity of the instrument. All results presented so far are therefore also the results of this aspect of validity.

4.10.1 Interpretation of the process validity of the instrument

Process validity involves using a variety of research methods to guard against acquiring a simplistic view of events (Anderson *et al.* 1994: 30-33). Developing the VOCP instrument used two different questionnaires with consequently different procedures for analyzing the data from the questionnaire, as well as interviews and trial use of the instrument. This variety of research methods prevented the VOCP instrument providing a simplistic view of chemistry practicals. Therefore the method of developing the VOCP instrument used a valid process. Furthermore, as students were seen as insiders in the research, there was also democratic validity in every step of the process (Anderson *et al.* 1994: 30-33).

Another indication that the process was valid is that the results and interpretation of results presented above in this chapter show that the aim of the research and the objectives of the research have been achieved. So, in empirically developing a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools, the following objectives have been achieved. The process has resulted in the:

- Design and development of an instrument which is both quick to use (see summary part) and allows the full range of students' views to be expressed (see explanatory part).
- Development of the instrument as a questionnaire (see instrument).
- Use of an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument (see procedures and sampling results).
- Use of Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the instrument (see results of using questionnaire 1, questionnaire 2 and the interviews).
- Evaluation of the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature (see face validity).
- Use of the instrument in schools in Gauteng (see trial use of the instrument).

The most important way that validity was ensured was to follow the lead provided by the development of the VOSTS instrument (Aikenhead & Ryan 1992: 477-491) in the empirical development of the instrument and attempts to minimize the ambiguity of the items. The departure from the VOSTS method in developing the VOCP instrument has been vindicated by the comparison of the views expressed in the VOCP instrument with views found in literature (see face validity).

4.11 Summary of Chapter 4

Following the stages of the research, the results and interpretation of results show in detail how the aim and objectives of the research were achieved and the validity of the VOCP instrument evaluated. In other words, a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools was empirically developed. This VOCP instrument is both quick to use (summary part of the instrument) and allows the full range of students' views to be expressed (explanatory part of the instrument). The format of the instrument is a questionnaire.

The process of developing the VOCP instrument was an empirical process of obtaining Gauteng grade 10 to 12 Physical Science students' input at each stage of the development of the instrument. The process thus allowed the use of Gauteng grade 10 to 12 Physical Science students' English words and phrases as much as possible in the VOCP instrument. These words and phrases were obtained and validated using two questionnaires and interviews. The purposive

sampling of schools ensured that the English language situation of South African (Gauteng) schools was incorporated into the research process, in that a school with low and a school with high achievement for English language in the senior certificate responded to questionnaires 1 and 2 respectively. Overall, the instrument was found to have process validity because of this empirical method used to develop the instrument.

The resultant instrument was used as a trial in three schools in Gauteng. The trial use of the instrument provided data for evaluating the reliability and further aspects of the validity of the VOCP instrument for that group of students. The reliability was acceptable for the summary part of the instrument (Cronbach alpha coefficient). The reliability for a reduced set of explanatory items was acceptable (Chi squared tests).

For the trial group of Gauteng students, the instrument was found to hold the potential to express students' views about the benefits and problems of chemistry practicals, and to have the potential to be useful to teachers. In other words, the instrument was found to be valid for both these aspects. Further evaluation of the validity included evaluation of the face validity of the instrument by comparing the views of Gauteng grade 10 to 12 Physical Science students, as expressed in the instrument, with views in literature. The instrument was found to have face validity in this aspect and the method used to establish the content domain of the instrument was thus vindicated.

Chapter four completed the presentation of the research. Chapter five draws the work to a conclusion with a review of the preceding chapters, a return to the research problem and recommendations for effecting improved practice.

