# EXPLORING INQUIRY-BASED EDUCATION IN A PROFESSIONAL LEARNING PROGRAMME FOR SCIENCE TEACHERS

**by**

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# DECLARATION

By submitting this thesis, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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# ABSTRACT

Schools worldwide have been struggling to produce good results in Mathematics and Science. In South Africa, in particular, continued poor results in both Mathematics and the Sciences are of great concern. This has led to the evaluation of current teaching and learning practices in these subjects and the type of pre-service and in-service training provided for Science teachers. Research has shown that the Inquiry Based Education approach (IBE) proves to be very successful in igniting and holding learner interest in Science; this ultimately leads to better performance and improved school results in Science. The Stellenbosch University Centre for Pedagogy (SUNCEP) is one training centre in the Western Cape in South Africa, which supports STEM education through programmes for learners and courses for teachers to introduce and develop teaching best practices. This study explored the effect of introducing Science teachers to Inquiry-Based Science education. It aimed to ascertain whether and how the introduction affected the teachers' perception and practice of Science teaching.

The transformative paradigm was chosen for this study since it was of an emancipatory nature. This choice was motivated by the assumption that this paradigm would allow teachers to reflect and move away from established practices. The study took the form of an action research project done with five Science educators within one district of the Western Cape Education Department in South Africa. Action research was deemed an appropriate research design for this project as it addresses practical problems in a positive way, and gives the participants an opportunity to be part of the project and to play an active role in finding solutions to the problems faced by Science education. The practical nature of action research, which is focussed on change, is well-suited to the classroom environment.

The teachers agreed to take part in a teacher professional learning programme where data could be collected through interviews and class observations before and after the learning programme. A thematic analysis of the data was done, and results from data sets before and after the programme were compared to ascertain whether there was any change in teachers' perceptions and practice.

The analysis indicated that all the participating teachers initially opted for more traditional teaching practices such as lecturing. However, the participating teachers were all open to learn about, and implement a new teaching method, namely Inquiry-based Science Education.

A number of changes were identified when sets of data before and after the learning programme were compared to each other. It became evident that there were some changes in teachers' perceptions and practice. It was found that teachers initially did not trust learners to take responsibility for their learning as teachers regarded learners as lazy and disinterested. However, when the participating

teachers did make a shift towards a more learner centred approach, learners were cooperative and participated actively. The study further highlighted that participating teachers were willing to move away from their customary teaching practices. In order for teachers to adopt new strategies a supportive environment where learning and collaboration can occur simultaneously, is required.

# OPSOMMING

Skole wêreldwyd sukkel om goeie resultate in Wiskunde en Wetenskap te lewer. In Suid-Afrika is veral die voortgesette swak resultate in beide Wiskunde en die Wetenskappe 'n groot bron van kommer. Dit het gelei tot die evaluering van die huidige onderrig- en leerpraktyke in hierdie vakke, asook die tipe voor-diens- en in-diensopleiding wat vir wetenskaponderwysers aangebied word. Navorsing het getoon dat die Ondersoek-gebaseerde Ovoedings benadering baie suksesvol blyk te wees om meer belanstelling by wetenskapleerders in diè vak te prikkel en te behou; dit lei uiteindelik tot beter vordering en verbeterde skooluitslae in Wetenskap. Die Stellenbosch Universiteit Sentrum vir Pedagogie (SUNSEP) is een van die sentrums in die Wes-Kaap in Suid-Afrika, wat WTIW-opvoeding (Wetenskap, Tegnologie, Ingeneurswese en Wiskunde opvoeding) ondersteun deur programme vir leerders, en onderrig aan WTIW-onderwysers aan te bied om hulle aan die beste onderrigpraktyke bekend te stel en daarin op te lei. Hierdie studie het die effek van die bekendstelling van Ondersoek-gebaseerde Wetenskap Opvoeding aan wetenskaponderwysers ondersoek. Die doel was om vas te stel of, en hoe die bekendstelling die onderwysers se persepsies en praktyk van wetenskaponderrig beïnvloed het.

Die transformatiewe paradigma is as teoretiese raamwerk vir hierdie studie gekies omdat dit van 'n emansipatoriese aard was. Die keuse van hierdie paradigma het berus op die aanname dat dit onderwysers in staat sou stel om na te dink, en weg te beweeg van vasgestelde praktyke. Die studie het die vorm aangeneem van 'n aksienavorsingsprojek wat gedoen is met vyf wetenskapopvoeders in een distrik van die Wes-Kaapse onderwysdepartement in Suid-Afrika. Aksienavorsing is as 'n toepaslike navorsingsontwerp vir hierdie projek beskou, aangesien dit praktiese probleme op 'n positiewe manier aanspreek. Dit het ook aan die deelnemers die geleentheid gegee om deel te wees van die projek en om 'n aktiewe rol te speel in die soeke na oplossings vir die probleme wat wetenskapopvoeding ondervind. Die praktiese aard van aksienavorsing wat op verandering gefokus is, is geskik vir die klaskameromgewing.

Die onderwysers het ingestem om deel te neem aan 'n professionele leerprogram waartydens data versamel is deur middel van onderhoude en klaswaarnemings voor en na die leerprogram. 'n

Tematiese analise van die data is gedoen en die resultate van datastelle voor en na die program is vergelyk om vas te stel of daar enige verandering in die persepsies en praktyke van onderwysers was.

