CHAPTER 6 – Summarized findings, implications and recommendations

6.1 Introduction

This chapter describes the findings, by summarizing the analyzed data and their implications and answers the research questions. The study set out to examine the understanding and application of ideas about evidence in experimental design in one secondary school in the Gauteng Province. In order to achieve this purpose the following procedures were undertaken:

- A diagnostic investigation of learners' understanding of the concepts of validity in experimental design.
- A diagnostic test was administered to assess Grade 10 Physical Science learners' understanding of concept of validity. The data collected were then used to answer the following research questions.

1. What understanding do learners in the first year of the Further Education and Training (FET) Physical Science course have of the concept of validity in experimental design?
2. What is the effect of exposure to open-ended investigations on the understanding of learners?

- An assessment of learners' application of concepts of evidence using a Common Tasks for Assessment (CTA) investigation task.

The CTA investigation task was used to answer the third research question:

3. How well can learners' understanding of scientific evidence be demonstrated by the CTA investigation task?

- Development and implementation of class tasks designed to help learners understand and apply concepts of evidence.

Literature reviewed in Chapter 2 revealed that teaching methods designed to teach the understanding and application of concepts of evidence should engage learners with a sense of the whole task (Gott and Duggan, 1996). The chapter argued that open-ended investigations and projects have a particular advantage here because they allow learners to carry out a whole task with the autonomy to put into practice their understanding and application of ideas about evidence. Chapter 2 also revealed that skills and values such as being able to think critically; solve problems; to collect, organize and analyze data; to work in groups as well as independently; to communicate effectively and to make responsible decisions could be realized through open-ended investigations and projects.

Furthermore, chapter 2 argued that the adoption of inquiry teaching and learning is likely to lead to the understanding and application of concepts of evidence in science. It is also assumed that the acquisition of concepts of scientific evidence might help the development of science process skills among learners. Chapter 2 also revealed that the paradigm shift to outcomes based education in South Africa could indeed encourage the understanding and application of concepts of evidence and the ability to solve problems among learners. Indeed, this is supported by Learning Outcome 1 of the Natural Sciences learning area which states that "*the learner will be able to act confidently on curiosity about natural phenomena and to investigate problems in scientific, technological and environmental contexts"* (Department of Education, 2002:8).

The information from the reviewed literature was therefore utilized to develop class tasks.

6.2 Summarized findings of the study

The following section presents the findings which emanated from the probes in the diagnostic test and the CTA investigation task as well as implications of these findings.

The learners' responses to the three probes in the diagnostic test revealed the following:

- In probe 1, which was concerned with the independent variable, the vast majority of the learners fall into the most sophisticated categories. This implies that the learners have a better understanding of the aspects of validity with regard to the independent variable. These findings differ from those of previous study by Albers et al (2003), who found that the understanding of Foundation University students of validity was slightly less sophisticated when it concerned the independent variable.

- In probe 2, which was concerned with determining the most control variables, the majority of the learners' responses also fell into the most sophisticated category. This implies that the learners also have a better understanding of the aspects of validity when dealing with the control variable. This high proportion of learners' responses in these categories appears to be similar to previous analysis of Foundation Physics students (Albers *et al*, 2003).
- Similar to the previous study in the Foundation University level, the majority of the learners focused on the quality of measurements when asked to determine the range and interval of the independent variable. This means that the learners' understanding of validity with regard to the interval and range of the independent variable is slightly less sophisticated than the other aspects of validity. The findings suggest that the problem was related to the learners' confusion over determining the interval and range of the independent variable. Their relative difficulty in this endeavour may partially be due to the fact that this issue was never dealt with in their Grade 9 Natural Sciences course.
- Learners' responses to both the pre-and post-tests indicated that learners' understanding did not change much between the pre- and post-tests. These findings concur with previous study (Albers, 2004). One of the reasons why learners' understanding did not change much between the pre-test and the post-test may be that these learners were exposed to the open-ended investigation tasks before, especially during their Natural Sciences CTA at grade 9 level. The other reason may that there was lack of formative assessment during the teaching of concepts of evidence through open-ended investigations. Consequently, there was no appropriate feedback to suggest where learners' strengths in the understanding of validity concept were and whether there was some area where there weaknesses and therefore a need to improve existed. Comparison between the results of the probes and the CTA investigation tasks indicate a higher degree of application of concepts of evidence in the CTA investigation task than in the probes.

