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Investigating the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry at grade11

(Protocol Number 2012ECE198)

by

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A research project submitted to the University of the Witwatersrand, Faculty of Humanities, Wits School of Education, in partial fulfilment of the requirements for the degree of Master of Science in Science Education.

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Abstract

This study was on the investigation of the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry at grade11. Two aspects were used to measure effectiveness. The first aspect was a change in learners' ability to answer questions before and after intervention. The second aspect was the programme's ability to eliminate common misconceptions in electrochemistry.

A sample of five schools was used in the study. At each school a pre-test was given to learners before intervention and a similarly structured and equally difficult task was given after intervention as a post-test. The marks for each learner were compared and the results for each school were analysed using a Wilcoxon signed rank test and a paired data test. Results from both methods of analysis reflected significant improvement in learners' ability to answer questions after intervention at all five schools that made the sample of the research. A question by question analysis was also done to check a change learners' ability to answer specific questions. Improvement in answering particular questions differed significantly, pointing out that certain concepts had been grasped better than others.

Interviews were held with both learners and their teachers. These interviews were held to try and determine the extent to which misconceptions had been identified and eliminated. Pre-tests and post-test analysis reflected that one common misconception, where learners define oxidation and reduction in terms of addition and removal of oxygen was completely eliminated. Learner interviews however reflected a 75% success rate in the elimination of the misconception. Analysis of pre-tests and post-test results also showed a 75% success rate in the elimination of a misconception of the second misconception, where learners take an oxidising agent as a substance that has been oxidised and a reducing agent as a substance that has been reduced, compared to 76% from analysis of the learners' interview results. Teacher interview results also reflected that the Sci-Bono outreach programme is to a high degree able to eliminate common misconceptions electrochemistry.

From lesson observation and teacher interviews another misconception came to light. The misconception held by some learners is that 'the oxidation number is the number of oxygen atoms in the molecule of a compound.' This misconception was also tackled.

During teachers' interviews it emerged that all host teachers perceive the Sci-Bono Subject Matter Experts as effective in eliminating the identified common misconceptions in electrochemistry.

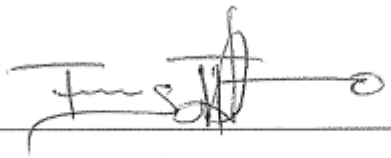
The researcher is convinced that the Sci-Bono outreach programme improves the learners' ability to answer questions in electrochemistry and that they address misconceptions in their teaching. The intervention however does not completely eliminate common misconceptions in electrochemistry. The Sci-Bono outreach programme is thus only effective to a certain extent in the teaching of electrochemistry at grade 11.

The study also revealed that the teachers at schools expect the Sci-Bono Subject Matter Experts to have better pedagogical skills and they also expect them to bring scarce resources when they visit schools. They expect them to be able to tackle all formal and informal experiments covered

in the grade11 curriculum. They believe that, in addition to enabling the elimination of misconceptions, the practicals carried out by the Sci-Bono SMEs also enhance understanding and provide practical skills to learners.

Declaration

I hereby declare that this research project report is my own work and that other than the parts indicated as quotations, no other part has been copied from another source. The paragraphs, sentences and phrases taken from other work have been cited and the reference recorded in the reference list. Sources of ideas that are not mine have also been referenced.

Signed:  (Trust Nkomo)

Date: 12/11/2014

Dedication

I dedicate this study to:

- My wife Shailet and my two sons Nyaladzi and Lakidzani for bearing with me when I could not be avail myself for our family time due to studies
- My primary school teacher, Mr Jele Khupe for giving me a strong foundation for my academic life

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I would like to thank my supervisor, Dr Emmanuel Mushayikwa for his immense contribution throughout the project. His guidance gave me direction, his support gave me strength and his patience, encouragement and understanding spurred me on to the end.

I would also like to thank the management of Sci-Bono Discovery Centre for allowing me to carry out a research on their programme, the Sci-Bono outreach team for allowing me to interfere with their programme and the Gauteng Department of Education for allowing me access into its schools to carry out my study. My special thanks go to all schools and the participants, through whose cooperation and involvement, this study was made possible.

I also thank Nanzelela Sibanda for helping me revive my statistics skills which I needed for analysing data, Enoch Mankune and Matodzi Netshikhudini for sharing with me some computer skills that I needed to put together the document.

I would also like to thank my wife Shailet for encouraging me to move on even when there were challenges. My thanks also go to Anele Davids for continuously asking about the progress of the report. This gave me the zeal to see it completed in time. I also thank him for sharing with me some of his books which were very useful in my study. May I also thank everyone else, who, directly or indirectly influenced my study.

May the good Lord bless you all.

Presentations related to this study

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List of abbreviations

CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Education
DoB	Department of Education
FET	Further Education and Training
GET	General Education and Training
MST	Mathematics, Science and Technology
NSC	National Senior Certificate
SME	Subject Matter Experts
SSIP	Secondary School Intervention Programme
TIMSS	Third International Mathematics and Science Study
UFS	University of Free State

CHAPTER 1 BACKGROUND TO THE STUDY

1.1 Introduction

The Department of Basic Education's report (2012) on the National Senior Certificate Examinations of 2011(p116), shows that learners have been performing poorly in physical sciences at matric level for quite some time. The Third International Mathematics and Science Study (TIMSS) report of 2011 also reflected that South African learners were performing well below par when compared with students across the globe. South African students, assessed at grade 9 achieved an average score of 332 points compared to an international benchmark of 500 points in science (Martin, Mullis, Foy & Stanco, 2012). The National Senior Certificate Examinations Report of 2011, DBE(, 2012, p116) gives percentage pass rates in physical sciences as 54.9% in 2008, 36.8% in 2009, 47.8% in 2010, 53.4% in 2011 and 61.3% in 2012. The percentages given are based on learners scoring 30% or better. The pass percentages do not consider the 60% pass which is a benchmark for qualifying for university entrance.

The knowledge and skills obtained in the learning of mathematics and science go a long way in contributing to the economy of the country as there are a number of processes in industry that require these skills and knowledge. In turn this positively affects the livelihood of the general population hence the interest in making efforts of increasing the success rate in the teaching and learning of this topic. The said efforts come in various forms, including teaching interventions as is the case with the Sci-Bono outreach programme. The study was thus motivated by the fact that the Sci-Bono outreach programme is a unique programme whose effectiveness has not been scientifically checked, particularly in the teaching of electrochemistry. Good models need to be expanded or replicated if they address an important issue like the one under discussion. On the other hand if shortcomings are identified, corrective measures have to be put in place.

Various efforts have been made with the view of raising the pass rate in physical sciences. A number of intervention programmes have been put in place in an attempt to improve learner performance in physical sciences. Sci-Bono Discovery Centre, a Science Centre for the Gauteng Department of Education, runs such programmes and among them is the Emasondosondo outreach programme.

1.2 Sci-Bono Discovery Centre

Sci-Bono Discovery Centre is a Science Centre that is a non-profit organisation that services the Gauteng Department of Education. Its purpose is to promote the teaching and learning of science, mathematics and technology and to increase public awareness and interest in science. Its services departments are Teacher Development Unit, School Support, Science Centre, Career Centre and Corporate Services. These services departments are described briefly below:

- The Teacher Development Unit is concerned with improving teachers' teaching in the field in terms of both content knowledge and methodology. The unit targets teachers at public schools. It organises and manages training workshops for teachers from public schools in Gauteng province. The target schools are schools that usually perform poorly in physical sciences and

mathematics at matric. One model of training involves training teachers at a particular centre for 21 days. During this period the School Support Unit provides relief teachers to stand in for those attending the training. These relief teachers are qualified mathematics and science teachers who are not formally employed. Before deployment to schools, relief teachers are given some training to orient them about the curriculum. The other model involves training teachers on weekends during the term or weekdays during the holidays. The duration of training a particular group of teachers is determined by the amount of content to be covered. For each particular topic covered, teachers are trained on content, methodology and assessment. This is done in an attempt to improve their competence in teaching when they get back to their schools.

- The Science Centre is an equivalent of a science museum. It is an exhibition centre whose main aim is to promote and improve public awareness and also arouse their interest in science. Visitors at the centre are taken around by guides, referred to at Sci-Bono as science communicators. These guides show and explain exhibits. There are 300 exhibits in the centre. The science communicators also conduct science workshops and science shows to teach and entertain visitors. Visitors also partake in science games as they interact with exhibits. The majority of visitors to Sci-Bono are schools from around Gauteng.
- The Career Centre is an arm that focuses on career guidance and counselling to learners. The career guidance team goes out to schools and holds career guidance sessions. At times learners come to the centre and sessions are held at the centre. Counselling services are mainly offered to the Saturday school students but are also made available to learners from around Gauteng and the general public. Sometimes the Career Centre Unit works in conjunction with the Science Centre where private companies and government departments present their exhibitions at the Science Centre and advertise science related careers that are associated with their organisations.
- The Corporate Services unit provides internal support to all other units in the organisation. The support given includes such things as managing human resources, general maintenance of the organisational assets and managing events in the organisation.
- The School Support Unit runs a number programmes that directly benefit learners at schools. Among other programmes, the unit runs a Saturday school programme at the centre.

- The Saturday school caters for grade 10 to 12 learners from schools in and around Johannesburg. These learners are taught physical sciences, mathematics, English and computer skills.
- The unit also runs a Secondary School Intervention Programme (SIPP), a Blended Learning programme and an outreach programme known as Emasondosondo project.
- SSIP is an intervention programme which involves weekend classes at selected priority schools in the province. Schools classified as priority schools are those schools whose matric pass rate is below the provincial set mark of 70%.
- Blended Learning programme is an afternoon revision programme for learners in grade 12. This programme is open to all grade 12 learners who may want revision in physical sciences, mathematics, life sciences and accounting. These subjects are offered on different days to accommodate those learners who may be doing two or more of these subjects at their schools. This arrangement enables them to attend all sessions of the subjects offered at Sci-Bono that they enrolled for at their schools.

- The Emasondosondo outreach programme is the programme under study and is described in the section that follows.

1.3 Sci-Bono Emasondosondo Outreach Project

The Sci-Bono Emasondosondo project is an outreach programme where a team of mathematics and science specialist teachers go out to schools to teach. These specialist teachers are referred to as subject matter experts. The target classes are grades 5 to 7 in the General Education and Training (GET) band and Grades 10 to 12 at the Further Education and Training (FET) band. The outreach team consists of 6 GET and 8 FET subject matter experts. Of the eight FET subject matter experts four are science specialists and the other four are mathematics specialists. The approach as of now is that these subject matter experts stick to a particular grade, with some of them have stuck to the same grades for the past four years or so. These teachers have varying qualifications and experience. Some of the subject matter experts have the experience of working as fulltime teachers at schools but others have only taught in the outreach programme. The majority of these subject matter experts in the programme have a teaching qualification.

The programme targets functional but underperforming high schools, with special emphasis on physical sciences and mathematics. These schools are recommended by the Department of Education. The districts choose schools that they feel will benefit from the programme. At the beginning of each year, each of the 15 districts of the Gauteng Department of Education provides a list of 5 schools to Sci-Bono. This gives a total of 75 schools. The outreach team then visits the five shortlisted schools per district in an exercise to identify and select the two most deserving ones for the implementation of the programme. This leaves them with 30 schools in the province. The school calendar allows the team to service only 25 schools per term. To bring the number down to 25 the outreach team draws a list of schools in order of performance and they also consider the resources each school has, that is, both material and human resources. The five most resourced schools then fall off but this is done in such a way that each district is represented in the remainder. Selection is thus done on high schools. GET schools included in the programme are supposed to be primary schools that are feeder schools for the secondary school where the FET programme is run. Where the high school has more than one feeder school, as is the case with most of them, the selected high school recommends one of the feeder schools based on weaknesses in mathematics and science that they observe in the learners they recruit for grade 8.

Each school is visited by the outreach team, which consists of science and mathematics subject matter experts, once a term to offer intervention classes in physical sciences and mathematics. For each class both science and mathematics sessions would be two hours each. The Sci-Bono subject matter experts offer tuition, both theory and practical work to these classes. The school teachers in charge of the classes for the particular subject would sit in the classroom throughout the lesson.

At its inception in 2004, the Emasondosondo outreach project aimed to raise learner interest in science, particularly physics (Wits/Sci-Bono Physics Emasondosondo Report, 2004). The team consisted of Sci-Bono demonstrators, Wits student teachers, their tutors and sometimes

visiting students from U.S.A. The team would go out to schools and carry out physics demonstrations that showed the wonder of science as well as its role in technology. They would also do demonstrations and group practical work that were linked to concepts covered in the school science curriculum (Taylor, 2013). The idea was to teach physics using apparatus, Taylor (2013) suggests.

The focus of the outreach programme has gradually changed. Instead of carrying out demonstrations, the outreach team members now literally teach. They assist both teachers and learners in tackling those topics that the school teachers find or perceive as difficult. This has been necessitated by the need to raise the percentage pass rate in mathematics and physical sciences at these schools. Science teaching and learning necessitates hands on experiments to be carried out. In most public secondary schools practical work is not done to expectation. One of the reasons is lack of confidence due to the fact that many science teachers are not competent in conducting these experiments, (Muwanga-Zake, 2006). The introduction of the new Curriculum Assessment Policy Statement (CAPS) in 2012 poses an even greater challenge as there is prescribed practical work to be done, both formally and informally. Hattingh, Aldous and Rogan (2007), argue that for intentions of science to be realised, the amount of practical work that learners have to do has to be significant.

There are also challenging topics that are not done well in examinations at matric as revealed by the Department of Education's NSC examination reports of 2012. The role of the outreach team is to tackle these topics and the related practical work at schools. Thus the Sci-Bono subject matter experts are meant to reach out to both learners and educators at these schools. In this way, the programme aims at improving results of the learners receiving direct intervention and at the same time empower the educators to be able to treat those aspects tackled or demonstrated by the Sci-Bono subject matter experts. Hattingh, *et al* (2007) reveal that teachers are motivated by colleagues whom they see trying new teaching methods, especially regarding practical work.

Sci-Bono subject matter experts have access to many resources for teaching purposes, perhaps more resources than teachers at ordinary public schools, especially those schools they serve. More often the Sci-Bono subject matter experts (SMEs) conduct computer mediated lessons. The topic to be taught by the Sci-Bono SMEs at any visit at the school is provided by the subject educator at the school. Ideally these educators would choose those topics they find difficult to teach or difficult for learners to comprehend. One topic often identified by the educators is electrochemistry.

1.4 Problem investigated in this study

The Sci-Bono Emasondosondo project hires SMEs to teach topics at schools. These topics are determined by perceived needs in the curriculum. These needs may be highlighted through examination reports or requests from schools. It is therefore important if and how these felt needs are being addressed. This study focuses on an evaluation of the effectiveness of one such intervention, namely the teaching of electrochemistry.

From the Examiners' reports, DBE (2011 & 2012), electrochemistry happens to top the list of the topics that are poorly done in examinations. De Jong, Acampo & Verdonk (1995), suggested that electrochemistry is difficult to teach and learn. Nestor, Shafer and Ditzler (2008) also rank electrochemistry among the most difficult topics. It is thus these topics perceived to be difficult that lead to poor learner performance in examinations. These are the topics that need to be concentrated on mostly by intervention programmes. The Sci-Bono outreach programme is meant to address this area as well. It is worth finding out how effective it is with regards to addressing this topic. The barometer for use in evaluating the effectiveness of the Sci-Bono outreach programme in the teaching of difficult topics was their effectiveness in teaching electrochemistry at grade 11. In the delivery of lessons on electrochemistry, the Sci-Bono SMEs give a pre-test to the class, introduce the content and explain the concepts. This involves learners conducting experiments in small groups. The SME would then discuss the experiments with the class and use them to explain certain phenomena. The class would then be given a post-test to find out if the learners have grasped the concepts taught.

Although there is an internal monitoring and evaluation process in place for this programme, there hasn't been an in-depth evaluation to determine the effectiveness of the programme to address particular issues, hence the need to evaluate the programme in detail. Such an evaluation would help the programme implementers, in this case, Sci-Bono, to develop a mechanism to improve the programme more directly, (Goe, Bell & Little, 2008).

1.5 Research questions

The study was undertaken to answer certain specific questions in mind. These were classified as main question and sub questions.

Main question

How effective is the Sci-Bono outreach programme in the teaching of electrochemistry at grade 11?

Sub questions

(i) How much change is observed in the learners' ability to answer questions on electrochemistry after intervention by Sci-Bono outreach educators?

(ii) Does the teaching by Sci-Bono outreach educators address the common misconceptions learners have in electrochemistry?

(iii) Does the teaching by Sci-Bono outreach educators change learners' thinking in concepts where they were diagnosed to have misconceptions?

1.6 Significance of the study

Any intervention of this kind is aimed at improving the understanding of concepts in the area of intervention. There is therefore need to know how effective it is. It is on this basis that the researcher had to evaluate the Sci-Bono outreach programme.

Investigating the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry would give the implementers valuable feedback as to whether there programme is achieving what it was meant to achieve or not. From this feedback decisions could be made that could lead either to the expansion of the project, refocusing the project or even marketing the programme for implementation by other bodies.

For management purposes it is also vital that the organisation is content that the programme it is running is worthwhile and effective.

The study will also provide valuable information for planning teacher development activities. Sci-Bono has a teacher development unit which works closely with the Gauteng Department of Education's similar unit in running training workshops for science, mathematics and technology teachers from public schools.

Sci-Bono outreach teachers themselves will benefit from the study as it is bound to reveal their areas of strength and weakness in the teaching of electrochemistry. This will influence them to come up with strategies that will make them more effective in teaching this and other difficult topics. Use of such strategies will benefit the learners who are beneficiaries of the programme as well as Physical science teachers from the target schools. Reddy (2006) links the improvement of South African learners in TIMMS 2011 to the interventions carried out.

1.7 Demarcation of the study

The study was undertaken at five public secondary schools in five of the fifteen districts of Gauteng province. Although the said programme targets grades 10 to 12 Physical sciences and Mathematics, the focus of this study was only on Physical sciences. The study was narrowed down to the teaching of only one topic, electrochemistry, at grade 11. Electrochemistry is one of the major topics in the knowledge area, Chemical Change. The study focused on learner's understanding of basic concepts of redox reactions, a subtopic in electrochemistry.

1.8 Organisation of the report

This research report consists of five chapters.

Chapter 1 gives the background of the study. It gives the overview of Sci-Bono and discusses the problem investigated. The chapter presents the significance of the study as well as the structure of the report.

Chapter 2 explains the theoretical rationale on which the study is based. It also discusses claims and findings by other researchers who have worked on studies related to the study in question.

Chapter 3 discusses the research design. It explains the design of tools, selection of sample and data collection methods as well as its analysis. This chapter describes the path followed by the researcher throughout the study.