Chapter 5 Conclusion to the development and evaluation of the Views On Chemistry Practicals instrument

In chapter 5, a review of the background and literature arguments, and of the methods and the results presented in this dissertation of limited scope, leads to the conclusion that the empirical development and validation of the VOCP instrument has provided a successful solution to the research problem. The problem was the absence of an instrument relevant for South African purposes that will determine students' views of the benefits and problems of chemistry practicals. The significance of the research lies not only in the VOCP instrument providing a description of a range of views held by Gauteng grade 10 to 12 students about the benefits and problems of Chemistry practicals, but also in the demonstrated potential for Gauteng teachers to improve their chemistry practicals using the VOCP instrument as a valid and needed tool for measuring their students views about the benefits and problems of chemistry practicals.

5.1 Background arguments provided the rationale for the research

In chapter one, an argument was developed showing that three important aspects of the South African situation highlighted the need for an instrument to measure South African (Gauteng) students' views of the benefits and problems of chemistry practicals. The first aspect was that South African teachers tend to view science practicals in terms of the benefits and the problems of practicals. Secondly, in general teachers do not know their students' views about chemistry practicals unless teachers ask students their views, and this applies to South African teachers as well. Finally, the potential exists for South African teachers to use their students' views of the benefits and problems of chemistry practicals to improve their facilitation of chemistry practicals.

There was therefore a clear need for an instrument for South African teachers to use to measure their students views of the benefits and problems of chemistry practicals. No such instrument was found in literature, so the research problem was identified as an absence of an instrument relevant for South African purposes that will determine students' views of the benefits and problems of chemistry practicals. The aim of the research was therefore to develop such an instrument. The instrument was developed for Gauteng Province of South Africa, using schools from the Tshwane South district.

5.2 Argument developed from literature supported the development of the VOCP instrument

In chapter 2, the following argument was developed and provided strong support for the development of the VOCP instrument and for the method in which the instrument was developed. Chemistry is a distinct science discipline, so an instrument was needed for measuring views on chemistry practicals and not science practicals in general.

Science practicals were shown to be important in a number of ways. For example, science practicals are the *sine qua non* of school science and provide a unique learning experience at school, which opens up ways in which teachers can implement changes for the better. Science practicals are seen as important for improving attitudes to science, thus ensuring the continued supply of students to follow careers in the scientific disciplines. For students themselves, science practicals are important for developing scientific literacy and procedural understanding. The continuous assessment component of the senior certificate makes science practicals important to South African students. Science practicals are also seen as important by curriculum developers and implementers because science practicals can be used to achieve outcomes in the cognitive, skills and affective domains, and practicals provide a way for education to be truly inclusive. Given the importance of science practicals, a sobering point was that practicals really need to be thought through to realize their potential. Therefore, the development of the VOCP instrument was supported as a contribution to teachers realising the potential of chemistry practicals in South Africa.

The review of the state of practical work in secondary schools in South Africa showed that practicals continue to be associated with certain benefits and problems. Achieving benefits, such as science practicals improving students' understanding, cannot be taken for granted in the South African situation. Furthermore, Gauteng teachers continue to face problems in running science practicals. Therefore the emphasis on benefits and problems in the VOCP instrument was justified. In South Africa, science practicals contribute to the continuous assessment for the senior certificate, science practicals form part of a science class and chemistry forms part of the Physical Science. The development of the VOCP instrument for measuring the views of Grade 10 to 12 Physical Science students in South Africa was thus supported.

Science practicals were shown by science education literature in general to be both beneficial and problematic. For various reasons there is a predominance in literature of opinion, and a lack of unequivocal research-based evidence, about the benefits and problems of practicals. This

deficit in literature lent support to the method used in developing the VOCP instrument. The method used students' opinions to empirically establish the content domain of the VOCP instrument, instead of turning first to literature for the content domain and then empirically developing the instrument from the literature-derived content domain.

Students' views were shown to play an important role in the success of teaching, but teachers' and students' views were shown to differ. Therefore the need for the VOCP instrument to allow teachers to measure students' views on chemistry practicals was confirmed. The wide range of student views on chemistry practicals highlighted the need for the explanatory part of the instrument, which can represent as fully as possible all the views on chemistry practicals.