Most learners' responses to the questions in the CTA investigation task revealed the following:

- The vast majority of learners clearly and coherently stated the problem investigated. They were able to formulate the investigative questions satisfactorily, showing they had awareness of the significance of variables. In other words, these learners generated investigative questions that explored the effect of one variable on another variable connected to a scientific phenomenon.
- The learners were able to identify the dependent and independent variable correctly.
- Learners were successful in describing the method to answer the problem/question investigated. Their investigation methods demonstrated an attempt to control variables and manipulate only one variable in an experiment.
- Learners were able to draw graphs with sensible scales, taking into account details such as units and labels.
- Learners were able to draw conclusions in the form of a trend (reflecting a relationship, in words and symbols plus conditions).
- Many learners had difficulty with the question on identifying the control variable. Most of them seemed to answer the question with only a rudimentary idea of what they were doing, with virtually no understanding of the concepts used in the question. However, close scrutiny of learners' responses, to the question regarding method followed to answer the investigative problem (5.3.4), revealed that the large majority of learners did design a logical system for organizing the testing of multiple variables. Thus there is evidence that these learners have an understanding of the concept of variable control. This may point to difficulties in understanding the question as asked, rather than the concepts being tested.

In general, the learners in this study performed showed their ability to apply their understanding of concepts of evidence in the assessment task used. This implies that the majority of learners can apply concepts of evidence and techniques involved in scientific inquiry. Therefore if presented with a problem to solve in a practical situation, the majority of learners could demonstrate the understanding of concepts of evidence to translate the problem into relevant practical activity and set up the conditions necessary to provide a solution. On the basis of these findings, it might be possible that whenever learners are required to demonstrate their understanding and apply the concepts of evidence which they have been taught in other science contexts, performance is high. Moreover, their CTA results indicated that the understanding of identifying variables, constructing graphs; describing the relationship between variables in a graph; formulating the investigative questions were the most applied concepts of evidence. Their relative success in these endeavours may be due to the fact that these learners were exposed to open-ended investigations before, from which the majority of them were able to see the impact of concepts of evidence on the resulting data. This means that the understanding of constructing graphs, formulating investigative question and deducing valid scientific relationships was enhanced during the teaching of concepts of evidence through open-ended investigations. The freedom to generate authentic questions and design investigations through open-ended investigations fostered learners' creativity by allowing them to put into practice their understanding and application of ideas about evidence. Indeed learners demonstrated the understanding of many recognizable concepts of evidence while engaging in open-ended investigations. Many investigations designed by learners illustrated their understanding of concepts of evidence such as reliability and validity during the teaching phase (of concepts of evidence through open-ended investigations). Hence the introduction of inquiry activities and open-ended investigations, which involve the understanding and application of concepts of evidence, could also provide the foundation for the development of the concepts in learners. On the basis of these results it might also be suggested that with more learner involvement in the learning process or in inquiry learning, there would be more understanding and application of concepts of evidence involved in scientific inquiry. As Helgeson (1994) pointed out that all of these skills of a practicing scientist are important and need to be consciously developed before one can carry out the processes of scientific inquiry.

6.3 Answers to research questions

As already mentioned, the data collected using the three probes in the diagnostic test were used to answer the first three research questions since the three probes in the diagnostic test were checking more of a planning part than the evaluation process.