Chapter 4 dwells on the results the diagnostic tests and interviews conducted. It probes the understanding of concepts of redox reactions by learners. It also interrogates the way these concepts are taught by the Sci-Bono outreach educators and how host teachers at target schools view the approach. The results are thus analysed in this chapter. The chapter also lays out a discussion on the implication of the results and analysis. It attempts to give the reasons of observed differences and/or similarities in performances in the pre-tests and post-tests. The chapter goes on to discuss observed changes regarding misconceptions as revealed by the tests and interviews as well as their implications.

Chapter 5 provides a conclusion of the study. Based on the analysis of results, the chapter answers the three research sub-questions and consequently the main research question. It provides recommendations, spells out limitations to this study and also suggests an area for further research.

1.9 Conclusion

This chapter gave an overview Sci-Bono and the problem under investigation. It sets out the research questions interrogated, the rationale of the study as well as the process of interrogation. The demarcation of the study was also given in terms of sample used as well as the part of the curriculum under scrutiny. This chapter also gave a summary of the structure of the research report.

Having laid down the background of the study, it is important to note that this study was not a ground breaking study. Similar studies have been carried out before under different conditions and on different foci. This means that there is a lot of existing literature on studies that dwelt on evaluation of educational projects, misconceptions and on learning in general. The next chapter will therefore focus on situating this particular study in relation to other studies by scholars who have covered related fields of study.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter gives the background of the intervention under scrutiny. It highlights the Mathematics, Science and Technology (MST) strategy, a framework in which the intervention being evaluated is based. Chapter 2 also reveals literature that focused on research which is to an extent related to this particular study. The literature covers an evaluation of intervention programmes, the teaching of electrochemistry, misconceptions in electrochemistry and the theoretical and conceptual frameworks used in the study.

Literature on the evaluation of interventions looks at what was evaluated, how it was evaluated and what the outcome was in each case. In the teaching of electrochemistry the literature highlights student performance in electrochemistry questions in one of the matric examinations and links this to misconceptions and conceptual change. Common misconceptions in electrochemistry are also highlighted in this chapter. In this section the literature focuses on what these misconceptions are and what research suggests.

Evaluation of teaching effectiveness as the theoretical framework on which this study is based is also discussed in detail. This chapter ends with a discussion on a conceptual change, which is the conceptual framework for this study.

2.2 The MST strategy

The NCS examination report of 2011, (Department of Basic Education, 2012) lamented on poor performance in physical sciences and mathematics at matric. There has also been an outcry that the number of learners taking mathematics from grade 10 to 12 is very small. This is not a new problem. As early as 2001 the problem had already been diagnosed. The economy of any country is driven by the advancement in technology. Advancement in technology is in turn, driven by studies in science and mathematics. There were a few problems that were identified at school level that were assumed to be contributing to the slow pace of technological advancement in South Africa, (MST Strategy, 2002 – 2008). The problems identified included the following:

- There were a few learners who chose to study mathematics and physical sciences at Grade 10.
- There were very few learners opting for Higher Grade level in these subjects.
- The pass rate in these subjects from Grade 10 to 12 was also very low, especially at Higher Grade level. There were very few learners who scored 30% or more in both mathematics and physical sciences.
- Local and international studies revealed that the numeracy ratings for South African primary schools were very low.

- The number of suitably qualified teachers for mathematics, physical sciences and technology was much lower than the demand in these areas.
- Facilities and resources were not adequate to enable effective teaching and learning in these subjects.
- Learners who passed these subjects at matric lacked financial support to study them at tertiary level.

The way in which these shortfalls had to be addressed was then what came to be termed the Mathematics, Science and Technology Strategy, (DoE, 2002). The Mathematics, Science and Technology Strategy was then drawn with the aim of increasing learner participation as well as the success rate in these subjects. The strategy focuses on teacher development, provision of resources and support material for teaching and learning as well as diagnostic testing in Grades 3, 6 and 9, (Gauteng Department of Education, 2010).

Teacher development would focus on increasing the number of suitably qualified and capable teachers who would offer effective instruction and assessment in Mathematics, Science and Technology. Schools also had to be provided with adequate materials that would enhance the teaching and learning of these subjects. Certain schools were selected to pilot the resource project and these were referred to as Dinaledi (Star) Schools. Grades 3, 6 and 9 are exit points for foundation phase, intermediate phase and senior phase respectively. Diagnostic testing at these grades would reveal where barriers are and what kind of barriers they are. This would enable the curriculum developers to plan the necessary interventions at specific stages, (Department of Education, 2010).

The Department of Education invited the private sector as well as non-governmental organisations to partake in the implementation of the MST strategy. This led to the birth of numerous intervention strategies aimed at achieving one or more of the set goals. The interventions also targeted different stages, Foundation Phase, Intermediate Phase, Senior Phase as well as the Further Education and Training Band (FET), (Department of Education, 2010).

At FET (Grades 10 to 12), teacher development focus led to the birth of the Advanced Certificate of Education, a course tailor-made by the local universities to give teachers further training on mathematics, mathematical literacy and physical sciences, (Department of Education, 2010). This course would enable the teachers to be able to effectively handle these subjects. The Department of Education provided bursaries for these courses. The Department of Education further provided bursaries at universities for students who wished to pursue studies in the field of mathematics and science teaching, (Department of Education, 2010).

2.3 Intervention Programmes

An intervention programme in the teaching of Physical sciences is not an invention of Sci-Bono. Intervention programmes have been implemented by different organisations. There are

programmes run by such institutions such as Maths Centre, Investec, Protec and many others. Concern about effectiveness of intervention programmes is not new either. This therefore suggests that this researcher is not the pioneer in researching this field.

Among those who walked this path are Alexander, van Wyk and Nkoane (2010) whose study led to the publishing of a paper entitled "The impact of a UFS community service intervention on Grade 12 science, mathematics and accounting: scholarship for teaching and learning." The paper was published in a book, Praxis towards Sustainable Empowering Learning Environments in South Africa. The research problem of this paper is the same research problem this study is focusing on. The purpose of this study is also closely related to that of the Alexander et al. (2010) paper. The purpose of the Alexander et al. (2010), paper was to investigate impact of a UFS community service intervention on grade 12 on the quality of teaching and learning in accounting, mathematics and physical sciences. This study looks into the effectiveness of an intervention in the teaching and learning of physical sciences. It is therefore almost a replica of part of the Alexander et al. (2010) study.

The major difference between the two studies is that in the Alexander et al. (2010) study, intervention was done by the University of Free State (UFS), a body that is independent from the Department of Basic Education whereas in this study, intervention was done by a non-governmental organisation which is an agency of the Gauteng Department of Education. In the UFS community service intervention project the target group consisted of grade 12 learners only whereas the Sci-Bono Emasondosondo outreach programme, the programme under study targets Grade 10 to 12 learners. Both the UFS community service and Sci-Bono Emasondosondo intervention projects however respond to the same call by the Department of Basic Education, that is, to improve the pass rate as well as the quality of passes in physical sciences and mathematics at matric. Findings from the UFS community service study cannot be generalised to assume that the Sci-Bono outreach programme would be equally effective because the implementation of the two intervention programmes are different. The UFS project was run in October and on Saturdays to prepare learners for final examinations (Alexander, van Wyk and Nkoane, 2010). The Sci-Bono outreach programme is run throughout the year, during the week and once a term for each school in the programme.

Because of the similarity of the Alexander *et al*. (2010) study and this study, the path of the researcher has been cleared in that the researcher will be able to borrow and adapt their methodology for this research. The study by Alexander *et al*. (2010) has had its results published and its weaknesses and challenges experienced by researchers were exposed. By knowing the problems and challenges associated with this kind of research, the researcher is better equipped to meet the challenges and hence prepared for them. The challenge is that although this may look like a replication of the Alexander *et al* (2010), this study is carried out at a different place, in a different context and at a different time.

Alexander *et al.* (2010), reports that the intervention was effective as evidenced by the questionnaire results analysis as well as the improvement recorded when June examination results were compared with November examination results. Incidentally this intervention took

place between the two examinations. The June examination was therefore taken as a control, that is, the performance of the learners before intervention.

Hartley, Treagust and Ogunniyi (2008) studied an intervention that involved the use of computers. Their paper is entitled, "The Application of computer assisted learning strategy in science and mathematics for disadvantaged grade 12 learners in South Africa," and is found in the International Journal of Educational Development, volume 28 of 2008.

The paper also investigates effectiveness of an intervention in the teaching and learning of science and mathematics. Its focus is however on the use of computers in science and mathematics lessons. Like the two studies discussed above, the study by Hartley, Treagust and Ogunniyi (2008), attempts to come up with a measure of success of an intervention in the teaching and learning of physical sciences and mathematics.

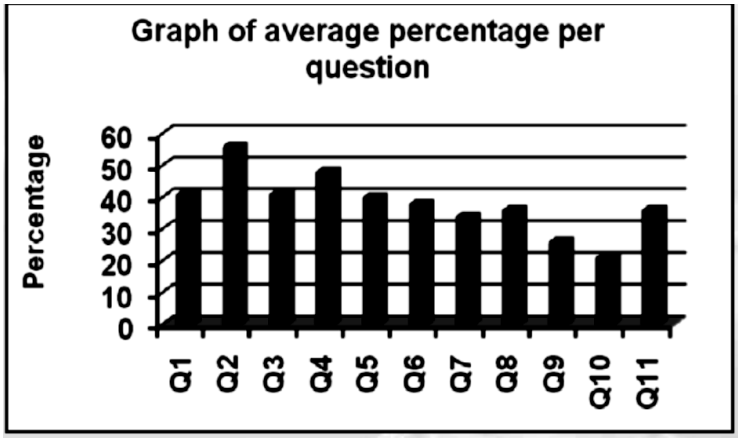
The purpose of the study by Hartley *et al.* (2008) was to find out how the computer assisted learning was run in the computer classrooms and how learners perceived the computer assisted learning classes. The latter, which deals with learner perceptions, is common ground for the two studies under discussion. The other similarity between this study and that of Hartley *et al.* (2008) is that the interventions being evaluated both involve the use of computers. Sci-Bono subject matter experts use computers in their instruction at schools hence their intervention programme is also computer assisted although the way the computers are used is different from the way they were used in the Hartley *et al.* (2008) study. They use different programs that support learning. They may also use other teaching strategies but presentations and interactive computer programmes form the bulk of lesson delivery. In finding the perception about the quality of teaching and learning in the Sci-Bono outreach programme, the researcher was also looking at the contribution played by the inclusion of computer use in the teaching and learning of physical sciences.

This study was, therefore, in a way, a combination of the two studies in that it looked at intervention involving the provision of human resources as is the case with the Alexander *et al.* (2010) study as well as intervention involving the use of computers. The similarity that exists between the two published papers and the similarities each of the papers has with this study qualifies them to be used as references in this study. The existing similarities gave the researcher a guide as to how he could conduct his research. They afforded the researcher the opportunity to engage with methods and tools planned for the research before implementation. Findings from Hartley *et al.* (2008) paper made the researcher think of a possible range of results from the schools he had to study.

2.4 Teaching of electrochemistry

The physical sciences curriculum is quite wide but Examination Reports for 2011 (Department of Basic Education, 2012) have all reflected that the section on electrochemistry is one of those in which performance by candidates is very poor.

Figure 2.1 Graph of average percentage pass per question for Physical Sciences Paper 2 of 2011.
(Adapted from DBE, 2012)



Q1	One-word answer to a statement – all content
Q2	MCQs – all content
Q3	Organic Chemistry – nomenclature
Q4	Organic Chemistry – physical properties
Q5	Organic Chemistry – reactions
Q6	Rate of reaction
Q7	Chemical equilibrium
Q8	Galvanic cells
Q9	Electrolytic cells
Q10	Chlor-alkali industry
Q11	Fertilisers
Q12	Photoelectric effect

Figure 2.1 above shows the percentage pass rate per question in paper 2, the chemistry paper. Questions 8, 9 and 10 all fall under electrochemistry. Questions 9 and 10 show the lowest percentage pass rate, with question 10 percentage pass rate being below 20% and question 9 being below the 30%. This is evidence that these were the most challenging questions in this particular examination, alluding to the fact that learners find electrochemistry to be difficult.

The difficulties which learners experience in electrochemistry are usually due to misconceptions they have in this topic. Niaz & Chacon (2003) express that there is growing interest in fostering conceptual change in learners' understanding of chemistry concepts, most specifically electrochemistry. This further confirms the existence of misconceptions in learners. Niaz & Chacon (2003) advise that teachers should be able to distinguish between algorithmic problems and conceptual problems. In their study they noted that mastering solving algorithmic problems by learners does not translate into the ability to solve conceptual problems. In the mentioned study, conceptual problems were solved by teaching experiments. Learners themselves noted this and raised it with their teacher. The other approach born from the research is that conceptual change can be facilitated by incorporating collaborative groups (Niaz & Chacon, 2003). The authors also recommend the strategy of creating difficulties for learners in order to promote progression. Such difficulties could be the use of higher order questions when testing learners both formally and informally. This tends to provoke their thinking. De Jong (2000) points out that learners have a negative view of chemistry because they do not understand the concepts. Some are said to remember the chemical formulae but cannot deduce the meanings of those chemical formulae. De Jong (2000) sees the important skill of chemistry teachers being the ability to identify learners' preconceptions so that they are able to foster conceptual change. A grey area identified by De Jong (2000) is the gap between research and teaching.

2.5 Misconceptions in electrochemistry

A misconception is defined as a student's conceptual and propositional knowledge which does not fully explain scientific phenomena and is not consistent with what is commonly agreed upon in science circles (Cho, Kahle and Nordland, 1985). Ganertt and Treagust (1992), listed a number of common misconceptions in electrochemistry but the list is not exhaustive.

Pines and West (1986) define a misconception as an imperfect understanding of a concept. Fischer (1983) takes misconceptions to be those conceptions that are at variance with scientifically accepted views. Throughout this study misconception is understood in terms of the definition by Pines and West (1986).

Schimmdt, Marohn and Harrison (2007) attribute miscoceptions to misleading or erroneous concepts received by the learners. This would be either from their teaching or from text books. Other researchers however refer to misconceptions as alternative conceptions. They argue that these alternative conceptions bring about the necessary conflict in learners' thinking and this would lead to the desired conceptual change, (Niaz, 2010). From a series of investigations on teaching models, Sanger and Greenbowe (2000) concluded that it was only the conceptual change strategies that would yield positive results in dealing with students' misconceptions.

Garnett, Garnett and Treagust (1990) give a list of common misconceptions in electrochemistry. These misconceptions are classified under oxidation and reduction, electrochemical cells and electrolytic cells. Those classified under oxidation and reduction comprised of the following:

- Some students take the charge of a particular monoatomic ion to be the oxidation state of that element.
- A polyatomic molecule or ion has an oxidation state and the oxidation state is the charge of the polyatomic ion.
- The addition of oxygen in a chemical equation can be used to identify oxidation.
- If a polyatomic species changes its oxidation state, that could be used to identify either oxidation or reduction of the polyatomic species.
- Some students also think that oxidation and reduction can occur independently.

Al-Balushi, Sulaiman, Ambusaidi, Abdullah, Al-Suaili, Ali and Taylor (2012) used a chemistry misconceptions diagnostic test comprising of sub-microscopic and visual representations in a study of 12th grade learners in Oman. Electrochemistry, combustion had the highest misconceptions. Their study also revealed that learners had difficulties in dealing with visual representations. They recommended that misconceptions diagnosed in research should be taken into account in the design and teaching and learning materials and activities.

Banda (2012) studied among other things conceptual understanding and learners' performance in electrochemistry as well as pre-service teachers' ability to identify misconceptions and to

address the misconceptions identified. The study showed that these teachers in most cases were unable to identify misconceptions. Pedagogical ideas suggested by the teachers included both teacher centred and learner centred practices. This study further confirms the existence of misconceptions in teachers, who are however expected to be addressing the misconceptions which students have.

In their study, Allsop and George (1982) found that learners were unable to recognise that there was oxidation and reduction in chemical reactions. Garnett and Treagust (1992) are of the opinion that some misconceptions emanate from the inappropriate use of definitions of oxidation and reduction. If the definition used is inappropriate or if it is not understood, it would then be a great challenge for a learner to use it appropriately. Use of a definition would be classified under Bloom's taxonomy as application. This is a relatively higher order skill which cannot be achieved when the lower level of understanding the concept has not occurred. If a learner holds a misconception about a certain concept, chances of that learner applying the concept correctly are minimal.

Sanger (1996) scrutinises definitions of oxidation and reduction and discusses how they may impact on the understanding of the underlying concept. He highlights some of the arguments brought forward by Herron regarding definitions of oxidation and reduction. One argument suggests that whilst the change in oxidation number, whether it increases or decreases can be used to determine whether the substance has been oxidised or reduced, these should not be used as definitions because the term "reduce" may be considered in its traditional meaning. This would in turn distort the real meaning of the process of reduction.

Some misconceptions also emanate from incorrect statements that are misleading from textbooks (Sanger and Greenbowe, 2000 and Kikas, 2004). The definition of oxidation as the addition of oxygen and reduction as the removal of oxidation is still found in some old text books and some of these text books are still referred to by both teachers and students. Their use of the information in the text books also rests on their ability to sift information in relation to syllabus content. Because some of them never refer back to the content specifications as laid out in the curriculum documents they then tend all the information provided hence the use of these obsolete definitions.

In their study, Ozkaya, Uce and Sahin (2003), one of the things they sought was to find the likely sources of students' misconceptions. Among other things, they found that misconceptions also emerged from rote-learning.

According to Doymous, Karacop and Simsek (2010) computer animated presentations can be used to improve conceptual understanding of microscopic chemical processes. The advantage of animations is that the motion helps to illustrate the molecular dynamic processes. This helps to overcome the challenge that is brought about the fact that learners are unable to visualise these concepts. Lee and Osman (2011) further reinforce this argument as they state that electrochemical processes are difficult to learn because of their abstract nature. They further

lament about the existing situation at schools, at least at the time of their study, that the use of multimedia, which some studies have considered vital, is still very low.

Liu, Andre and Greenbowe (2008) found out that simulations designed for the teaching and learning of electrochemistry were used differently by the students, depending on their prior knowledge levels. Those whose prior knowledge was high would first accomplish their tasks using formulas and then use simulations for confirming their answers. Those with a low level of prior knowledge in chemistry would use the simulations as their main resource in their attempts to accomplish tasks. They suggested a need for research to be directed to to the use of simulations for students with different characteristics.

Rosenthal and Sanger (2012) however argue that there may be misrepresentations and misconceptions that can emanate from animations. This was revealed in their study where simulations were used to depict oxidation reactions.