The underlying assumption of developing the VOCP instrument as a tool for teachers to use to improve chemistry practicals was supported by literature showing that students' views can be used by a teacher wanting to improve her (his) teaching. Action research was discussed as a suitable way for teachers to accomplish this improvement. Existing instruments commonly used in science education research were found to be insufficient for measuring students' views about the benefits and problems of chemistry practicals in South Africa, so the need for the development of the VOCP instrument was again apparent.

In total, literature therefore provided a strong argument supporting the development of the VOCP instrument for improving chemistry practicals in South African (Gauteng) schools. The review of the literature thus added to the rationale for the development of a two-part instrument, designed for use by teachers.

5.3 The method and results of developing the VOCP instrument

The most important factor guiding the method for developing the VOCP instrument was the need to ensure as much as possible that the English language in the VOCP instrument is understandable to target students, namely Gauteng grade 10 to 12 Physical Science students. The method was therefore informed by the method used to develop the VOSTS instrument. In developing the VOCP instrument, the method used to develop the VOSTS instrument was adapted so that, instead of using literature, Gauteng students' views were used to establish the domain of the instrument. This was necessary as science education literature was not specific to the South African science education tradition and did not provide an unequivocal basis for the content domain of the VOCP instrument.

The four stages in the process of developing and trialling the VOCP instrument provided a method that attended to the South African linguistic situation. Data were collected from different schools using two questionnaires, interviews and trial use of the VOCP instrument. The purposive sampling, based on the English language results of the school, ensured that the language of students with poor English results was represented in the instrument, but those students with better English results articulated the meaning of the statements made by the first group of students. The strength of the method was that these empirically derived views, as expressed in the items of the VOCP instrument, were checked for meaning, understandability and completeness of the items in the interview stage. It turned out that the empirically derived items were predominantly meaningful, understandable and complete, but the data from the interviews did prompt improvements to a few items of the VOCP instrument. The resultant VOCP instrument comprises a two-part questionnaire, which provides teachers with a summary part (based on the SLEI format) for quick and easy use, and an explanation part which teachers can use to describe in more detail the views held by their learners on the benefits and problems of chemistry practicals.

The method using questionnaires and interviews to empirically develop the VOCP instrument was a method with process validity, and further methods were used to probe the reliability of the VOCP instrument and confirm the validity of the VOCP instrument in other aspects. Data from trialling the VOCP instrument at three schools were used in these methods. For the group of three schools, the Cronbach alpha coefficient (0.7672) for the data of the summary part of the instrument indicated that the summary part of the instrument is reliable. For the group of three schools, the Chi squared results for the explanatory part of the instrument showed that deleting some of the items increased the reliability. The shortened reliable explanatory part of the instrument is presented in Appendix F, but all items are included in the VOCP instrument presented in Appendix E. The VOCP instrument therefore allows students' views to be expressed in all their diversity.

In complementing the process validity of developing the instrument, the validity of the VOCP instrument itself was demonstrated using three methods. Firstly, the instrument was shown to express the views of the trial group of students about the benefits and problems of chemistry practicals. This represented both functional and face validity for Gauteng grade 10 to 12 Physical Science students.

The second method validating the VOCP instrument was the comparison of the views expressed in the VOCP instrument with the views expressed in literature. This method not only showed that the face validity of the VOCP instrument extends to those familiar with the science education literature but also affirmed the methodological decision to empirically establish the content domain of the VOCP instrument. This comparison between VOCP views and literature views highlighted the significance of the VOCP instrument in providing a current record of views held by South African students on chemistry practicals. This record has not existed up to now.

The third and final method of validating the VOCP instrument was to demonstrate that data obtained from using the instrument with the trial group of Gauteng students can be used by teachers for improving their planning and running of chemistry practicals. This is a particularly significant result because the research was motivated by the need for an instrument which teachers can use to improve chemistry practicals.