The first research question of this study was: *What understanding do learners entering the Further Education and Training (FET) Physical Science course have of the concept of validity in experimental design?*

This research question refers to the understanding of validity in experimental design that the learners have at the beginning of the course. The major findings of this study were that the sample investigated began the study with a level of understanding equal to a group of Foundation University students tested in the previous study. The findings of this study also revealed that learners' understanding of concepts of evidence in experimental design is at a satisfactory level. This means that these learners have little problems with controlling variables and selecting independent variable in experimental design. In addition, they show awareness and significance of variables in experimental design.

The second research question of this study was: *What is the effect of exposure to open-ended investigations on the understanding of learners?*

This research question refers to the effect of the intervention on learners' understanding.
In the introduction to this study, the point was made that learners' understanding (and therefore application) of concepts of evidence in general appear to become better as a result of increasing experience of scientific investigations. In other words, an understanding of what constitutes validity in experimental measurement and how to proceed in tackling investigative tasks is acquired from exposure to a sequence of experiences of school science (Gott and Duggan, 1996). However, the findings from this study indicate that the intervention does not seem to have made a major effect since the difference in the number of responses between the pre-test and post test is relatively

small. In fact, the intervention did not change the understanding of validity. However, (at most) this interpretation cannot be supported statistically due to the low frequencies for some of the alternative options. Therefore it is not possible to make inferences as to whether the understanding of concepts of evidence can easily be taught through a sequence of open ended investigative tasks. Garratt and Tomlinson (2001), point out that in teaching learners the skills they need to set up valid experiments in science, all teachers can really do is to stimulate and enthuse them, and point them in the right direction.

The third research question in this study was: *How well can learners' understanding of scientific evidence be demonstrated by the CTA investigation task?*

This research question refers to the application of concepts of evidence in experimental design among learners. The data obtained from the CTA investigation task was used to answer the third research question because the CTA investigation task was asking more of an evaluation process than the planning part. The findings from the CTA investigation task showed that if presented with an investigative problem or task in the CTA, the majority of learners can demonstrate their knowledge and understanding of concepts of evidence to translate the problem into relevant practical activity and set up the conditions necessary to provide a solution.

6.4 Recommendations:

The findings of this study have some implications for the teaching of secondary school science, curriculum development, learning facilitators (subject advisers), science learners and science teacher education in South Africa. Consequently, the following recommendations are made which may significantly improve the development of understanding of concepts of evidence in secondary school science classrooms. The results of this study highlight the need for providing secondary science learners with opportunities to practice and develop the understanding of concepts of evidence. Gott and

Duggan (1996) suggest that open-ended investigations have a particular advantage here because they allow learners to carry out the whole task and put into practice their understanding and application of ideas about evidence. This also improves learners' competence in science process skills because open-ended investigations also foster the practice and development of these skills in learners. The researcher also suggests that teachers need to provide on-going inquiry activities in secondary science classrooms in order to enable learners apply the concepts of evidence and use science process skills frequently. This requires the teacher to provide more opportunities for learners to do this, as well as using suitable assessment tasks and appropriate feedback so that learners can identify their strengths and see where they are still weak and need to improve. This implies that secondary school science teaching methodology and assessment tasks should be structured in such a way that science teachers should be able to integrate concepts of evidence in inquiry situations and outcomes-based Curriculum 2005. The assessment tasks should also engage learners in such a way that they experience the application of concepts of evidence and science process skills in inquiry or problem-solving contexts. Science teachers should therefore make provision for open-ended investigations in their classrooms. Indeed it has been suggested that open-ended investigations and projects have a particular advantage in helping learners understand (and therefore apply) concepts of evidence since they (open-ended investigations and projects) allow learners to carry out a whole task with the autonomy to put into practice their understanding of, and apply, ideas about evidence (Gott and Duggan, 1996). This is one area of teaching and learning which the Gauteng Department of Education should prioritize in order to meet the expectations and principles of the new curriculum (Curriculum 2005), which requires understanding and application of concepts of evidence in science classrooms. The introduction of open-ended investigations and projects is likely to lead to the understanding and application of concepts of evidence in experimental design, as shown in chapters 4 and 5. Science learning facilitators or subject advisers should assist science teachers with ideas on how open-ended investigations or meaningful investigations can be implemented in science classrooms. Recently, guides and planning documents have become available. These provide a scaffold for both teachers and learners in the process of developing meaningful or open-ended investigations (Hackling and Fairbrother, 1996).