At grade 12 learners will have to apply their understanding of redox reactions to the electrodes. One of the electrodes is an anode and is defined as the electrode at which oxidation takes place whilst the cathode is defined as the electrode where reduction occurs (Schimmdt, et al, 2007). If the concept of oxidation and reduction is not well comprehended, then it will therefore be difficult for learners to classify the electrodes in both galvanic and electrolytic cells. Some learners will only be able to predict reactions taking place at the electrodes only when the electrodes are marked positive or negative (Schimdt, et al. 2007).

Ceyham and Karagölge (2005) found that most students demonstrating misconceptions were still able to calculate cell potentials correctly, which is consistent with prior research suggesting that some students capable of solving quantitative examination problems often lack understanding of the underlying concepts. Ogude and Bradley (1996) in their study on college students found that whilst students were able to do correct electrochemical calculations, very few could give correct answers to qualitative questions where deeper conceptual understanding was required.

2.6 Theoretical Framework: Evaluating teaching effectiveness

The study focuses on evaluating the effectiveness of an intervention programme. Jahangiri, Mucciolo, Choi & Spielman (2008) define teaching effectiveness as "the extent to which the teaching activity fulfils its intended purpose, function and goal." They recognise and appreciate the fact that different institutions have different goals but argue that evaluating teaching effectiveness is proof that the institution is committed to improvement. This is in agreement with the definition of formative evaluation given by Hopkins (1989).

Educational evaluation is a process of gathering information whose analysis would give conclusions that can be used in decision making (Cronbach, 1984). Evaluation of a programme can either be formative or summative. According to Hopkins (1989), formative evaluation is

used to check if the programme is on course or not. Formative evaluation thus provides useful information that can be used to improve the programme. One can therefore conclude that formative evaluation checks and shapes the programme being evaluated. When used in evaluating teaching effectiveness, formative evaluation would give feedback that would be used to improve students' learning. Summative evaluation checks the achievement of the objectives at the end of the programme on check. The kind of evaluation the researcher did is formative evaluation since the programme is still running. Results have a potential to be used for the improvement of the programme.

Lee (1999) points out that teaching effectiveness is evaluated against teacher's behaviour. The behavioural aspects considered are teaching methods used, use of knowledge and expertise, use of own experience, communication style in general and how is given.

2.6.1 Strategies to measure teaching effectiveness

To evaluate teaching effectiveness, there has to be a measure of some sort. Berk (2005), came up with 12 strategies of measuring teaching effectiveness. These are listed as follows:

(i) Student ratings
(ii) Peer ratings
(iii) Self-evaluation
(iv) Videos
(v) Student interviews
(vi) Alumni ratings
(vii) Employer ratings
(viii) Administrator ratings
(ix) Teaching scholarships
(x) Teaching awards
(xi) Learning outcome measures, and
(xii) Teaching portfolios

After studying the various strategies, Berk (2005), points out that each method has its own advantages and disadvantages. He suggests that evaluators could use any combination they deem valuable, but however recommends that among the strategies chosen, be student ratings which evaluators should start with. From his recommendations one understands that some strategies would be suitable for both formative and summative evaluation whilst some would be suitable for only one kind of evaluation. From the whole list the researcher only considered one. This is due to the scope and depth being covered in this study. A consideration has also been made that an intervention programme has to be measured by outcomes (Goe, Bell and Little, 2008).

According to Goe, Bell and Little (2008), evaluation of teaching effectiveness can be done by measuring inputs, processes and/or outputs. They point out that what a researcher measures, is a reflection of what is valued hence the reflection itself is valued. Teaching effectiveness can be measured in various ways. Goe, Bell and Little (2008), list some of these as classroom observations, analysis of classroom artefacts, teaching portfolios, teachers' self-report of

practice, students' ratings of teacher performance and value added models. Value added models are those strategies that are meant to measure what learners have gained from the teaching process. Goldhaber and Antony (2003) propose that value added measures give summary of contributions made by different factors in the teaching process, towards improvement in learner achievement.

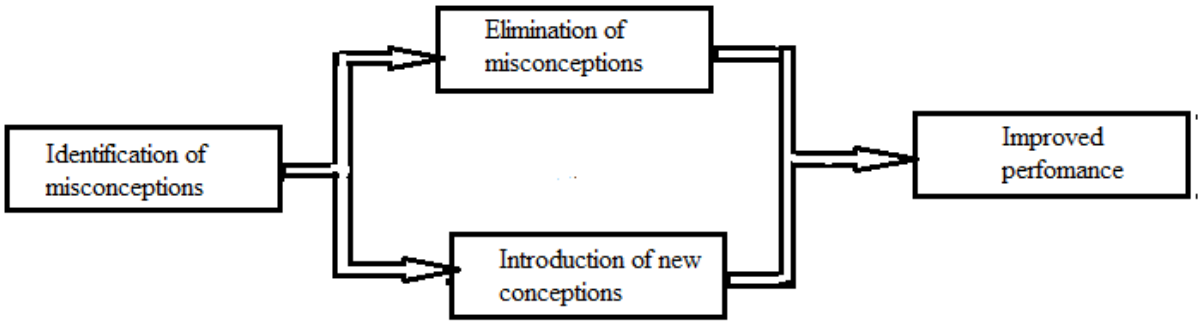
Jahangiri, Mucciolo, Choi & Spielman (2008), stress four methods for measuring teaching effectiveness. These are student assessment, peer assessment, self-assessment and the triangulation method which combines the three methods. From their study, Jahaniri, Muccilo, Choi & Spielman (2008) discovered that student assessment was the most popularly used but in different ways. Self-evaluation was found to be the least used method. They however recommend the routine use of the triangulation method, presumably because it involves the major stakeholders in the teaching-learning situation.

Educational evaluation can be done by objectives, competences, achievements, process or outcomes (T-Kit on Educational Evaluation in Youth Work). Following the T-Kit approach, in this study the researcher chose to evaluate the programme by objectives of the programme. One main objective of the programme is to help learners improve their understanding of science concepts. If this is achieved then the programme is assumed to be effective. Braskamp, Brandenburg, & Ory (1984) proposed that student learning is evidence of teaching effectiveness. This is what Goe, Bell and Little (2008), refer to as outcomes. Paulsen & Dailey (2002) argue that evaluation of programme effectiveness should determine whether the programme achieved what it was meant to achieve or not. This seems to suggest that effectiveness should be measured in terms of intended outcomes, which in this case would be learner achievement.

2.7 Conceptual Framework

Student learning in this study is based on the conceptual change model proposed by Posner, Strike, Hewson and Gertzorg (1982). Drawn from the conceptual change model, a new model of effectiveness designed involves the elimination of misconceptions and introduction of new conceptions which should result in improved performance by learners.

Figure 2.2 Concept substitution model for improved performance



Constructivists hold a view that before school instruction, learners already have certain knowledge and they suggest that this knowledge be taken into consideration when teaching.

The ideas learners have may be “vague”, “wrong” or “correct”. Their being wrong or right is when they are being measured against a certain accepted scientific idea.

It is when the idea does not align with the accepted ideas that a teacher would want to shift the learner’s thought and understanding towards this accepted scientific idea. Hewson, Beeth and Thorley (1998) refer to this as teaching for conceptual change. Teaching for conceptual change should therefore result in some form of change regarding the idea the learner initially had.

Chi (1992), defines conceptual change as the occurrence of changes either within or between existing knowledge structures. According to Hewson, Beeth and Thorley (1998), conceptual change is “an active, interactive, and connective process requiring changes of different kinds such as addition, linkage, rearrangement and exchange of ideas. In the model they propose, the concepts to focus on are the status of the idea and what they have termed conceptual ecology. The status of an idea is defined as the level at which the idea is known and accepted by the person holding it. There are three factors that influence the status of an idea and these are its intelligibility, plausibility and fruitfulness. Conceptual ecology, “deals with all the knowledge that a person has, recognises that it consists of different kinds, focuses attention on the interactions within the knowledge base, and identifies the role that these interactions play in defining niches that support some ideas,” (Hewson, Beeth and Thorley ,1998).

Hewson, Beeth and Thorley (1998) suggest a model they call, teaching for conceptual change. They define this as teaching that explicitly aims to shift students’ thinking in order to lead to conceptual change. The guidelines suggested for the model developed by Hewson, Beeth and Thorely (1998) revolve around ideas, metacognition, status and justification.

2.8 Conclusion

This chapter highlights the root of the problem statement. It links the study with the national issue, the MST strategy and describes how it is being tackled. It describes ways in which some similar intervention programmes have been evaluated. An area of concern, electrochemistry, is discussed and the discussion dwells on misconceptions which actually make the topic difficult to teach and learn. The conceptual framework on which the study was based is explained. Finally the chapter discusses the strategies of evaluating teaching effectiveness. The next chapter gives details of the design and approach that was used in this study.

CHAPTER 3 RESEARCH METHODOLGY

3.1 Introduction

This chapter covers the paradigm and the research design that was used to evaluate the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry at grade 11. It explains how the change observed in the learners' ability to answer questions on electrochemistry after intervention by Sci-Bono outreach educators was measured. The other research question dwelt on whether the teaching by Sci-Bono outreach educators clears the common misconceptions that learners usually have in electrochemistry or not. The methods of gathering data to answer these questions are also discussed in this chapter.

The chapter goes further to interrogate methods and tools as well as the selection of participants. Also discussed in this chapter is the validity and reliability of both the methods and tools used in the study. Ethical issues that were considered in the study are explained.

3.2 Evaluation research

Research undertaken in this study is categorised as educational evaluation research. Evaluation has been defined in different ways by different scholars. Cronbach (1984) defines educational evaluation as a process of gathering and treating information in order to come up with a decision for a particular education programme. This definition does not assume that education evaluation is only conducted or called for by the education programme implementers. Such kind of evaluation would benefit stakeholders of any other education programme related to the programme being evaluated.

As in the case of this study, Sci-Bono runs a kind of intervention programme, to be specific, the Emasondosondo outreach programme. Interrogation of this study could have an influence on decision makers at Sci-Bono, funders of the programme, beneficiaries of the programme or any other stakeholder in this programme. Results of the study may also influence decisions by stakeholders of other programmes and even those who are considering engaging in similar or related programmes.

This research evaluates the effectiveness of one of the programmes in the implementation of the MST strategy. It focuses on measuring performance change due to intervention and also sets to establish whether the intervention addresses misconceptions and also whether the teaching by the Sci-Bono SMEs brings about any conceptual change that leads to the elimination of the common misconceptions in electrochemistry.

3.3 Research Design

3.3.1 Research Paradigm

The paradigm that was found to be suitable for this study is the eclectic mixed methods pragmatic paradigm. This paradigm allows for both narrative and numeric approaches to

answering research questions (Teddlie &Tashakkori, 2009). Creswell and Plano Clark (2006) suggests that the mixed methods approach focuses on collecting and analysing data quantitatively and qualitatively in a single study. Creswell and Plano Clark (2006) is of the opinion that qualitative data and quantitative data can be distinguished by identifying data as either open-ended or close-ended. He suggests that close-ended data is classified as quantitative data whilst open-ended data would be classified as qualitative data. Close-ended data would be limited specific responses gathered through such methods as check lists whereas open-ended data would be responses from methods such as interviews.

The advantage of mixed methods research is that it allows for triangulation. Creswell (2012), defines triangulation as a process whereby different types of data or different methods by which data is collected. Triangulation helps the researcher to determine the validity and credibility of his/her findings in that they will be viewed from different angles.

In this particular study, effectiveness was measured by improvement in learner performance which was presented numerically and this was analysed quantitatively. Deductive logic was used in this instance. On the other hand effectiveness was judged from teachers' comments or answers to interview questions relating to the lesson. This kind of data was presented textually and hence analysed qualitatively, thus inductive logic came into play. The use of the two methods therefore qualifies the approach to this study as a mixed methods approach.

3.3.2 Research alignment

Table 3.1 Research question and research method alignment

Sub question	Method	Rationalisation
(i)	Testing (pre-test and post-test)	The difference in performance in the two tests show whether there is improvement or not.
(ii)	Observation	To see if misconceptions are identified and tackled during the lesson.
	Interviews	Teachers interviewed would give a second opinion as to whether misconceptions were tackled during the lesson.
(iii)	Interviews	Learners explanations as to why they gave particular answers would give an indication as to whether the misconceptions they had have been eliminated
	Testing (pre-test and post-test)	Responses in the post-test would reveal whether the misconception identified in the pre-test was eliminated or not.

The study included three methods of data collection which are observation, diagnostic tests (pre-test and post-test) and interviews.

3.3.3 Pre-test and post-test

According to I-TECH (2008), pre-tests and post-tests measure knowledge gained from intervention. Knowledge gained is what Berk (2005) classified as learning outcomes in his model. Allen & Nimon (2007) and Rockwell & Korn (1989) found the pre-test and post-test model to be quite effective in measuring change in participants receiving instruction on extension programming. This increased the researcher's interest in using this model.

Learners were given a pre-test before the lesson and a post-test at the end of the lesson. Learner performance in the pre-test is an indicator of how much learners know in that particular topic before intervention. The performance in the post-test indicates how much learners know in the topic after intervention. It can then be determined from these results whether there was an improvement in performance or not. Any change in performance would be attributed to the intervention. This would answer the first research question which seeks to find out how much change is observed in learners' ability to answer questions in electrochemistry after the Sci-Bono outreach programme intervention.

The two tests covered content which included areas where there are usually misconceptions. They measured the same variables as suggested by Gall, Gall and Borg (2003). The pre-test results would reveal whether learners had those misconceptions before intervention or not. For those learners whose results would have reflected that they have misconceptions in the pre-test would be checked through their post-test scripts. Responses in the post-test for those particular questions would show whether the misconceptions were eliminated or not. The proposed model of conceptual change, the Concept Substitution Model requires the identification of misconceptions, elimination of those misconceptions and substituting them with correct conceptions in order to improve learners' ability to answer science questions.

The pre-test and post-test are designed in such a way that they are similar in terms of content coverage, concepts and questioning technique. I-TECH (2008) proposes that in a post-test one could use the same set of questions or questions of comparable difficulty. In this study the researcher used questions that were of comparable difficulty. The tests have to be comparable so that the analysis is valid.

3.3.4 Lesson observation

The researcher observed one lesson at each of the five schools. In all cases the researcher sat in the classroom throughout the lesson to observe all activities taking place and made field notes. For the field notes, the researcher used the observation tool shown in an appendix C. The major aspects that the researcher needed from lesson observation were whether there were any misconceptions revealed during the lesson and if they were, whether they were tackled or not. Taylor (2013) brings up a concept of "classroom reactivity threat" which changes the normal classroom dynamics. This is brought about by the introduction of a stranger in the classroom. In this case there were two strangers, the Sci-Bono SME and the researcher.

Lesson observation also revealed the strategies used by the Sci-Bono outreach teachers as well as the learners' responsiveness to the strategies. This gave a clue as to how Sci-Bono outreach teachers enable learners to understand concepts and also how they deal with misconceptions. The post-test and interviews would later reveal whether the misconceptions had been dealt with successfully or not.

3.3.5 Interviews

Interviews were held with the physical science teachers teaching the classes under study and a sample of learners from these classes. In the interview with the subject teacher, the researcher wanted to find out if he/she is aware of the misconceptions which the learners had in electrochemistry or not and whether he/she thinks they were well dealt with successfully or not. The researcher also wanted to know the ideas the teacher has on addressing the misconceptions.

In the interview with the learner the researcher wanted to find out why the learner gave particular responses in both the pre-test and the post-test and also find out if. Here the researcher only targeted the questions 1.1 and 2.1 and 2.2. These are the questions whose responses would reveal whether learners have misconceptions in question or not.

The advantage of interviews is that one can make a follow up to a response that has been given by the respondent.

3.4 Instrument design

There are four instruments the researcher used to collect data in this study. The instruments included a pre-test (appendix A), a post-test (appendix B), and a researcher's observation tool (appendix C), a structured interview questionnaire for the learners (appendix D) and a structured interview questionnaire for the host teacher (appendix E). These instruments are discussed in detail in the paragraphs that follow.

3.4.1 Pre-test and post-test

There are a number of tests available for use in research that the researcher could have used but Mouton (2001) is of the view that existing tests are those that were designed in particular contexts hence they would not fit every other situation. In light of that view the researcher had to design tests for this study from scratch.

The pre-test and post-test designed had open ended questionnaires. They were designed to probe the same content and concepts hence they were very similar and of the same level of difficulty.

Most items were actually the same. In questions 1.1, the pre-test required the definition of oxidation whilst the post-test required the definition of reduction. Whilst the question tested the understanding of definitions it was also used to test if there are learners who have a misconception of defining oxidation and reduction in terms of the addition and removal of oxygen.

In the pre-test questions 1.2, 1.3 and 1.4 differed from the post-test in the compounds used. In the pre-test carbon compounds were used whilst in the post-test sulphur compounds were used. The method of calculating the oxidation number is the same. These questions test the basic skill required when dealing with chemical reactions in electrochemistry.

Question 2.1(a) tests two things, first whether a learner is able to identify an oxidised substance from the reaction given in an equation and secondly it tests whether the learner has that misconception of taking a reducing agent to be a reduced substance. This misconception can be confirmed in the response to the next question, 2.1(b) which seeks an explanation for the choice the learner has given as a reducing agent. Those with the misconception would give a reason that it is because the substance is reduced during the reaction.

Questions 2.3.1 and 2.3.3 seek to find out if learners are able to visualise what is happening in a reaction when they are given a chemical equation that represents a particular redox reaction. Question 2.3.2 seeks to find out if a learner is able to identify spectator ions in equations for redox reactions.

These questions test the same things in both the pre-test and the post-test. In the whole of question 2 all the items in the pre-test refer to the equation,

$Fe_{(s)} + CuSO_{4(aq)} \rightarrow Cu_{(s)} + FeSO4_{(aq)}$, whereas in the post-test the equation of reference is

$Zn_{(s)} + Pb(NO_3)_{(aq)} \rightarrow Pb_{(s)} + ZnNO_{3(aq)}$.

What both tests seek to find out is what should form the core of the lesson, according to the physical sciences CAPS document which lays out the scope and depth of topics covered at the three different grades, that is, 10, 11 and 12. The tests were thus designed in consultation with this document.

The difference between the pre-test and post-test scores helps to show the concepts and competences that were taught well and those that need to be done again using a different approach (I-TECH, 2008).

3.4.2 Interview questions for learners

The researcher asked learners only questions that sought to find information regarding common misconceptions, that is, to find out if they still had misconceptions after intervention. These questions were just about responses they had given or alternative responses they could still give as well as questions from the practical. During the interview the researcher was writing learners' responses in the spaces provided on the questionnaire sheets. The information was being captured as the interviewee gave each response, that is, the response was written before the next question was asked. The questionnaire that was used is shown in Appendix D.