5.3.1 The limitations of the research

Only two substantial limitations emerged in the process of developing the VOCP instrument. The first is that analysis of questionnaire 1 data would have benefited from additional input by judges other than the researcher as sole judge. The second limitation is that the instrument was developed to measure the views of Gauteng students but the samples for the empirical development of the instrument were limited to the Tshwane South district in Gauteng. Both these limitations are an artifact of the limited nature of the research reported here and not an indication of an intrinsic flaw in the research design. In larger scale research there would have been a bigger team of researchers providing input at each stage of research, and sampling would have covered the whole of Gauteng.

5.4 The significance of the research

The methods used have achieved the aims of the research to empirically develop a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools. The resultant VOCP instrument is a significant research result for the two reasons highlighted above and reiterated as follows.

Firstly, the empirical development of the VOCP instrument created a record of a range of students' views about chemistry practicals held by grades 10 to 12 Physical Science students in Gauteng (Tshwane South) from 2002 to 2003. Most of these views have appeared in science education literature at some stage or another and in some context or another, but the

combination and chemistry specificity is a unique result of the empirical development of the VOCP instrument.

Secondly, the research is significant because it has produced a valid and necessary instrument which can be used by Gauteng teachers to improve their planning and running of chemistry practicals. The VOCP instrument has been shown to allow grade 10 to 12 Physical Science students from Gauteng to express their views about the benefits and problems of chemistry practicals in summary and in full explanatory detail.

5.5 The research problem has been solved by the research

In conclusion, the VOCP instrument is a valid and significant instrument which has been empirically developed as a two-part instrument to measure the views on chemistry practicals held by grade 10 to 12 Physical Science students in Gauteng schools. The research process of developing the VOCP instrument has therefore solved the research problem that, prior to the successful completion of this research, there was an absence of an instrument relevant for South African purposes that determines students' views of the benefits and problems of chemistry practicals.

5.6 Motivation for improved practice and recommendations

Chapter two provided motivation for the use of the VOCP instrument to improve teachers' practice. When teachers obtain knowledge of their students' views on chemistry practicals, the teachers should be in a position *inter alia* to:

- think through the practicals they plan in a way which improves the practicals,
- use a rationale for practicals that is truly satisfying to their students,
- find a way to unlock the benefits of practicals, such as achieving improved student understanding with practical work,
- focus on the laboratory as a learning environment,
- address the problems their students perceive with chemistry practicals, and
- attend to a wide range of student views and consequently refine and improve their practicals.

Furthermore, the VOCP instrument has been designed to facilitate use by teachers. Following the SLEI format, the summary part of the VOCP instrument fits onto one page (low copying costs and short time needed to fill in) and is easily hand scored by teachers. Explanations of students' choices can be obtained using the explanatory part of the VOCP instrument as a whole or using only those items needed at a particular time.

Box 1 in chapter 4 gives an example of how data from using the VOCP instrument could be used immediately to improve chemistry practicals for that group of students. Immediate action to improve practice is a feature of action research (see chapter 2). Therefore, substantiated motivation exists for teachers to use action research to improve their practice.

The researcher therefore recommends that the VOCP instrument be made available to Gauteng Physical Science teachers through in-service and pre-service programmes as part of action research training. In this way, teachers could learn to improve their practice immediately using action research.

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**Appendix A Letter from Gauteng Department of Education
granting permission to conduct the research**

**Appendix B Questionnaire 1 to derive categories of views and
typical statements**

**Appendix C Questionnaire 2 to derive subcategories of views and
representative explanations**

Appendix D Categories and subcategories with corresponding statements and explanations

Appendix E The complete Views on Chemistry Practicals instrument

This appendix contains all the items developed and used in the trial instrument.

Appendix F The shortened reliable explanatory part of the Views on Chemistry Practicals instrument

This appendix contains the explanatory part of the VOCP instrument as a reduced set of reliable items.