If science learning facilitators do not have sufficient knowledge with regard to this aspect of science, they should be encouraged to liaise with academics or higher learning institutions who may suggest ways of implementing meaningful investigations without spending large amount of money on facilities and equipment.

6.5 Problems experienced with this study

6.5.1 Problems experienced with the literature study

The researcher experienced a lack of literature on the understanding and application of concepts of evidence in experimental design, particularly in the South African context. Although there were more studies on the reliability concept than on the validity concept, these sources were either outdated or focused on the University learners. The researcher also failed to find publications on the link between Curriculum 2005, inquiry teaching and learning, open-ended investigations and concepts of evidence in experimental design, in South African situations.

6.5.2 Demand of the class tasks designed to develop an understanding of concepts of evidence in learners.

There were some disadvantages of an open-ended instructional approach during the intervention. This approach posed substantial management challenges for the researcher. Having eight or nine groups of learners all working at the same time required the researcher to evaluate and mediate the learners' questions and plans. The researcher needed to determine what needed to be modified, how to probe the learners so that he could assess their plans, and make decisions about what changes to suggest to learners. Moreover, learners' investigations (in the class tasks) consumed substantial amounts of time and this was therefore an expensive exercise, in terms of time, to both the researcher and learners. Consequently, some groups might have performed the investigations for the sake of completing the tasks.

6.6 Limitations of the study

The research was confined to the understanding and application of concepts of evidence in experimental design, in one secondary school in the Gauteng Province. Therefore the study's results cannot be generalized beyond secondary schools because primary schools, teacher training colleges and universities are not represented. Moreover, this was a pilot study and the sample size was small, therefore the researcher is careful not to make any claim that my descriptions, explanations, and recommendations are transportable to all other secondary school physical science classrooms.

6.7 Conclusion

Literature reviewed has revealed that the nature and structure of science supports the adoption of inquiry learning and that the understanding and application of concepts of evidence in experimental design can be enhanced and developed through open-ended investigations. Reviewed literature also established that a paradigm shift to outcomes based education in South Africa could indeed encourage the understanding and application of concepts of evidence and the ability to solve problems among learners.

Through this study, it was established through empirical research that secondary school physical science learners can apply ideas about evidence in experimental design. It was established that their relatively success in this endeavour could be due the fact these learners were exposed to open-ended investigations. It can be stated; as a result, that this is one area of teaching and learning which the Gauteng Department of Education should prioritize in order to meet the expectations and principles of Curriculum 2005 which is based on outcomes based education and inquiry teaching and learning. Open- ended investigations in secondary school science are likely to comply with the practice suggested in Curriculum 2005 which could contribute to the development of concepts of evidence in learners.

6.8 Areas for further research

Interesting new research questions would arise in science classroom environments redesigned according to recommendations based on the findings of this study. Two possibilities suggest themselves readily. The first is a detailed analysis of factors that may have prevented learners to identify the control variables in the CTA investigation task. Of possible interest would be questions such as:

- Are the majority of learners unable to understand (and therefore apply) the concept of control variables?
- Is the question on this aspect in the CTA investigation task not tapping learners' knowledge and, therefore, underestimating their understanding?

A second possibility would be the expansion of the database. An analysis of a much larger sample would possibly yield a more useful set of that than the one discussed here.

Moreover, a close qualitative study of learners in action carrying out the investigations, intended to help them understand and apply ideas of empirical evidence, is needed.