Question 1 is meant to be used to check if learners have that misconception where they perceive oxidation as the addition of oxygen. In question 2 the interviewer wants to find out if learners understand the concept redox reactions and whether there are any who still have the misconception that the oxidised substance is the oxidising agent and that the reduced substance is a reduced agent.

Question 3 is a follow up on the post-test response for question 3.1. First it is meant to find out whether the learner is going to give the same reason he/she has written. Secondly it serves to check the existence of a misconception. In question 4 learners will demonstrate their understanding of the concepts of oxidation and reduction. Other learners may not have the misconception but their answers may make them appear as if they have the misconception when they don't. There are learners who would know that a reducing agent is a substance that has been oxidised but may fail to establish this substance from an equation. They would therefore give the different answers (the two substances) for 3.1 and 3.2 knowing that one of them is correct but not knowing which one it is. This position will therefore be established by a response to question 4.

3.4.3 Structured interview questionnaire for teachers

A structured interview questionnaire was also designed for the host physical sciences teachers. The instrument is captured in Appendix E. The researcher was recording responses in the blank spaces under each question in the questionnaire sheet during the interview. This was done after each response was given, that is, before the next question was asked. Clarification was sought whenever the researcher felt there was need for clarity in a particular response.

Items 1 and 2 were meant to determine whether the teacher identified any misconceptions or not. This was not a test for the teacher but it was meant to help the researcher in case he missed some misconceptions. The second item further probes whether the teacher is content in the way in which the misconceptions were tackled.

Item 3 requires information regarding the effectiveness of the practical work done. During the lesson, one of the activities was a practical activity which learners did in groups. They were supplied with test tubes with copper sulphate solution and had to add iron filings. The teacher used this experiment to explain oxidation and reduction in a redox reaction.

A response to item 4 would give either an area of good practice, weakness or omission by the intervener in the opinion of the host teacher. A response to item 5 would reflect the perception of host teacher regarding elimination of misconceptions by the Sci-Bono SME. This is closely related to item 2.

Item 6 is meant to extract information from the teacher about the weakness of the lesson in general. When the word weakness is used the instrument there are very slim chances that the information may be forth coming. The aspect of "ubuntu" tends to suppress negative comments about others.

Item 7 seeks to get any input from the teacher. Having asked for particular information the researcher needs to have courtesy to give the interviewee an opportunity to say or ask anything he/she may think of relating to the matter under discussion.

3.4.4 Validity and Reliability of instruments

Two important aspects of research findings are reliability and validity. Scholars have defined each of these concepts in different ways and from different angles.

3.4.4.1 Validity

In quantitative research validity refers to whether the research measures what it is meant to measure or not. The pre-test and post-test were face validated and piloted before being administered. The instruments were checked for content and questioning techniques by the supervisor who is an expert in science. The instruments were also shared with matric physical science examiners and teachers who also gave their opinions. With their recommendations questions 2.1, 2.2 and 2.3 were changed. The original questions did not ask the learner to explain his/her answers. It was argued that without an explanation a learner who makes a correct guess will not be distinguished from the learner who knows the answer. This then led to the inclusion of part second part which seeks for an explanation.

Validating the tests ensures that the tests are reliable data collection tools. A wrong answer given by a participant should be due to lack of knowledge not because of interpreting the question wrongly, (I-TECH, 2008). Bell (2010) argues that an experiment that goes without a control group has internal validity threats. The difference between the tests could be assumed to have been caused by intervention when in fact there may be other factors which could have come into play. Maree and Pietersen (2007) list such factors as history, selection, instrumentation, maturation, attrition, testing effect and selection bias.

3.4.4.2 Reliability

Reliability refers to the possibility of the same results being obtained when the study is repeated on the same sample (Maree & Pietersen, 2007). According to Golafshani (2003), when the study is reliable then the results should be repeatable, stable or similar over a given period of time. To test the reliability of a study some researchers use the test-retest method. The test-retest method may reflect stability which is one aspect of reliability. The instruments were tested for both validity and reliability through piloting.

3.4.4.3 Piloting

Van Teijlingen and Hundley (2002) define a pilot study as a smaller version of the main research study that is carried out prior to the main study. In addition to checking for validity and reliability, a pilot study also helps the researcher to check for clarity of the questions, gaps in the instrument and the time the participants will take to interact with each instrument (Wellman, Kruger and Mitchell, 2005). The research instruments were piloted at two schools that had not been selected for the study but are in the selected districts. The questions were found to be clear and concise. Learners interviewed indicated that they understood questions clearly. This included those questions they could not answer. After collecting scripts at the first school it discovered that some pre-tests and post-tests were not paired. For some learners there were pre-tests only and for others there were had post-tests only. This showed that there was need to have a systematic way of collecting scripts to ensure that all scripts are collected. The researcher and the teacher were to collect the scripts from learners whilst the learners were seated in their rows. At the next school the system was introduced and it worked well. Instead of asking learners to submit their scripts, the teacher collected the scripts from learners' desks. A pre-test and a post test were designed. These instruments were checked by the supervisor for relevance, lack of ambiguity and simplicity of language. Questions need to test what is covered

in the lesson and should not give room for being misunderstood. Changes were suggested and implemented.

In the process of piloting the instruments, two changes were made to both the pre-test and post test. Questions 2.1, 2.2, 3.1, 3.2 and 3.3 require an answer and an explanation for each answer given. Initially these sub-questions that need explanations were not numbered. The researcher realised that numbering of each item was necessary for recording purposes since there were cases where the answer was correct and the explanation was wrong or vice versa. A response to each sub-question had to be captured separately in the record as being correct or wrong. The two sub-questions referred to, were then numbered as (a) and (b) for each question.

Initially there were two sub-questions in question 1 for both the pre-test and post-test. Question 1.3 was added after piloting both the pre-test and post-test. These additions were effected because responses to question 1.2 in both the pre-test and post-test could not show whether the answer was calculated or it was mere guess work. In the revised question papers, getting the answers correct to 1.2 and 1.3 is enough proof that the learner has mastered the concept. The other reason was that coincidentally the answer was the same for both CO_2 in the pre-test and SO_2 in the post-test. The pre-test and post-test were structured in such a way that the questioning technique in the same in both. For the pre-test and post-test results to be comparable, questioning should have the same level of difficult. Howard (1980) argues that the frame of reference for the pre-test and the post-test should be the same to eliminate bias. This can only be achieved if the two are structured in the same way, otherwise the comparison of the two tests would be invalid.

3.5 Sample

The study was carried out at five schools that were then current beneficiaries of the Sci-Bono outreach programme. The schools were from five districts in Gauteng Province in South Africa.

As referred to earlier, at the beginning of each term, the Sci-Bono outreach team contacts schools in their programme to find out the topics which the schools want to be assisted with for each grade. The schools under study were the five of the seven schools that had requested for intervention in electrochemistry, redox reactions, in particular at grade 11. Two of these schools could not be included in the study as they were selected for piloting. In selecting schools for piloting, random sampling was used, where all the seven schools had equal chances of being selected. These schools are part of the twenty-five schools which were being serviced by the Sci-Bono outreach team during that period.

Although electrochemistry is one of the challenging topics, most of the recipient schools prefer to seek for help in doing practical work that is done as part of continuous assessment.

3.6 Data collection

During the study, learners were then given the pre-test and the post test. The scripts with tests were marked and the marks were recorded.

During the intervention the researcher sat in the classroom throughout the lesson. The researcher only helped the intervener in the distribution and collection of pre-test and post-test

scripts. During the lesson the researcher wrote field notes. Guided interviews were conducted for both the school teachers and the selected learners and their responses were recorded.

A schedule for data collection was set and each school was made aware of the day of the visit.

Table 3.2 Schedule of data collection

School	Date	Activity	Participants	Possible number	Actual number
A	18 April 2013	Pre-test	Learners	25	24
		Post-test	Learners	25	24
		interview	Learners	5	5
		Interview	Teachers	1	1
B	2 May 2013	Pre-test	Learners	37	37
		Post-test	Learners	37	37
		interview	Learners	5	5
		Interview	Teachers	2	2
C	17 May 2013	Pre-test	Learners	30	27
		Post-test	Learners	30	27
		interview	Learners	5	4
		Interview	Teachers	1	1
D	30 May 2013	Pre-test	Learners	30	30
		Post-test	Learners	30	30
		interview	Learners	5	5
		Interview	Teachers	1	1
E	6 June 2013	Pre-test	Learners	21	18
		Post-test	Learners	21	18
		interview	Learners	5	5
		Interview	Teachers	1	1

The schools covered in this study were typical township schools where attendance is hardly 100% in each class throughout the week. For the dates scheduled for the schools attendance in grade 11 classes was 100% in only two of the five schools. The number of expected learners for the pre-test and post-test was in all cases the number of grade 11 learners registered for Physical Sciences at each school. Absenteeism is also one factor that is said to be contributing to poor performance at matric (Dikgale, 2012). In school C one learner who had been invited to an interview turned up but asked not to be interviewed. As per ethics rules, the researcher allowed the learner to exercise that right to withdraw. Shenton (2004) stresses on the importance of the research participants' right to withdraw if they so wish. This gives credibility to the research. It was only in school B where there were two teachers interviewed. This was

because this was the only school where two teachers shared grade 11 physical sciences classes among the schools in which the research was carried out.

3.7 Data Analysis

To purpose of gathering data is to use the data to answer the research questions. Data on its own does not answer this question unless it is analysed. Having collected the data, this data has to be interrogated statistically and otherwise so that it provides answers to the research questions. There are various methods of analysing data but only certain kind of data can be analysed using a particular method, also depending on what one intends to find out. For the pre-test and post-test two methods of data analysis were used, the Wilcoxon signed-rank test and the Paired Data Test.

The Wilcoxon signed-rank test is a non-parametric test. In this method of data analysis the two variables are the pre-test and post-test marks. This test however uses one variable which in this case is the difference between the pre-test score and the post-test score. The differences are converted to absolute values and these are then ranked. The test thus does not use the actual values Pietersen and Maree (2007). The sums of rank numbers for positive and negative ranks are calculated and compared. If the sum of positive ranks is much bigger than the sum of negative values then it would be an indication that there was better performance in the post-test. This has to be concluded by a statistical calculation where the p-value is compared with the critical value, α to reject or fail to reject a given hypothesis.

Having used a non-parametric method of data analysis there is need to verify the results by analysing the same data using a parametric method. The parametric method used in this study was the paired data test. A paired data test is used where observations are dependent. In this study the observations were the pre-test and post-test scores. The use of this method is not concerned with the use of the marks themselves but the change in the marks of an individual instead, (Gordon and Gordon, 1994). A hypothesis, H_o: mean of differences = 0, is put forward. From the two scores for each individual, a difference is calculated. The mean of differences of the sample are also calculated. A standard deviation for the differences is then calculated. The standard deviation is used to calculate the t-statistics. The calculated t-statistics value is then compared with t_α (t-critical) from the student t-table. Depending on the outcome, the researcher can either reject or fail to reject the hypothesis.

Interview results were analysed by coding. This involved classifying responses into categories that have specific meanings. Certain conclusions were therefore drawn from the analysed results. Results of the tests were presented in tables and graphs whilst results of interviews and lesson observation were presented in graphs only.

Table 3.3 Methods of analysis for instruments used

Sub question	Instrument	Method of analysis
(i)	Pre-test and Post-test	Wilcoxon signed-rank test
		Paired data test
(ii)	Teacher interview questionnaire	Coding
	Lesson observation field notes	Coding
(iii)	Learner interview questionnaire	Coding

3.8 Description of lesson

After the pre-test the Sci-Bono Subject Matter Expert would discuss with learners the concept of a redox reaction. He would ask them to define oxidation and reduction. Depending on the learners' responses he would give the definition as stated in the CAPS document. From the second school onwards he would even draw learners to the now obsolete definitions which talk about the addition and removal of oxygen and hydrogen. The SME would also stress that oxidation and reduction can be identified by changes in oxidation states from equations and products from an observed reaction.

Learners were given some chemical formulae and asked to identify the oxidation states of particular elements in the formulae. The first few examples would be done on the board by learners. More of these exercises were worked in groups and by individuals but revision of all examples involved the whole class.

In groups students were given two test-tubes, one containing iron filings and the other containing copper sulphate solution. They were asked to record the characteristics of the substances they had been given in terms of state and colour. The students were then asked to pour the iron filings into a test tube with copper sulphate solution, shake the test tube, observe and then record their observations. The observations were discussed in groups and then discussed by the whole class together. The Sci-Bono SME led the discussion on reasons for changes noted. This was meant to lead to learners noticing that new substances had been formed. A further discussion was held on what the new substances were. This was followed by writing a word equation. From the word equation learners were asked to write a balanced chemical equation. The teacher helped those learners who could not do it on their own. A few more examples on balancing equations were worked out.

The teacher introduced another exercise of determining oxidation numbers of particular elements in the equations. Here he also introduced the concept of spectator ions. When he noticed that they could now do it easily he went on to relate the increase and decrease of oxidation numbers to oxidation and reduction respectively. Another exercise of identifying elements that had been oxidised or reduced was introduced. Learners had to identify these in equations they had balanced in the previous exercise. Once there was reflection that this had been mastered, from the response of the students, the teacher would go on to introduce the

terms reducing agent and oxidising agent. Basing on the misconception that some leaners take the oxidising agent to be the substance that has been oxidised, the teacher turned to use analogies. One analogy was about cheating in a game. He said that there is a cheater and the cheated. He would say that the cheater is not the one who is cheated as such the oxidising agent cannot be the one that is oxidised. After this there was yet another exercise where learners would identify the oxidising agents and the reducing agents in the chemical equations. This exercise was more to do with the reasoning for identifying a particular substance than merely identifying the substance.

3.9 Ethical Issues

Maree (2007, 306) stresses that the Helenski Declaration of 1972, requires that an ethics clearance be sought from the ethics committee if the researcher has to use human subjects in his research. As such, this study was cleared by the University of the Witwatersrand ethics committee by providing me with the clearance to proceed with the study. Having obtained the ethics clearance the researcher had to request the Gauteng Department of Education to allow me to access its schools for study purposes. This was granted by the Management and Research Directorate of the Gauteng Department of Education. Permission was also sought from Sci-Bono Discovery Centre to carry out a study on one its programmes, the outreach programme. This included management and teachers involved in the study. The next move was to seek access into the schools where research was to be conducted. This was granted instantly when the researcher got to the schools.

The letters of introduction and requests to involve learners in the study were sent to schools at least two weeks before actual date on which the research had to be conducted. This was to give learners and parents time to engage with me or any third party persons should they require clarity. The letters stated that participating in the study was voluntary and that any participant could withdraw from the study anytime should they decide to. Learners were also promised anonymity and that the data will be kept in a safe inaccessible location and will be destroyed after five years. The researcher promised to provide the Gauteng Department of Education and Sci-Bono Discovery Centre the final report of the study once it has been accepted and endorsed by the University of the Witwatersrand.

3.10 Conclusion

This chapter has highlighted the approach that was used and steps in the whole study. The chapter started with the classification of this study as evaluation research. It defined and described evaluation research and also explained the value of this study to the stakeholders of the Sci-Bono outreach programme which is under study. It went on to give the design of the study. In the research design it covered such areas as research paradigm and research alignment. The research paradigm chosen for the study was described as a mixed method paradigm. The method allows data to be analysed quantitatively as well as qualitatively. Strengths of the paradigm were discussed, together with the relevance of the paradigm to this particular study. Also discussed in this section is the research alignment. This deals with

particular methods of data collection being aligned to research questions and this alignment being justified. The three data collection methods, pre and post tests, lesson observation and interviews are explained with a particular link to the study.

All items of each of the research instruments were interrogated to clearly show their relevance in gathering data required to answer the research questions.

The researcher also discussed validity and reliability of the instruments, that is, what this means and also how validity and reliability were ascertained in this research. These were explained as the measurement of quality of the instruments used to collect data. It cannot be over emphasised that the quality of the research is dependent on the quality of the tools. Face validation and piloting were mentioned as the methods used to test and strengthen validity and reliability. The instruments were improved through these two processes.

The sample of schools as well as teachers and learners used as subjects in the study was described. This consisted of 6 teachers and 139 learners from 5 schools in 5 different districts of the Gauteng province. The method of sampling was also discussed.

Data collection processes were explained in terms of what data was collected, from whom, how and when. This was summarised in table 2.1, with figures target as well as actual numbers for participants. A challenge of having to change a dates for data collection was also highlighted. The methods of data analysis were given and each method was aligned to each instrument and the research question. The methods used were Wilcoxon signed rank test and Paired T-test for pre and post tests, percentages for interviews and coding for lesson observation. This was also given in tabular form in Table 2.2.

Finally the chapter discusses ethical issues. Having used human subjects there are systems that need to be put in place to avoid violation of other people's rights in the process of collecting, analysing and using data. The study was sanctioned by the Wits Ethics Committee, the Department of Education, schools involved and each of the human subjects gave consent. In addition to this the researcher made recorded declaration regarding anonymity and keeping of data captured from each participant during the data collection process. Major stakeholders were promised copies of the research study once it is sanctioned. Participants would also have access to the report should they wish to read it.

The next chapter displays and manipulates data to give meaning to the figures in terms of what the study seeks to find.

CHAPTER 4 DATA ANALYSIS

The research question of this study talks to the effectiveness of teaching. It is about finding out how effective the Sci-Bono outreach programme is in the teaching of electrochemistry at grade 11. In the previous chapter, in the section of Research Alignment, instruments were aligned with research questions to ensure that data is collected for that particular research question. Data alone does not answer a research question unless it is analysed. A change may be observed in the data collected but that change may not be significant. It is only after analysing the data that one can tell whether the change is significant or not. When the change is significant it can then be attributed to intervention but if it is not significant it may have occurred by chance.

4.1 Research question 1

The first sub-question is: How much change is observed in the learners' ability to answer questions in electrochemistry after intervention by Sci-Bono outreach educators?

In measuring the effectiveness of the teaching by the Sci-Bono outreach teachers, a change in performance in tests was chosen as an indicator. This led to the designing of a pre-test and a post-test that were used to collect data. In this study the pre-test result is taken to be reflecting what learners knew at the beginning of the lesson, that is, before treatment. On the other hand, the post-test result is taken to reflect what a particular learner knows at the end of the lesson, that is, after treatment. The difference in the two is thus the change in their ability to answer questions in this particular topic. Face validation by experts to ensure that the pre-test and post-test measure learners' knowledge in redox reactions at grade 11 level as they were meant to be.

For each school where the study was done, both results were captured in tables and the difference for each learner was calculated. It was also indicated whether the difference was positive or negative. A positive difference indicates an improvement in performance which in this case is associated with the lesson delivered. A negative difference, on the other hand would mean a decrease in the level of performance in answering questions, which could also possibly have been caused by the intervention.

4.1.1 Results and analysis for school A

Table 4.1: Raw scores for School A

Learner	SCORES		Difference	Learner	SCORES		Difference
	Pre-test	Post-test			Pre-test	Post-test	
A01	2	5	3	A14	2	12	10
A02	4	10	6	A15	5	6	1
A03	0	2	2	A16	5	10	5
A04	2	12	10	A17	3	8	5
A05	7	10	3	A18	4	8	4
A06	5	9	4	A19	4	8	4
A07	3	10	7	A20	2	12	10
A08	4	10	6	A21	8	12	4
A09	6	5	-1	A22	4	11	7
A10	4	7	3	A23	1	3	2
A11	3	7	4	A24	0	12	12
A12	4	12	8	Average	**3.4**	**8.9**	**5.5**
A13	0	12	12				

The tests had 14 items each thus the highest possible mark was 14. The number of learners who wrote both the pre-test and the post-test was 24 for school A.

The results from student A09 show a decrease in performance. In the post-test the learner was able to answer 5 of the questions he/she had answered correctly in the pre-test. The question whose response was wrong in the pre-test for this learner was question the one where the learner was asked to state the ion which increased in concentration. There are two possible causes of this observation. It could be either the learner got confused during the lesson when the concept was explained or the learner in both cases just guessed the answer to this particular question.

Learners A03, A13 and A24 had a score of zero in the pre-test. The scores of zero in the pre-test could mean that these learners had not retained any of the tested concepts and skills from the lessons the class had on this topic. The improvement in performance varied greatly after intervention. A03 could only give two correct responses whilst learners A13 and A24 were able to give 12 correct responses each. This difference can be attributed to the individual learners' potential. One may argue that learners A13 and A24 have much greater potential in the learning of science than learner A03. Felder (1993), points out that learners perceive information given to them in different ways and therefore comprehend at different rates. Felder (1993) further argues that if the learner's learning style matches the teaching style of the teacher, then the learner is bound to comprehend and hence learn better and retain the information longer.

Considering the CAPS pass percentage of 30% (DBE, 2010), a mark of 4.2 would qualify for a pass. According to this rating there was an increase of 66.7% in pass rate from 25% to 91.7%. The post-test percentage pass rate of 91.7% is well above the set the Gauteng Department of Education's provincial target of 80% pass. This can be taken to mean that the intervention programme is meeting one of the MST strategy goals of increasing the pass rate in physical sciences.

Universities and other tertiary institutions demand a minimum of 60% in physical sciences to accept a candidate to take up a science course at their institutions. Because of this consideration, for the purpose of this study, a mark of 60% or above was considered a quality pass. 60% of 14 is 8.4. Any score above 8.4 was thus be considered a quality pass. In the pre-test there wasn't even a single quality pass but in the post test the percentage of quality passes was 58.3%. This increase also meets one other goal of the MST strategy that talks to the improvement of the quality of passes.

The results in the table generally show an improvement. The average improvement in marks is 5.5. Faced with such results what the question that comes to the mind of the researcher is whether this change is significant or not. This thus calls for statistical analysis. The data was therefore subjected to two types of statistical analysis, the Wilcoxon signed rank test and the paired t-test to determine whether the change is statistically significant or not. Two tests were used to strengthen the conclusion. The paired t-test was used to either confirm the results from the Wilcoxon signed rank test or to reject them.

4.1.1.1 Wilcoxon Signed Rank Test for School A

The Null hypothesis is that the pre-test scores and the post-test scores are the same
$H_{o:}$ Pre-test and post-test scores are the same.
H_a: Pre-test and post test scores are not the same.

Figure 4.1 Wilcoxon signed Rank Test for school A

STUDENT EDITION STATISTIX 7.0

WILCOXON SIGNED RANK TEST FOR POSTTEST - PRETEST

SUM OF NEGATIVE RANKS	-10.500
SUM OF POSITIVE RANKS	289.50
NORMAL APPROXIMATION WITH CONTINUITY CORRECTION	3.971
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION	0.0001

TOTAL NUMBER OF VALUES THAT WERE TIED	22
NUMBER OF ZERO DIFFERENCES DROPPED	0
MAX. DIFF. ALLOWED BETWEEN TIES	0.00001

CASES INCLUDED	24	MISSING CASES	0

Testing at 95% confidence level our p-value is 0.00001. This is less than the critical value of $\alpha = 0.05$. On the basis of this probability we reject the null hypothesis which states that the pre-test scores and the post-test scores are the same. This probability is too small to suggest that this could have happened by chance (Gordon & Gordon 1994, 397). This therefore means that the two samples are significantly different such that the difference can be attributed to the intervention. The significant positive can be attributed to the intervention.

4.1.1.2 Paired T Test for school A

Figure 4.2 Paired T Test for school A

	Variable 1	*Variable 2*
Mean	3.416666667	8.875
Variance	4.34057971	9.070652174
Observations	24	24
Pearson Correlation	0.119527583	
Hypothesized Mean Difference	0	
df	23	
t Stat	-7.747959378	
P(T<=t) one-tail	3.69774E-08	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	7.39549E-08	
t Critical two-tail	2.068657599	

Using the paired t test at 95% confidence level the p-value obtained is 0.0000. This is also far less than 0.05. This suggests that the difference between the pre-test and post-test scores is significant.

If we compare T = 6.58 with $t_{23}(0.025) = 2.069$ from t –distribution table the magnitude of the calculated T is greater than the magnitude of t_{α}. We thus arrive at the same conclusion that there is significant difference between the pre-test scores and the post-test scores. This reinforces the fact that the change was caused by the intervention. The result gives a positive value of 5.5417 as the mean of change in learners' ability to answer questions after the intervention.

Whilst statistics confirm that the Sci-Bono outreach programme in the teaching of electrochemistry at grade 11 improves learners' ability to answer questions, the average score of 9.8 obtained after intervention is still too low. When converted to percentage it gives 63.6% which is far below the provincial pass rate target of 80%. Such interventions are meant to help schools achieve the provincial target.

4.1.2 Results analysis for school B

Table 4.2: Raw scores for school B

Learner	SCORES		Difference	Learner	SCORES		Difference
	Pre-test	Post-test			Pre-test	Post-test	
B01	0	6	6	B20	4	11	7
B02	0	2	2	B21	3	11	8
B03	2	4	2	B22	0	11	11
B04	2	5	3	B23	1	9	8
B05	1	3	2	B24	1	12	11
B06	3	3	0	B25	1	7	6
B07	4	7	3	B26	1	9	8
B08	2	2	0	B27	3	4	1
B09	3	9	6	B28	4	5	1
B10	4	3	-1	B29	3	8	5
B11	2	7	5	B30	0	4	4
B12	6	11	5	B31	1	7	6
B13	1	9	8	B32	1	8	7
B14	2	5	3	B33	3	6	3
B15	3	9	6	B34	2	3	1
B16	2	10	8	B35	1	4	3
B17	8	9	1	B36	6	8	2
B18	6	12	6	B37	1	7	6
B19	2	6	4	**Average**	**2.4**	**6.9**	**4.5**

For school B the pre-test average score was very low. Only one learner, B17 had a score above 50%.Learners B01, B02, B22 and B30 all had a score of zero in the pre-test. This means that these learners could not remember any of the tested concepts and skills from the lessons the class had on this topic. Nine other learners were able to give only one correct response out fourteen, whilst eight scored 2 and seven scored 3. This was a reflection that the learners remembered very little of what they had been taught in this topic. One would assume that the topic had not been treated well at that time. There was however marked improvement in learners' ability to answer questions after intervention. The average rose to 6.9, showing an increase of 4.5.

Learner B17, having had the highest score in the pre-test, improved his/her score by only one mark whereas lots of those who had scored lower than him/her in the pre-test recorded much better improvement, some of them performing much better than him/her. On close scrutiny of the learner's scripts the researcher found that the learner still did not get right the same questions he could not answer in the pre-test except for one. This would suggest that he still held the misconceptions he held before intervention. The intervention can be assumed to have been aimed very low. According to I-TECH (2008), if lower scorers in the pre-test tend to show greater improvement in the post-test whilst the higher scorers remain stable, then the training

is aimed very low. Alternatively if higher scorers in the pre-test tend to show greater improvement in the post-test whilst the lower scorers remain stable, then the training is aimed very high. Aiming high or low depends on the pre-knowledge that the learners have. If learners lack the basic concepts and skills in a particular topic then they should be given these foundation skills first. The time taken on this will also depended on how long the learners take to master the concepts. In a normal class of mixed ability if the teacher spends more time on basics, the knowledge of the learners who do not need the basics remain constant, even if they are kept busy. When tested at the end of the lesson these learners are not likely to show any improvement as they would not have learnt anything new.

There was an increase of 62% in pass rate from 10.8% to 73%. The post-test percentage pass rate of 73% is below the set the Gauteng Department of Education's provincial target of 80%. Although the intervention programme is meeting one of the MST strategy goals of increasing the pass rate in physical sciences, it stills falls short of meeting the target. As an intervention programme it ought to.

In the pre-test at school B there wasn't even a single quality pass but in the post test the percentage of quality passes was 35%. This increase also meets one other goal of the MST strategy that talks to the improvement of the quality of passes.

4.1.2.1 Wilcoxon Signed Rank Test for School B

The Null hypothesis is that the pre-test scores and the post-test scores are the same
$H_{o:}$ Pre-test and post-test scores are the same.
H_a: Pre-test and post test scores are not the same.

Figure 4.3 Wilcoxon Signed Rank Test results for school B

STUDENT EDITION STATISTIX 7.0

WILCOXON SIGNED RANK TEST FOR POSTTEST - PRETEST

SUM OF NEGATIVE RANKS	-3.0000
SUM OF POSITIVE RANKS	627.00
NORMAL APPROXIMATION WITH CONTINUITY CORRECTION	5.102
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION	0.0000
TOTAL NUMBER OF VALUES THAT WERE TIED	35
NUMBER OF ZERO DIFFERENCES DROPPED	2
MAX. DIFF. ALLOWED BETWEEN TIES	0.00001

CASES INCLUDED	35	MISSING CASES	2

Testing at 95% confidence level our p-value is 0.00000. This is less than the critical value of $\alpha = 0.05$. On the basis of this probability we reject the null hypothesis which states that the pre-test scores and the post-test scores are the same. The interpretation is that the two samples are significantly different and that the difference is attributed to the intervention.

4.1.2.2 Paired T Test for school B

Figure 4.4 Paired T Test results for school B

	Pre-test	*Post-test*
Mean	2.405405405	6.918918919
Variance	3.525525526	8.743243243
Observations	37	37
Pearson Correlation	0.276258678	
Hypothesized Mean Difference	0	
df	36	
t Stat	-9.050932903	
P(T<=t) one-tail	4.15778E-11	
t Critical one-tail	1.688297694	
P(T<=t) two-tail	8.31556E-11	
t Critical two-tail	2.028093987	

Using the paired t test at 95% confidence level the p-value obtained is 0.0000. This is less than 0.05.

When T = 9.05 is compared with $t_{37}(0.025) = 1.960$ from t –distribution table the magnitude of the calculated T is greater than the magnitude of t_{α}. We therefore arrive at the conclusion that there is significant difference between the pre-test scores and the post-test scores. This significant difference means that the change was caused by the intervention. The conclusion is that the intervention was effective and according to the displayed t statics the increase in the mean was 4.5135. This indicates a positive change in learners' ability to answer questions after the intervention.

4.1.3 Results analysis for school C

Table 4.3 Raw scores for school C

Learner	SCORES		Difference	Learner	SCORES		Difference
	Pre-test	Post-test			Pre-test	Post-test	
C01	2	10	8	C15	2	14	12
C02	4	8	4	C16	6	10	4
C03	2	12	10	C17	2	11	9
C04	4	9	5	C18	8	14	6
C05	2	8	6	C19	10	11	1
C06	6	14	8	C20	2	11	9
C07	5	13	8	C21	3	10	7
C08	8	14	6	C22	2	4	2
C09	3	11	8	C23	4	14	10
C10	4	9	5	C24	4	11	7
C11	6	10	4	C25	8	14	6
C12	5	6	1	C26	0	2	2
C13	5	7	2	C27	3	12	9
C14	3	11	8	**Average**	**4.2**	**10.4**	**6.2**

In school C there were 27 learners doing physical sciences in grade 11and they all took part in the intervention lesson conducted by the Sci-Bono Subject Matter Specialist. The pre-test and post-test were both marked out of 14. Learner C26 had a score of zero in the pre-test and two in the post-test. Before intervention this learner had did not understand any of the concepts or skills tested. After intervention the learner still understood very little. This may suggest that this particular learner is a slow learner. This lesson can also be assumed to have been aimed low since there was greater improvement from those learners who had scored low in the pre-test (I-TECH, 2008). This can be seen from the comparison between the performance of learner C19 and the rest of the learners. Despite the lesson being aimed low, learner C26 still had a very small improvement. This could mean that the learner's misconceptions did not change at all.

There was an increase of 44% in pass rate from 30% to 74%. The post-test percentage pass rate of 74% is however below the set the Gauteng Department of Education's provincial target of 80%. Although the intervention programme is meeting one of the MST strategy goals of increasing the pass rate in physical sciences, it stills falls short of meeting the target. As an intervention programme it ought to, since these intervention programmes are meant to address defaults in the teaching of physical sciences. Intervention models are taken to be examples of best practice and if they fail to meet set targets it raises concern.

Any score above 8.4 is thus considered a quality pass. In the pre-test at school C there was only one quality pass whereas in the post –test there were 21 quality passes. This means that the intervention improved the quality passes from 4% to 78%.

4.1.3.1 Wilcoxon Signed Rank Test for School C

The Null hypothesis is that the pre-test scores and the post-test scores are the same
$H_{o:}$ Pre-test and post-test scores are the same.

H_a: Pre-test and post test scores are not the same.

Figure 4.5 Wilcoxon Signed Rank test for School C

STUDENT EDITION STATISTIX 7.0

WILCOXON SIGNED RANK TEST FOR POSTTEST - PRETEST

SUM OF NEGATIVE RANKS	0.0000
SUM OF POSITIVE RANKS	378.00
NORMAL APPROXIMATION WITH CONTINUITY CORRECTION	4.529
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION	0.0000

TOTAL NUMBER OF VALUES THAT WERE TIED	26
NUMBER OF ZERO DIFFERENCES DROPPED	0
MAX. DIFF. ALLOWED BETWEEN TIES	0.00001

CASES INCLUDED	27	MISSING CASES	0

Testing at 95% confidence level our p-value is 0.00000. This is less than the critical value of $\alpha = 0.05$. On the basis of this probability we reject the null hypothesis which states that the pre-test scores and the post-test scores are the same. This probability is too small to suggest that this could have happened by chance (Gordon & Gordon 1994, 397). The interpretation of this is that the two samples are significantly different such that the difference can be attributed to the intervention.

4.1.3.2 Paired T Test results for School C

Figure 4.6 Paired T Test results for school C

	Pre-test	*Post-test*
Mean	4.185185185	10.37037037
Variance	5.618233618	9.626780627
Observations	27	27
Pearson Correlation	0.440079137	
Hypothesized Mean Difference	0	
df	26	
t Stat	-10.85133829	
P(T<=t) one-tail	1.88321E-11	
t Critical one-tail	1.705617901	
P(T<=t) two-tail	3.76641E-11	
t Critical two-tail	2.055529418	

Using the paired t test at 95% confidence level the p-value obtained is 0.0000. This is also far less than 0.05.

If we compare T = 10.5 with $t_{26}(0.025) = 2.056$ from t –distribution table the magnitude of the calculated T is greater than the magnitude of t_{α}. We therefore arrive at the conclusion that there is significant difference between the pre-test scores and the post-test scores. This difference is attributed to the intervention hence the intervention was effective in improving the learners' ability to answer questions on electrochemistry by a mean of 6.1852.

4.1.4 Result analysis for school D

Table 4.4: Raw scores for school D

Learner	SCORES		Difference	Learner	SCORES		Difference
	Pre-test	Post-test			Pre-test	Post-test	
D01	4	9	5	D16	4	12	8
D02	0	6	6	D17	0	9	9
D03	0	6	6	D18	0	10	10
D04	0	10	10	D19	1	6	5
D05	0	6	6	D20	0	1	1
D06	1	10	9	D21	2	13	11
D07	3	7	4	D22	1	11	10
D08	0	4	4	D23	0	9	9
D09	0	14	14	D24	9	12	3
D10	1	4	3	D25	0	12	12
D11	1	10	9	D26	4	9	5
D12	2	14	12	D27	2	11	9
D13	0	3	3	D28	1	5	4
D14	2	10	8	D29	0	6	6
D15	3	14	11	D30	0	7	7
				Average	**1.4**	**8.7**	**7.3**

Of the 30 learners who were involved in the intervention lesson, 14 of them scored zero in the pre-test. The other scores were also very low except for one, that is, for learner D24. The average for the pre-test, 1.4, was also very low. This suggests that most learners either remembered very little or nothing at all from the lessons on this topic. This may further suggest that this topic had not been tackled well by the teacher. This could be a result of a mismatch between the teaching style of the teacher and the learning styles of the learners (Felder, 1993).

The difference in averages between the pre-test and the post-test is quite high, showing marked improvement in performance. In school D there was also a greater improvement observed from low scorers in the pre-test than the high scorer (D24). As suggested by I-TECH (2008), the lesson was aimed low. The interesting observation is however that there are three learners who outperformed learner D24 who had been no match for them in the pre-test. Taking into consideration the argument by Felder (1993), chances are that the learning style of learner D24 matched the teaching style of his/her physical science teacher but did not match the teaching style of the Sci-Bono Subject Matter Specialist who conducted the intervention lesson.

There was an increase of 84% from 3% to 87% in pass rate. The post-test percentage pass rate of 87%.

In the pre-test at school D there was a single quality pass which in percentage was 3.7% but in the post test the percentage of quality passes was 43%. This increase also meets one other goal

of the MST strategy that talks to the improvement of the quality of passes. Of the 13 quality passes recorded in the post-test, 3 of them were 100% scores.

4.1.4.1 Wilcoxon Signed Rank Test results for School D

The data was then subjected to the Wilcoxon signed rank test and it yielded the results below.

The Null hypothesis is that the pre-test scores and the post-test scores are the same
$H_{o:}$ Pre-test and post-test scores are the same.
H_a: Pre-test and post test scores are not the same.

Figure 4.7 Wilcoxon Signed Rank Test results for school D

STUDENT EDITION STATISTIX 7.0

WILCOXON SIGNED RANK TEST FOR POSTTEST - PRETEST

SUM OF NEGATIVE RANKS	0.0000
SUM OF POSITIVE RANKS	465.00
NORMAL APPROXIMATION WITH CONTINUITY CORRECTION	4.772
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION	0.0000
TOTAL NUMBER OF VALUES THAT WERE TIED	27
NUMBER OF ZERO DIFFERENCES DROPPED	0
MAX. DIFF. ALLOWED BETWEEN TIES	0.00001

CASES INCLUDED	30	MISSING CASES	0

Testing at 95% confidence level our p-value is 0.00001. This is less than the critical value of $\alpha = 0.05$. On the basis of this probability we reject the null hypothesis which states that the pre-test scores and the post-test scores are the same. This probability is too small to suggest that this could have happened by chance (Gordon & Gordon 1994, 397). We may therefore conclude that the two samples are significantly different such that the difference can be attributed to the intervention by the Sci-Bono outreach educators.

4.1.4.2 Paired T Test for School D

Figure 4.8 Paired T Test results for school C

	Pre-test	*Post-test*
Mean	1.366666667	8.666666667
Variance	3.895402299	11.95402299
Observations	30	30
Pearson Correlation	0.39246729	
Hypothesized Mean Difference	0	
df	29	
t Stat	-12.34330642	
P(T<=t) one-tail	2.27609E-13	
t Critical one-tail	1.699126996	
P(T<=t) two-tail	4.55219E-13	
t Critical two-tail	2.045229611	

Using the paired t test at 95% confidence level the p-value obtained is 0.0000. This is also far less than 0.05.

If T = 12.34 is compared with $t_{29}(0.025) = 2.045$ from t –distribution table the magnitude of the calculated T is greater than the magnitude of t_{α}. We therefore arrive at the conclusion that there is significant difference between the pre-test scores and the post-test scores. This difference is attributed to the intervention.

4.1.5 Results analysis for school E

Table 4.5 Raw Scores for school E

Learner	SCORES		Difference	Learner	SCORES		Difference
	Pre-test	Post-test			Pre-test	Post-test	
E01	3	10	7	E10	4	8	4
E02	1	4	3	E11	4	10	6
E03	1	5	4	E12	7	9	2
E04	4	7	3	E13	0	9	9
E05	2	7	5	E14	3	10	7
E06	6	12	6	E15	3	9	6
E07	3	8	5	E16	7	12	5
E08	4	9	5	E17	8	7	-1
E09	1	8	7	E18	5	9	4
				Average	**3.7**	**8.5**	**4.8**

At school E there were only 18 learners who took part in the intervention lesson. The pre-test scores varied from 0 to 8. One learner, E13, scored zero and three learners, E01, E03 and E09 scored one each. These scores may be assumed to indicate that these learners did not comprehend much from the lesson they had with their physical sciences teacher in this topic. In the post-test all learners except one recorded some improvement, showing gain in knowledge or skills from the intervention lesson. Incidentally the learner who scored the highest mark in the pre-test, and the only mark above 50% showed a poorer performance in the post-test. One would assume that the learner got confused during the intervention lesson. This can also be attributed to a mismatch between the learning style and the teaching style. The learner's learning style may have matched very well with that of the physical sciences teacher when he was first exposed to this topic.

There was an increase in pass rate of 72% from 22% to 94%. The post-test percentage pass rate of 94% is well above the set the Gauteng Department of Education's provincial target of 80%. This can be taken to mean that the intervention programme is meeting one of the MST strategy goals of increasing the pass rate in physical sciences.

In the pre-test there wasn't even a single quality pass but in the post test the percentage of quality passes was 55.6%.

4.1.5.1 Wilcoxon Signed Rank Test results for School E

The Null hypothesis is that the pre-test scores and the post-test scores are the same.

H_o: Pre-test and post-test scores are the same.
H_a: Pre-test and post test scores are not the same.

Figure 4.9 Wilcoxon Signed Rank Test for School E

STUDENT EDITION STATISTIX 7.0

WILCOXON SIGNED RANK TEST FOR POSTTEST - PRETEST

SUM OF NEGATIVE RANKS	0.0000
SUM OF POSITIVE RANKS	325.00
NORMAL APPROXIMATION WITH CONTINUITY CORRECTION	4.359
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION	0.0000

TOTAL NUMBER OF VALUES THAT WERE TIED	24
NUMBER OF ZERO DIFFERENCES DROPPED	0
MAX. DIFF. ALLOWED BETWEEN TIES	0.00001

CASES INCLUDED	25	MISSING CASES	0

Testing at 95% confidence level our p-value is 0.00000. This is less than the critical value of $\alpha = 0.05$. On the basis of this probability we reject the null hypothesis which states that the pre-test scores and the post-test scores are the same. This probability is too small to suggest that this could have happened by chance. We can therefore conclude that the two samples are significantly different and that the difference is attributed to the intervention. This further suggests that the intervention was effective in causing a positive change in learners' ability to answer questions in electrochemistry.

4.1.5.2 Paired T Test for School E

Figure 4.10 Paired T Test results for school E

	Pre-test	*Post-test*
Mean	3.666667	8.5
Variance	5.176471	4.264706
Observations	18	18
Pearson Correlation	0.463224	
Hypothesized Mean Difference	0	
df	17	
t Stat	-9.09074	
P(T<=t) one-tail	3.07E-08	
t Critical one-tail	1.739607	
P(T<=t) two-tail	6.14E-08	
t Critical two-tail	2.109816	

From these results the t statistics value of -9.142857143 is outside the range between the critical value of 2.160368652 and the P value of 4.52274. The fact that it does not lie between these values means that the hypothesised mean difference of 0 should be rejected.

Using the paired t test at 95% confidence level the p-value obtained is 0.0000000614. This is also far less than 0.05 and this means that the differences between the pre-test and the post-test scores are significant. The significant difference indicates that the intervention was effective. The difference between the post-test and the pre-test is 4.833333. This is the degree by which the learners' ability to answer questions was raised by the intervention.

4.1.6 Question analysis

Having compared the total scores between the pre-tests and post-tests it is worth looking at the performance in each question both in the pre-test and the post tests. The tests were set at the same level of difficult and the question for each number tests exactly the same concept as the question in the other test. This analysis will help identify whether for a particular concept there has been a significant change in learners' conceptions.

Table 4.6: Correct responses for school A

SCHOOL A			
Question	Pre-test	Post-test	Increase
1.1	6	19	13
1.2	10	19	9
1.3	9	20	11
1.4	3	17	14
2.1a	10	17	7
2.1b	7	17	10
2.2a	8	10	2
2.2b	2	10	8
2.3.1a	6	14	8
2.3.1b	0	4	4
2.3.2a	10	19	9
2.3.2b	7	18	11
2.3.3a	7	13	6
2.3.3b	1	6	5

Graph 1: Correct responses for school A

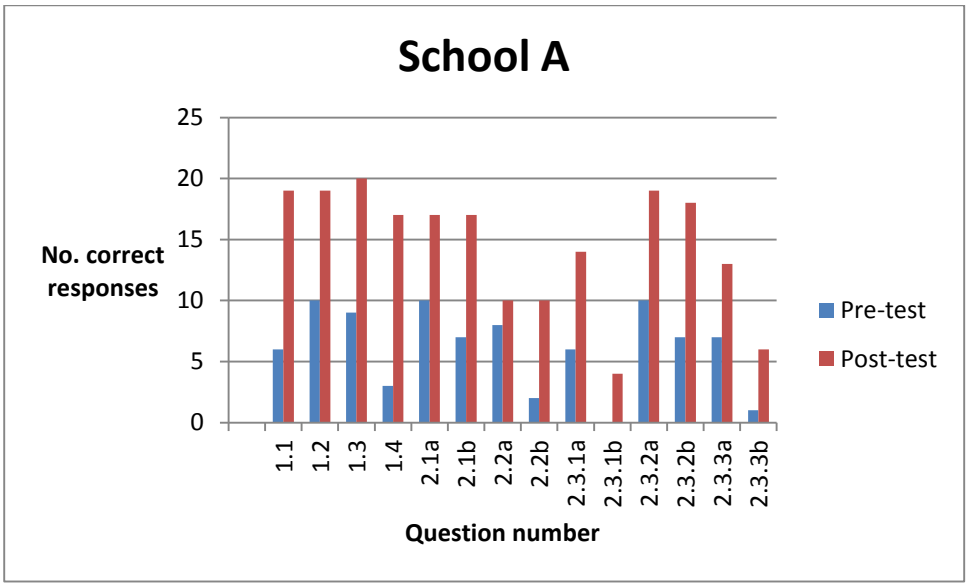


Figure 4.11: Paired Two t-Test Sample for Means for school A

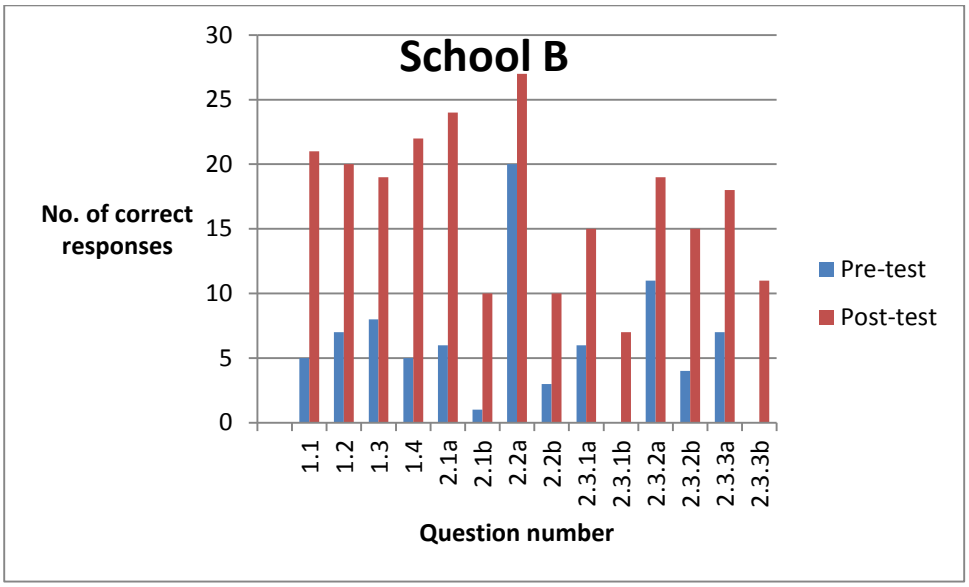
	Pre-test	*Post-test*
Mean	6.142857143	14.5
Variance	11.51648352	26.73076923
Observations	14	14
Pearson Correlation	0.762851883	
Hypothesized Mean Difference	0	
df	13	
t Stat	-9.229715575	
P(T<=t) one-tail	2.26137E-07	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	4.52274E-07	
t Critical two-tail	2.160368652	

From these results the t statistics value of -9.142857143 is outside the range between the critical value of 2.160368652 and the P value of 4.52274. The fact that it does not lie between these values means that the hypothesised mean difference of 0 should be rejected hence the differences are significant.

Table 4.7: Correct responses for school B

Question	Pre-test	Post-test	Increase
1.1	5	21	16
1.2	7	20	13
1.3	8	19	11
1.4	5	22	17
2.1a	6	24	18
2.1b	1	10	9
2.2a	20	27	7
2.2b	3	10	7
2.3.1a	6	15	9
2.3.1b	0	7	7
2.3.2a	11	19	8
2.3.2b	4	15	11
2.3.3a	7	18	11
2.3.3b	0	11	11

Graph 4.2: Correct responses for school B



The total number of learners in school B was

Figure 4.12: Paired Two t-Test Sample for Means for school B

	Pre-test	*Post-test*
Mean	5.928571429	17
Variance	26.07142857	34.61538462
Observations	14	14
Pearson Correlation	0.780979244	
Hypothesized Mean Difference	0	
df	13	
t Stat	-11.16604848	
P(T<=t) one-tail	2.46669E-08	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	4.93338E-08	
t Critical two-tail	2.160368652	

From the above results the t statistics value of -11.16604848 is outside the critical value of 2.160368652 and the P value of 4.93338. We thus reject the hypothesised mean difference of 0 hence the differences are significant.

Table 4.8: Correct responses for school C

Question	Pre-test	Post-test	Increase
1.1	9	20	11
1.2	15	23	8
1.3	13	24	11
1.4	10	22	12
2.1a	9	19	10
2.1b	4	14	10
2.2a	19	20	1
2.2b	5	14	9
2.3.1a	13	19	6
2.3.1b	2	14	12
2.3.2a	11	22	11
2.3.2b	7	20	13
2.3.3a	11	19	8
2.3.3b	2	12	10

Graph 4.3: Correct responses for school C

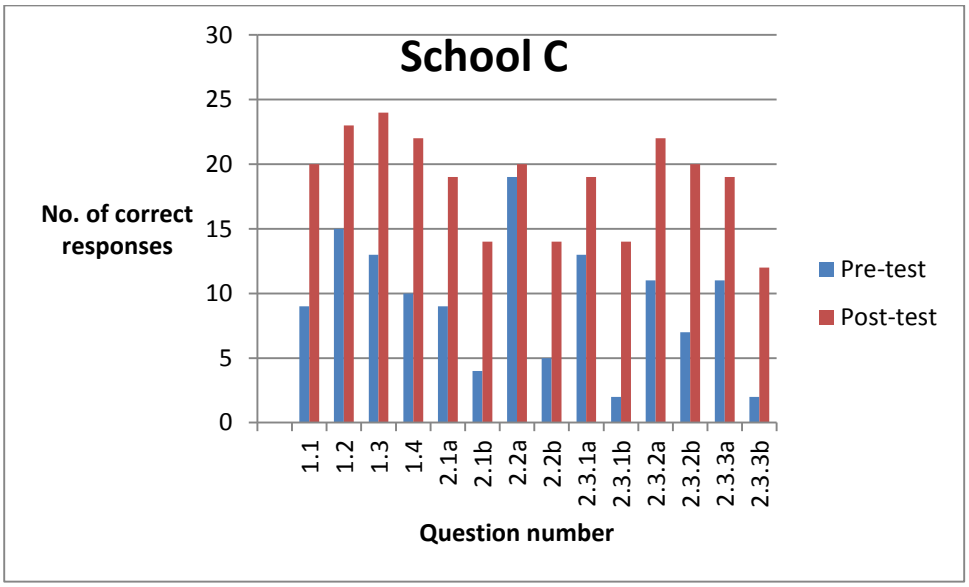


Figure 4.13: Paired Two t-Test Sample for Means for School C

	Variable 1	*Variable 2*
Mean	9.285714286	18.71428571
Variance	24.52747253	14.21978022
Observations	14	14
Pearson Correlation	0.787302953	
Hypothesized Mean Difference	0	
df	13	
t Stat	-11.54306514	
P(T<=t) one-tail	1.66219E-08	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	3.32438E-08	
t Critical two-tail	2.160368652	

From these results the t statistics value of -11.54306514 is outside the critical value of 2.160368652 and the P value of 3.32438. The fact that it does not lie between these values means that the hypothesised mean difference of 0 should be rejected hence the differences are significant.

Table 4.9: Correct responses for school D

Question	Pre-test	Post-test	Increase
1.1	1	25	24
1.2	4	24	20
1.3	3	24	21
1.4	0	18	18
2.1a	7	17	10
2.1b	0	14	14
2.2a	6	16	10
2.2b	1	11	10
2.3.1a	5	22	17
2.3.1b	0	21	21
2.3.2a	7	16	9
2.3.2b	3	16	13
2.3.3a	5	16	11
2.3.3b	0	16	16

Graph 4.4: Correct responses for school D

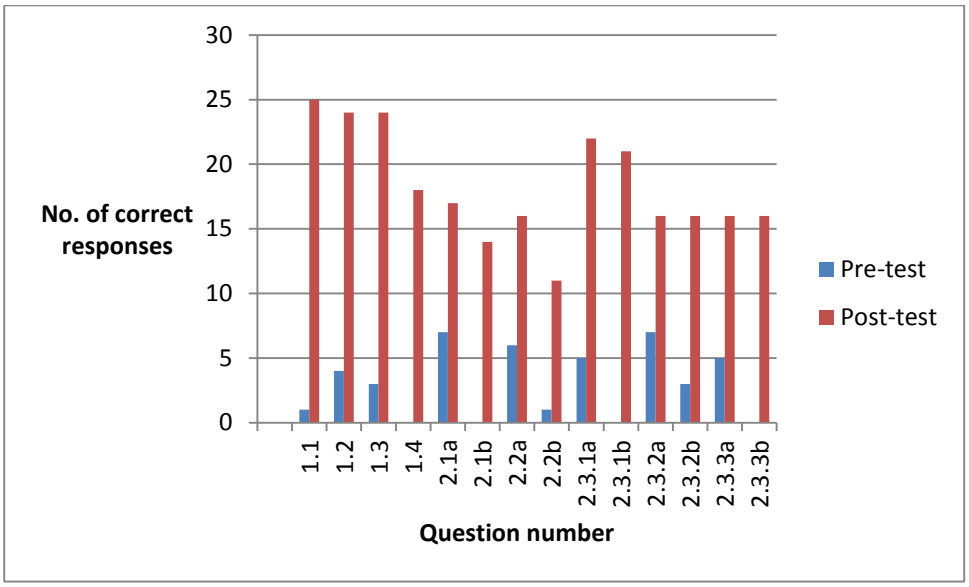


Figure 4.14: Paired Two t-test Sample for Means for school D

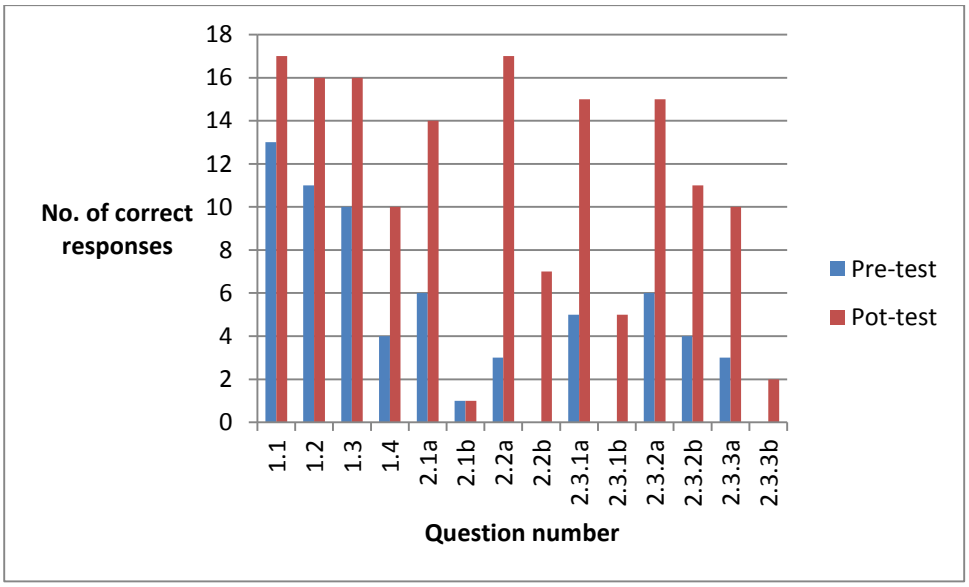
	Pre-test	*Post-test*
Mean	3	18.28571429
Variance	7.230769231	17.75824176
Observations	14	14
Pearson Correlation	0.006788353	
Hypothesized Mean Difference	0	
df	13	
t Stat	-11.47667893	
P(T<=t) one-tail	1.78043E-08	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	3.56087E-08	
t Critical two-tail	2.160368652	

From the above results the t statistics value of -11.47667893 is outside the critical value of 2.160368652 and the P value of 3.56087. We thus reject the hypothesised mean difference of 0 hence the differences are significant.

Table 4.10: Correct responses for school E

Question	Pre-test	Post-test	Increase
1.1	13	17	4
1.2	11	16	5
1.3	10	16	6
1.4	4	10	6
2.1a	6	14	8
2.1b	1	1	0
2.2a	3	17	14
2.2b	0	7	7
2.3.1a	5	15	10
2.3.1b	0	5	5
2.3.2a	6	15	9
2.3.2b	4	11	7
2.3.3a	3	10	7
2.3.3b	0	2	2

Graph 4.5: Correct responses for school E



An analysis was also done on each question in the in the two tests. There was significant improvement in performance generally and this was proved statistically.

Figure 4.15: Paired Two t-test Sample for Means for school E

	Pre-test	*Post-test*
Mean	4.714285714	11.14285714
Variance	17.45054945	30.59340659
Observations	14	14
Pearson Correlation	0.787590498	
Hypothesized Mean Difference	0	
df	13	
t Stat	-7.04768127	
P(T<=t) one-tail	4.3503E-06	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	8.70059E-06	
t Critical two-tail	2.160368652	

From the above results the t statistics value of -7.04768127is outside the critical value of 2.160368652 and the P value of 8.70059. We thus reject the hypothesised mean difference of 0 hence the differences are significant.

This further reinforces the conclusion that the intervention contributed to the improvement in learners' ability to answer questions.

4.1.7 Discussion on test questions

Looking at individual questions, improvement was not the same for all. The differences between correct responses in particular questions in the pre-test and post-test revealed areas that were covered well or not in the lessons conducted by the Sci-Bono outreach team. This varied from school to school but there was a trend. From the collated results of the five schools, the concepts that were covered very well were those encompassed in questions 1.1, 1.2, 1.3, 1,4 and 2.3.2b. This where there was the greatest improvement in correct responses to the questions since highest differences translate to greatest improvement.

Question 1.1 sought a definition of reduction in the pre-test and oxidation in the post-test. These definitions are in terms of electron transfer, whether the electrons are lost or gained. If this concept is mastered correctly then a learner should be able to define both. Arguably if the learner cannot define one, it also means that he/she will not be able to define the other. A greater number of correct responses for this question in the post-test means that more learners are now able to give correct definitions both oxidation and reduction. Ganertt and Treagust (1992) argue that understanding what oxidation and reduction is key to identifying these reactions in equations. Their study revealed that there were misconceptions that emanated from the definitions of these terms being used inappropriately. The significant increase in the ability to correctly define the terms means that Sci-Bono outreach educators are able to deal with such misconceptions.

Questions 1.2, 1.3 and 1.4 dealt with identifying the oxidation states of elements in compounds. The questions were as follows:

1.2 Pre-test: What is the oxidation number of carbon in carbon dioxide (CO_2)?

1.2 Post-test: What is the oxidation number of sulphur in sulphur dioxide (SO_2)?

1.3 Pre-test: What is the oxidation number of carbon in carbon monoxide (CO)?

1.3 Post-test: What is the oxidation number of sulphur in sulphur trioxide (SO_3)?

1.4 Pre-test: What is the oxidation number of carbon in a carbonate ion (CO_3^{2-})?

1.4 Post-test: What is the oxidation number of sulphur in a sulphate ion?

The calculation for the three questions is the same but is pitched at different levels which are determined by the number of oxygen atoms, that is, for 1.2 and 1.3 and by the charge of the ion for 1.4.

It is crucial for the learners to have this skill in electrochemistry so that they are able to identify what was oxidised or reduced in any redox reaction. It is therefore one of the basic skills required in electrochemistry. The Sci-Bono outreach educators have thus been found to be successful in advancing this skill in learners.

Question 2.3.2b which was also well done sought an explanation as to why the learner had chosen a particular ion as a spectator ion. There were more correct responses to this question than for the preceding question which required them to choose a spectator ion among three given ions. This means that more learners understood that the oxidation state of a spectator ion does not change even if some of those learners could not identify the spectator ions. Their inability to identify the spectator ions suggests that they either did not realise the need or were unable to determine the oxidation states of elements or ions in the given equation. This further suggests that some learners may have the skill of calculating oxidation states but cannot apply this skill where it is required.

The least improvement was in questions 2.2a, 2.2b, 2.3.2a and 2.3.3a in general. School A however had a very low improvement in 2.3.3b.

In question 2.2a learners were asked to identify the substance that had been oxidised from a given equation. The inability of learners to answer this question confirms the conclusion made above that although learners have acquired the skill of calculating oxidation states they do not recognise where this skill is required. It is also interesting to note that a question preceding this was asking them to identify a reducing agent. More learners answered this correctly. It therefore means that those who correctly identified a reducing agent but could not identify what was oxidised are unable to link the two terms. This may also mean that some learners do not realise the fact that oxidation and reduction are not independent of one another.

Question 2.2b sought an explanation as to why the learner has chosen a particular substance as having been oxidised. For this question there were more correct responses than the preceding question meaning that there are learners who answered this correctly but who had failed to identify the substance that was oxidised. This means that although question 2.2b is a comprehension question, in this particular instance, for these learners, it has been a recall

question in that these learners could remember from the lesson that oxidation is determined by an increase in oxidation state. If these learners had understood the concept they would have done the calculation and this would have influenced their choice as a response to the preceding question which required them to identify the substance that was oxidised.

In question 2.3.2a learners were asked to identify spectator ions in the reaction but they were given options. The question reads: During the reaction there are iron ions, copper ions and sulphate ions in solution. Which of these ions are spectator ions? Poor performance in this question may suggest that most learners guessed the answer by picking one of the given options. This includes some of those who gave the correct response. Some of the interviewed learners indicated that they had guessed the answer and some of these had given the correct response. This means that even after the lesson, there are some learners who still could not identify ions in a given equation. The general observation made during the lessons was that this concept was well tackled but questions were being directed to the class and individual learners were giving answers. It was not easy for the teacher then, to notice that there were learners who could not identify these ions from the equation.

Question 2.3.3a, which was also not done well required learners to identify the ion that increased in concentration during the reaction. An interesting observation is that there were less correct responses compared to the next question which sought a reason for a choice for this particular question. There were learners who could give a correct reason whereas they could not pick the correct response. This indicates that the fact that the concentration of products increase during the reaction was well grasped. It also further reinforces the researcher's argument that the weakness of the lesson was that it failed to impart the skill of identifying ions involved in the reaction.

From the above discussion one would conclude that the intervention was effective in improving learners' ability to answer questions although the level of improvement varied from one question to another.

4.2 Misconceptions

The third sub-question talks to the success in tackling misconceptions. The question says," Does the teaching by Sci-Bono outreach educators eliminate the common misconceptions learners have in electrochemistry?" This question was answered through the pre-test and also through the teachers' interviews. There are questions that tested the common misconceptions in both the pre-test and the post-test. One misconception which learners have in this topic is that tend to define oxidation and reduction in terms of oxygen. The other one is that oxidising agents are taken to be substances that are oxidised during the reaction and reducing agents as substances that are reduced during the reaction. These misconceptions are going to be classified as follows:

Misconception 1: Oxidation is the addition/gain of oxygen.

OR

Reduction is the removal/loss of oxygen.

Misconception 2: A reducing agent is the substance that is reduced during a reaction.

OR

An oxidising agent is the substance that is oxidised during a reaction.

4.2.1 Pre-test and post-test

The discussion and the data in this section refers only to a sample of learners that were interviewed.

In the pre-test and post-test misconception one could be given as it is stated above or in a way that gives the same meaning as above. This is because question 1.1 asks for a definition. Misconception 2 can be revealed in question 2.1b where a learner is asked to give a reason why he/she has chosen a particular substance, in response to question 2.1a, as a reducing agent. A learner harbouring this misconception would say that he/she has chosen that substance because it is reduced during the reaction. This does not matter whether the response to question 2.1a is correct or wrong. A response to question 1 on its own would not reveal this conception.

Data regarding these two misconceptions was collected from checking responses to these two questions in the pre-test. Once found in the pre-test, this was recorded. The answer to the same question by that learner in the post-test was checked to find out if the learner still had the misconception or not. This was also recorded.

Table 4.11: Record of misconceptions identified in the pre-test and in the post-test for the learners who were interviewed.

School	**Misconception 1**		**Misconception 2**	
	Pre-test	Post-test	Pre-test	Post-test
A	3	0	7	2
B	0	0	4	1
C	2	0	5	2
D	1	0	5	1
E	0	0	3	0
TOTAL	**6**	**0**	**24**	**6**

In the pre-test, a total of 6 of the interviewed learners were identified as having misconception 1 and in the post-test none of them revealed this conception. From these results one can conclude that the intervention had a 100% success rate in eliminating the misconception. It can however be argued that this misconception is only in the definition of oxidation and not in the definition of reduction. There is a possibility that learners could still define reduction wrongly. It can also be argued that this could just be a result of rote learning or just simple recall since this has been covered in the lesson.

As for misconception 2 there was a total of 24 of the interviewed learners found to be having this misconception in the pre-test. Of these 24 learners, 6 of them repeated the same response in the post test and 18 gave correct responses. This means that the 6 still had the same view

they had at the beginning of the lesson. This was despite an increase in their overall mark. The success rate in eliminating this misconception was 80%. This refers to only the interviewed learners who exhibited this misconception in the pre-test.

4.2.2 Interview with learners

Learners were interviewed to find out if they still held the misconceptions that had been identified from their pre-tests.

4.2.2.1 Misconception 1

Five learners were interviewed at each of the five schools. This included all the 6 learners from the three schools whose pre-test scripts reflected that they had the misconception. The learners' responses were interpreted by the researcher and classified into two meanings, misconception apparent and misconception eliminated. The results were as follows as shown in the table below.

Table 4.12 Comparison of misconception 1 held at pre-test time and at interview time

School	No. of learners interviewed	No. of interviewed learners who had the misconception in pre-test	No. of interviewed learners showing misconception at the interview
A	5	3	0
B	5	0	0
C	5	2	2
D	5	1	0
E	5	0	0
TOTAL	25	6	2

None of the interviewed learners who did not reflect holding the misconception in pre-test showed it in the interview. From those who were previously found to be having the misconception, all except two, incidentally from the same school, were found to be still having the same thought. This was despite the two of them not having reflected this in the post-test although they did not give the correct response. They still felt oxygen had something to do with oxidation. They however did not think that reduction had anything to do with oxygen, which explains why they did not show this misconception in the post-test. This result reduces success rate of eliminating this misconception for this group from the 100% obtained from the analysis of their tests to 66.7%. This also suggests that instead of the obsolete definitions of oxidation and reduction that are in terms of addition and removal of oxygen respectively being considered one misconception, they need to be separated into two misconceptions as has been revealed that a learner may actually exhibit only one of them.

4.2.2.2 Misconception 2

Five learners were interviewed at each of the five schools. This included learners whose pre-test scripts reflected that they had the misconception. The learners' responses were also coded and the codes were put into two categories, one for cleared misconceptions and the

other for those who reflected a degree of the misconception in their responses. The results were as follows as shown in the table below.

Table 4.13 Comparison of misconception 2 held at pre-test time and at interview time

School	No. of learners interviewed	No. of learners who had the misconception in pre-test	No. of learners showing misconception at interview
A	5	5	2
B	5	3	1
C	5	5	1
D	5	5	1
E	5	3	0
TOTAL	25	21	5

4.2.3 Interview with teachers

Six teachers were interviewed by the researcher at the five schools where research took place. The teachers were interviewed to find their perception about the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry at grade 11, particularly dealing with misconceptions. The interview was structured. The questions were open ended and this required qualitative analysis. The method used in analysing teachers' interviews was coding. As suggested by Cohen and Manion (1994), for some questions, the responses were assigned to coding categories that had been predetermined.

Question 1 sought to find out if the school teachers had learnt something from the Sci-Bono subject matter experts as they delivered a lesson to the grade 11 physical sciences class. Two predetermined categories were established for this question. It was either the teacher had learnt something or not. For having to be considered to have learnt something, the teacher had to state what it is that he/she had learnt. Failure to indicate what one had learnt even if someone claims to have learnt would not qualify the individual to be considered as having learnt. Just some minutes after the lesson, a teacher would definitely remember what he/she learnt.

Three categories into which responses would be classified were drawn. Results were as follows in table 4.14.

Table 4.14: Record of what host teachers gained from Sci-Bono SMEs

Teacher	**What the teacher gained from Sci-Bono SME's lesson**		
	Content knowledge	Pedagogical Skills	Nothing
A		√	
B		√	
C		√	
D1		√	
D2		√	
E			√

Only one teacher claimed that he had not learnt anything from the lesson. It would be difficult to tell whether the claim is true or not. There are individuals who are not assertive and who do not want to expose their weaknesses. The other five teachers all pointed out that they had gained some skills in the teaching of this topic. These included relevant analogies used in explanations, the simple and effective experiment that requires minimal resources as well as simple ways of explaining abstract concepts.

The second research question focuses on whether misconceptions are addressed in class or not. In question 2 the teachers had to indicate if they had observed misconceptions or not. Like in question 1, their responses were accepted at face value. They had to divulge the misconceptions that they had identified in the lesson. The question further sought to establish whether in the teacher's view, the identified misconception had been addressed or not. For the researcher to categorise the response the interviewee would qualify his/her opinion by a reason as to why he/she thinks the misconception was addressed or not. Results are shown in table 4.15.

Table 4.15: Responses of teachers on misconceptions

Teacher	**No. of misconceptions exposed**	**Misconceptions addressed**	**Reason given as to why teacher thinks misconception was addressed or not**
A	1	yes	yes
B	3	2 out of 3	yes
C	1	yes	no
D1	2	yes	yes
D2	3	yes	yes
E	1	no	yes

Teacher B felt that 2 out of 3 misconceptions exposed had been addressed. When asked why he thought so it emerged that what he really meant was that it had not been addressed properly. Teacher E claimed that the misconception had not been addressed. When the researcher referred him to a particular section of the lesson the teacher argued that the misconception was not addressed immediately.

Table 4.16: Misconceptions identified by teachers and teachers' perceptions on whether the misconceptions were eliminated or not.

Teacher	Misconception identified	Misconception eliminated
A	A substance that is oxidised is an oxidising agent	yes
B	A substance that is reduced is a reducing agent	yes
	The oxidation number is the number of oxygen atoms in a molecule of a compound	yes
	The concentration of the spectator ions change during a reaction	no
C	A substance that is reduced is a reducing agent	yes
D1	Oxidation is the addition of oxygen	yes
	A substance that is reduced is a reducing agent	yes
D2	A substance that is oxidised is an oxidising agent	yes
E	A substance that is reduced is a reducing agent	no

Four misconceptions were identified by the teachers and these were as follows:

Misconception 1: Oxidation is the addition of oxygen.

Misconception 2: A substance that is oxidised is the oxidising agent/ a substance that is reduced is a reducing agent.

Misconception 3: The oxidation number is the number of oxygen atoms in a molecule of a compound

Misconception 4: The concentration of the spectator ions changes during a reaction.

Graeber, Tirosh and Glover (1989) argue that if teachers have misconceptions they are unable to recognise errors made by learners in those particular concepts. If a teacher identifies a misconception then it means he does not have that misconception himself. One teacher identified misconception 1 and he felt that the misconception was addressed and eliminated. Five out of six teachers identified misconception 2. Four of these teachers were of the opinion that the misconception was addressed and eliminated. However one teacher argued that that the misconception had been addressed but had not been eliminated. His argument was that although the Sci-Bono SME had addressed the issue, in the given pre-test, not all of them would answer question 3.2 (a) correctly. A counter argument would be that answering question 3.2 (a) does not necessarily mean that a learner has that misconception. It could be that the learner failed to identify the reducing agent. This would stem from the fact that the learner is not able to determine what is reduced or oxidised from the equation.

The two teachers who identified misconception 3 were content that this misconception was well tackled by the Sci-Bono SME. One teacher came up with misconception 4 which the researcher however found controversial. His argument was based on the question 3.3. He argued that even after the lesson some learners would choose a spectator ion as an answer to a question which requires an ion whose concentration either increases or decreases. The

researcher takes this as controversial because the learner could take a spectator ion as an answer not knowing that it is a spectator. If the learner cannot identify a spectator ion it does not mean that he/she has misconception 4. From the pre-test and post-test results there are learners who gave a wrong answer for the spectator ion but gave the correct reason. The reason being given in this case was that "its oxidation state does not change". These learners knew this as a fact but could not identify from the equation the substance whose oxidation state does not change. This supports the claim in DBE (2012, p117) that some learners are unable to answer certain science questions because they seriously lack mathematical skills that are required to answer questions. Wilson and MacGillivray (2007) made the same claim about tertiary learners studying engineering who were subjects in their study.

Question 3 also deals with elimination of identified misconceptions. The rating scale is 1 to 10 but in coding this was put in two categories, 1 to 4 as ineffective and 5 to 10 as being effective.

Table 4.17: Rating of Sci-Bono SMEs' effectiveness by host teachers

Teacher	**Rating**	**Category**	
		Effective	**Not effective**
A	7	√	
B	7	√	
C	8	√	
D1	9	√	
D2	8	√	
E	7	√	

All respondents' ratings fell in the category 'effective'.

Question 4 referred to the practical that was carried out. The responses were classified into three categories, eliminating misconceptions, enhancing understanding and gaining practical skills. Enhancing understanding could also mean eliminating misconceptions because for misconceptions to be eliminated, the learner should be having a better understanding of the concept. Therefore when a teacher gave a response that a response that seemed to encompass the two, the researcher would probe further to find out whether an element of misconception comes out. The researcher would however not mention the word misconceptions in the question. Results were as captured the table below.

Table 4.18: Teachers' perceptions of effect of practicals

Teacher	Eliminates misconceptions	Enhance understanding	Gain practical skills
A		√	√
B	√	√	
C		√	
D1		√	√
D2	√	√	
E		√	√

Only two out the six teachers gave responses that reflected an element of elimination of misconceptions. In all responses there were hints of enhancing understanding of the concepts. This can also be related to misconceptions in that if the practical activity enhanced learners' understanding of the concept, then it prevents the development of misconceptions. Three teachers made mention of practical skills being gained by the learners.

When the Sci-Bono outreach team visits the schools, teachers at the schools would be aware of what the SME would teach at their school. One would assume that they therefore have expectations which are not necessarily recorded anywhere. The researcher thus created three categories to determine whether the expectation is in terms of content knowledge, methodology or provision of resources. This information was obtained from responses to question 6. Table 4.19 shows the results.

Table 4.19: Teachers' expectations from Sci-Bono SMEs

Teacher	Expectation from Sci-Bono SMEs		
	Content	Pedagogical skills	Resources
A		√	√
B		√	√
C		√	√
D1		√	√
D2		√	√
E			√

All teachers expected the Sci-Bono SMEs to bring some resources for use at their schools and five out of six teachers expect the SMEs have better and more effective methods of instruction. They argue that Sci-Bono has everything teachers require to teach effectively and that the SMEs use resources like computers as well as apparatus for all the informal and formal experiments for grades 10 to 12. Because of this expectation, they want the SMEs to cover a lot ground within a short space of time that is made available to them.

In all response to question 6, teachers expressed the need for more visits to the selected schools. Two teachers pointed out that the two hour sessions were too long since their learners were used to at most one hour sessions. One of them went on to suggest that two one-hour sessions would be more effective than a one two-hour session. None of the teachers pointed out a weakness on the teaching itself.

For question number 7, a courtesy question, the comments given were more of reinforcing responses given in question 6. Nothing new of interest came from the responses.

4.2.4 Lesson observation

During the intervention lessons the researcher sat in the classroom and wrote field notes in a template shown in appendix C. The misconceptions picked by the researcher were the same in all the five classes and they were two.

Misconception 1: The oxidation number is the number of oxygen atoms in a molecule.

Misconception 2: A reducing agent is a substance that is reduced during a reaction / an oxidising agent is a substance that is oxidised during a reaction.

Misconception 3: There are copper atoms in copper sulphate solution.

In the field notes the researcher would capture the misconception that came into light, check and capture the activities that followed. In analysing the results the activities that followed the exposure of a misconception were categorised. There were two categories, one for the activities that the researcher deemed to be tackling the misconception and those that were deemed not to be addressing the misconception. The researcher gave special attention to the interaction between the learner who revealed the misconceptions and the Sci-Bono SME to check if there could be change of conception in the learner. Results are indicated in the table below.

Table 4.20: Researcher's views on tackling and elimination of misconceptions in lessons observed

School	Misconception	Tackled	Eliminated
A	2	Yes	Yes
B	1	Yes	Yes
	2	Yes	Yes
C	2	Yes	Yes
D	2	yes	Yes
	3	yes	yes
E	2	yes	yes

Misconception 1 was revealed at school B when a learner gave an answer to say that "the oxidation number of carbon in carbon monoxide is 1 because there is one_oxygen in carbon monoxide." By "one oxygen," the learner was referring to one oxygen atom. The Sci-Bono SME through the question back to the class. One learner worked it out very well on the board. The SME explained it further with another example on the board. Learners were then given another example to do individually. Before revising the example with the whole class, the SME moved around the class to check if the learners were following. Among the learners visited was the learner who had revealed his misconception. The SME nodded at the correct answer written by the learner.

Misconception 2 was revealed at all the five schools. The teacher tackled this with an analogy which seemed to be very effective where he used the term "hirer" and "hired" in one process of hiring. He stressed that the person who is hiring is not the one who is being hired hence the oxidising agent cannot be the one being oxidised. The analogy seemed to be working.

The learner who raised misconception 3 at school D did not understand the difference between copper ions and copper atoms. The Sci-Bono SME picked the misconception and gave a detailed explanation as to how the copper gets to be seen as a solid after the reaction. For learners to understand the concept, he started with the formation of ions from atoms and then

the formation of atoms from ions. He gave another example of a reaction and asked learners questions to determine if they had grasped the concept. The learner who had raised the misconception was also made to answer a similar question where she had reflected a misconception. This time she answered it correctly.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides conclusion of the study, recommendations, and limitations to this study and also suggests an area for further research. Based on the analysis of results, the chapter answers the two research sub-questions and consequently the main research question.

5.2 Conclusion

This section summarises the research findings from the study. Research findings from this study are related to findings from other studies in literature that investigated the effectiveness of teaching interventions. It is however important to realise the uniqueness of the intervention programme that was focussed by this study.

5.2.1 Research Findings

As stated earlier, the main research question, that seeks establish the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry in grade 11 cannot be answered directly but however answers to the two sub-questions would give us an idea as to whether it is effective or not. The sub-questions were as follows:

(iv) How much change is observed in the learners' ability to answer questions on electrochemistry after intervention by Sci-Bono outreach educators?

(v) Does the teaching by Sci-Bono outreach educators clear the common misconceptions learners have in electrochemistry?

The first sub-question question called for an investigation to measure a change in learners' ability to answer questions after the intervention and compare it with the ability to answer questions before the intervention. The second sub-question sought to establish whether misconceptions identified before or during intervention are cleared or not. Host teachers' perceptions were that misconceptions were dealt with satisfactorily by the Sci-Bono educators. Learners attributed their understanding of concepts to the practical work they conducted during the lesson.

5.2.1.1 How much change is observed in learners' ability to answer questions in electrochemistry after intervention by Sci-Bono outreach educators?

To provide an answer to this question, measurements had to be taken in terms of pre-test and post-test results. The difference between the two tests thus provides the change in question.

In the five schools where the investigation was done there was a positive difference for the individual learners. The existence of a positive change between the pre-test and the post-test does not necessarily mean that the change was caused by intervention as change could be by chance. To find out if the change was not by chance, a statistical analysis was done. In the five schools it was found that there was an improvement in performance and that improvement in performance did not occur by chance. The improvement is thus attributed to the intervention by the Sci-Bono outreach programme.

There was also a marked difference between the pre-test average and the post-test average in each of the five schools, the post-test average being higher. Analysis of results reflected that there was a significant change in learners' ability to answer questions on electrochemistry after intervention. This means that the intervention had a positive effect in learners' ability to answer questions in electrochemistry.

5.2.1.2 Does the teaching by Sci-Bono outreach educators address the common misconceptions learners have in electrochemistry?

From lesson delivery it was evident that the Sci-Bono outreach educators are able to pick the misconceptions from learners' responses to oral questions asked. This also showed that the Sci-Bono outreach educators are aware of the common misconceptions that leaners have in electrochemistry. The researcher noted that all misconceptions that were exposed during each lesson were addressed. Host teachers who also remained in the classrooms during lesson delivery by Sci-Bono outreach educators were in agreement that the misconceptions had been tackled. Taking this into consideration the researcher comes to a conclusion that the teaching by Sci-Bono outreach educators addresses the common misconceptions learners have in electrochemistry. There was however one case where there was concern about the time lapse between the misconception exposure and the subsequent address.

5.2.1.3 Does the teaching by the Sci-Bono outreach educators eliminate the common misconceptions learners have in electrochemistry?

One common misconception in electrochemistry at grade 11 is that oxidation is considered to be the addition of oxygen and reduction as the removal of oxygen. From the analysis of the interview results it was found that only 66.7% of the interviewed learners had the misconception eliminated. The intervention therefore did not clear the misconception since it is still exhibited in some leaners.

The other misconception tackled in this research is that a reducing agent is the substance that is reduced and that an oxidising agent is the substance that is oxidised during the reaction. Four of the five teachers also identified this as a misconception that learners had. This misconception was tested for in question 2.1b. Question 2.1a requires learners to identify a reducing agent and in question 2.1b the learner is asked to explain his/her choice for question 2.1a, that is, why he/she thinks that particular substance is a reducing agent. The correct response for this question is that the substance has been oxidised. Among the few interviewed learners there were those who in the pre-test had given the reason that the substance had been reduced. These are the learners who had the misconception. In the post-test 80% of them gave a correct response that the substance is oxidised. Contrary to these results only 41% of the sample answered the question correctly in the post-test, a rise of 31% from 10% in the pre-test.

Based on the results discussed above it cannot be claimed that intervention is effective in eliminating the common misconceptions in electrochemistry.

5.2.1.3 Effectiveness of the intervention programme

From the discussion in 5.2.1.1 that is based on the statistical analysis of results, it is evident that the Sci-Bono outreach programme does contribute to an improvement in learners' ability to answer questions on electrochemistry. The intervention was however found to have a very small success rate in eliminating misconceptions that learners have in electrochemistry. This suggests that the Sci-Bono outreach programme is only effective to a certain extent in the teaching of electrochemistry at grade 11.

5.3 Limitations of the study

The Sci-Bono outreach programme covers twenty-five high schools per year. The schools under study were only five, which is 20% of the schools. This may not necessarily be a reflection of what would happen at all the schools. The schools under study had minor differences and these minor differences would be assumed to exist in all schools served by the Sci-Bono SMEs.

Learners' behaviour varied from one school to the other. In two of the schools learners were very passive. They were not ready to give answers. At one of these schools their physical sciences teacher kept on interjecting. Whenever they gave an answer to a question asked they would always look at their teacher for approval. The teacher would also exclaim when a wrong answer is given. This therefore affected learner participation in class. There is also a possibility that learners could have had questions but could not ask these questions fearing what the questions could trigger from the teacher.

Being observed by a stranger, the researcher may also have had an effect on teaching and learning process at these schools.

Fonseca and Conboy (2006) relate the achievement in science to the quality of teaching and the said quality of teaching may also be associated with an individual teacher. The grade 11 physical sciences teachers at the schools where research was conducted are also at different levels of competence. As such, the level of achievement in the pre-test is influenced by how the lessons on this topic were conducted by the host teacher. The magnitude of the improvement in the ability to answer questions depends on the level at which learners are before intervention. If the level of achievement in the pre-test is very high, the magnitude of improvement in performance will be small but this would not necessarily mean that the intervention is not effective.

The lessons conducted by the Sci-Bono SMEs are two hour sessions which learners are not used to. This also affects the concentration span of the learners. No matter how good the presentation could be, if the learners are not concentrating then learning would be compromised.

What was observed during the intervention lessons may not necessarily be what happens daily in the classrooms where intervention takes place. Taylor and Lelliott (2013) asked a very interesting question regarding classroom observation. They query whether classroom observation could be considered to be a good measure of classroom practice.

Some scholars who criticise the use of such post-tests ask whether the participants would still remember the facts and apply the skills they learnt from this lesson a week, a month or a year later (I-TECH 2008). This is a valid question in that the topic under study is a grade 11 topic and the skills acquired here are also made use of in the grade 12 final examinations. The researcher however subscribes to the school of thought that time does not matter if learners understood the concepts. It is mainly what is learnt by rote learning that learners easily forget.

It is also a fact that there still would have been a positive difference between the pre-test and post-test even if this lesson had been conducted by the host teacher. The use of the positive difference as a measure of effectiveness is therefore not adequate.

Teachers had a general observation of the lesson. They were not guided on what to concentrate on which would be required in the interview. If they had known what they would be asked, they would have been more cautious about those aspects during the lesson and would perhaps give better informed responses.

5.4 Recommendations

Much as it is required for learners to identify what has been oxidised or reduced using oxidation states, it is also important for teachers to explain the use of oxidation states to identify spectator ions. This was hardly stated in the lessons observed.

An exercise should be given to learners during the lesson where they are given an equation and they identify ions present in the reactants and in the products. In the day to day teaching, in addition to such class exercises, learners should be given homework which should be marked by the teacher so that he/she is able to pick what each learner could have missed during the lesson. There is a general tendency of teachers using learners to mark their own or peers' homework. This has a disadvantage in that the teacher does not pick up individual learners' weaknesses that may need immediate attention. These weaknesses may go unnoticed until too late or never noticed at all. As a basic skill, this would affect the concepts which are built on this basic concept.

For a greater impact the number of visits by the Sci-Bono outreach team to each school should be increased. Visiting a school once a term does not have much influence, especially considering the wide physical sciences curriculum. Perhaps there would be need to reduce the number of schools so as to increase the number of visits per school.

A more sustainable intervention is an intervention at a higher level. An intervention that focuses on teachers so that they are able to deliver at expected optimum levels at their schools. Targeting teachers would also enable the intervener to cover more ground. If for a particular topic one teacher per school is trained then the intervener would have indirectly reached all the represented schools at the same time. Therefore more schools and more topics can be covered in one year. Topic coverage with teachers would be much faster than when the same content is delivered to teachers. With teachers, there would less time spent on teaching content except where there are misconceptions at that level. There would however be a need to focus on

pedagogy and assessment as well. This would improve the competence of teachers in their work. The other advantage of focussing on teachers is that during training these teachers would share best practices and would also develop links with other teachers whom they can turn to whenever they need help.

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APPENDIX A

Redox Reactions Pre-test/Questionnaire

Code: _____ School: _____ Date: _____

INSTRUCTIONS

Answer all questions in the spaces provided.

1.1 Define the term oxidation.

_____

1.2 What is the oxidation number of carbon in carbon dioxide (CO_2)?

_____

_____

1.3 What is the oxidation number of carbon in carbon monoxide, (CO)?

_____

_____

1.4 What is the oxidation number of carbon in a carbonate ion (CO_3^{2}-)?

_____

_____

2 Iron reacts with copper sulphate solution to produce copper and iron sulphate solution. The following equation represents the reaction. $Fe_{(s)} + CuSO_{4(aq)} \rightarrow Cu_{(s)} + FeSO_{4(aq)}$

2.1 Which substance is a reducing agent in this reaction?

_____

Explain your answer:

_____

_____

2.2 Which substance has been oxidised in the reaction?

_____

Explain your answer:

_____

_____

2.3 During the reaction there are iron ions, copper ions and sulphate ions in solution.

2.3.1 Which of these ions increase in concentration?

_____

Explain your answer:

_____

2.3.2 Which of these ions are spectator ions in this reaction? _____

Explain your answer:

_____

2.3.3 Which of these ions decrease in concentration? _____

Explain your answer:

_____

APPENDIX B

Redox Reactions Post-test/Questionnaire

Code: _____ School: _____ Date: _____

INSTRUCTIONS

Answer all questions in the spaces provided.

2.4 Define the term reduction.

_____

2.5 What is the oxidation number of sulphur in sulphur dioxide (SO_2)?

_____

_____

2.6 What is the oxidation number of sulphur in sulphur trioxide monoxide, (SO_3)?

_____

_____

2.7 What is the oxidation number of sulphur in a sulphate ion (SO_4^{2}-)?

_____

_____

3 Zinc reacts with lead nitrate solution to produce lead and zinc nitrate solution. The following equation represents the reaction. $Zn_{(s)} + Pb(NO_3)_{(aq)} \rightarrow Pb_{(s)} + ZnNO_{3(aq)}$

3.1 a) Which substance is a reducing agent in this reaction?

_____

b) Explain your answer:

_____

_____

3.2 a) Which substance has been oxidised in the reaction?

_____

b) Explain your answer:

_____

_____

3.3 During the reaction there are zinc ions, lead ions and nitrate ions in solution.

3.3.1 a) Which of these ions increase in concentration?

_____

b) Explain your answer:

_____

3.3.2 a) Which of these ions are spectator ions in this reaction?

_____

b) Explain your answer:

_____

3.3.3 a) Which of these ions decrease in concentration?

_____

b) Explain your answer:

_____

APPENDIX C

Researcher's observation tool

School: _____ Date: _____

Misconception observed by researcher	Misconception addressed by Sci-Bono SME

Other observations relevant to the study

_____
_____
_____
_____
_____
_____
_____
_____
_____

_____
_____
_____
_____
_____
_____
_____
_____

APPENDIX D

Interview Questions for Learners

1. Is oxygen required for the oxidation of any substance?

   _____

   Explain your answer

   _____

   _____

2. In the experiment the nail developed a brown colour coating. What substance is the brown coating?

   _____

   How does the brown coating develop?

   _____

   _____

3. In question 3.1 (a) you said that _____ is the reducing agent. Why do you think so?

   _____

   _____

   _____

4. From a chemical equation how would you identify which element has been reduced or oxidised?

_____

_____

_____

APPENDIX E

Interview Questions for School Teacher

1. What did you as an individual gain from the Sci-Bono intervention?

   _____
   _____
   _____

2. Did you notice any misconceptions which learners had in this topic? If so, what are they? In your view do you think they were addressed? Why do you think so? Were these misconceptions eliminated or not? Why do you think so?

   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____

3. Using a scale 1 to 10 how would you rate the effectiveness of the Sci-Bono outreach programme in eliminating misconceptions in the teaching of electrochemistry?

   _____

4. What is it that you think learners benefited from the practical?

   _____
   _____

5. When the Sci-Bono SME took your class you had some expectations. Have your expectations been met? Why do you say so?

   _____
   _____
   _____

6. What do you think the Sci-Bono teachers should do to become more effective in the teaching of electrochemistry at grade 11?

   _____
   _____
   _____
   _____

7. Do you have any comment other comment about the Sci-Bono outreach programme or this lesson that we observed?

   _____
   _____
   _____
   _____

APPENDIX F

GAUTENG PROVINCE
Department of Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2013/257

GDE RESEARCH APPROVAL LETTER

Date:	12 December 2012
Validity of Research Approval:	4 February 2013 to 27 September 2013
Name of Researcher:	Nkomo T.
Address of Researcher:	P. O. Box 32152
	Braamfontein
	2017
Telephone Number:	073 607 6819
Email address:	trustnkomo@gmail.com
Research Topic:	Investigating the effectiveness of the Sci-Bono outreach programme in the teaching of electrochemistry at grade 11
Number and type of schools:	FIVE Secondary Schools
District/s/HO	Ekhuruleni South; Gauteng West; Johannesburg Central; Johannesburg North and Johannesburg West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

.....

Mrs F.L. Tshabalala

Acting Director: Knowledge Management and Research

DATE: 13/12/12

Office of the Director: Knowledge Management and Research

9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

APPENDIX G

Ethics Clearance Letter

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Student Number:
0513728A
Protocol Number:
2012ECE198

Date: 27-Feb-2013

Dear Trust Nkomo

Application for Ethics Clearance: Master of Science

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has considered your application for ethics clearance for your proposal entitled:

Investigating the effectiveness of the Sci-bono outreach programme in the teaching and learning of electrochemistry at grade 11.

The committee recently met and I am pleased to inform you that clearance was granted.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learner etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely

M Mabeta

Mats'e Mabeta
Wits School of Education
011 717 3416

Cc Supervisor: Dr. E Mushayikwa