Die ontleding van die data het aangedui dat al die deelnemende onderwysers meestal tradisionele onderrigmetodes soos klasgee , verkies het. Die deelnemende onderwysers was egter almal oop om opleiding in 'n nuwe onderrigmetode naamlik Ondersoek-gebaseerde Wetenskapopvoeding, te ontvang en om dit te implementeer. 'n Aantal veranderings is geïdentifiseer toe datastelle voor en na die leerprogram met mekaar vergelyk is. Daar was definitiewe aanduidings dat onderwysers wel hul persepsies en praktyk verander het.

Daar is gevind dat onderwysers aanvanklik nie leerders vertrou om verantwoordelikheid vir hul leer te neem nie, aangesien onderwysers leerders beskou as lui en nie geïnteresseerd nie. Toe die deelnemende onderwysers egter 'n skuif na 'n meer leerdergesentreerde benadering gemaak het, was die leerders samewerkend en het hulle aktief deelgeneem. Die studie het verder beklemtoon dat onderwysers bereid is om weg te beweeg van hul gevestigde onderrigpraktyke. 'n Ondersteunende omgewing waar leer en samewerking gelyktydig kan plaasvind, word benodig vir onderwysers om nuwe strategieë aan te neem.

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# LIST OF ACRONYMS

| | |
|---|---|
| CAPS | – Curriculum and Assessment Policy Statement |
| CD | – Compact disc |
| DBE | – Department of Basic Education |
| E-lesson | – Electronic lesson |
| FET | – Further Education and Training |
| HEQ | – Highest educational qualification |
| IBE | – Inquiry-Based Education |
| IBSE | – Inquiry-Based Science Education |
| IMSTUS | – Institute for Mathematics and Science Teaching Stellenbosch University |
| LAMAP | – La Main à la Pâte |
| LSA | – Large-scale Assessments |
| LP | – Learning Programme |
| NASAC | – Network of African Science Academies |
| NCS | – National Curriculum Statement |
| NQF | – National Qualification Frameworks |
| NRC | – National Research Council |
| NSES | – National Science Education Standards |
| OBE | – Outcomes-based Education |
| PRIMAS | – Promoting Inquiry-based learning in Mathematics and Science education, |
| RNCS | – Revised National Curriculum Statement |
| RPT | – Research participating teacher |
| RPTs | – Research participating teachers |
| SA | – South Africa |
| SAQA | – South African Qualifications Authority |
| SC | – Senior Certificate |
| SACMEQ | – Southern and Eastern Africa Consortium for Monitoring Educational Quality |
| SciMathUS | – Science and Mathematics at University Stellenbosch |
| STEM | – Science, Technology, Engineering and Mathematics |
| SUNCEP | – Stellenbosch University Centre for Pedagogy |

TIMSS – Trends in International Mathematics and Science Studies

TPL – Teacher Professional Learning

USA – United States of America

WCED – Western Cape Education Department

ZPD – Zone of proximal development

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# Chapter 1: **INTRODUCING THE STUDY**

## 1.1. Setting the scene

Worldwide there is concern regarding the decreasing number of Science graduates and those choosing a scientific career in Science related fields (Bonous-Hammarth, 2000; Chapa & Rosa, 2006). This trend is particularly noticeable among women and ethnic groups who, in western literature, are regarded as minority groups in science related fields (Bonous-Hammarth, 2000). As attitudes towards Science are formed early in a child's school career (Gibson & Chase, 2002; Tai, Qi Liu, Maltese & Fan, 2006), one has to ensure that Science teaching at school level will capture and hold learners' interest in order to increase the number of students choosing Science when entering higher education or as careers. Seymor & Hewitt, (1997) posit that improving the quality of Science teaching will result in an enhanced interest in Science amongst students.

I have been a Physical Sciences educator for the past 30 years. Due to my passion for the subject and for teaching, I would like to make a contribution to the quality of Science education through the professional development of teachers. I started my teaching career as a Physical Sciences teacher teaching in various schools in the Western Cape after which I had an opportunity to teach Physics in schools in England for five years. This variety of teaching environments provided me with a rich teaching experience in teaching Science in schools. In 2009 I was employed by the Institute for Mathematics and Science Teaching Stellenbosch University (IMSTUS), and joined the team in their SciMathUS component as a Physical Sciences facilitator. SciMathUS is a year-long, post-matric bridging programme in Science and Mathematics at Stellenbosch University. For the next five years I learnt of and had the opportunity to use elements of Problem-based Learning and Inquiry-based Education (IBE) as I taught Physical Sciences to post-matric students who desired to strengthen their ability and understanding of Mathematics in Science, with the aim to gain access to a Science related field at the University. In 2012 IMSTUS was amalgamated with the Centre for Education Leadership and Management (CELEMUS), and the centre now known as Stellenbosch University Centre for Pedagogy (SUNCEP), was formed. In 2013 I moved to the Teacher Professional Learning (TPL) component within SUNCEP where I, still as a Physical Sciences facilitator, became responsible for developing material and running courses for Natural and Physical Sciences teachers.

## 1.2. Teaching and learning in Science education: The role of IBE

Studies in education have highlighted pitfalls in traditional teaching methods, where the teacher is the central figure, and have encouraged more contemporary teaching and learning methodologies which focus on student engagement and learning activities which are student-centred (Muianga, Klomsri, Tedre & Mutimucuio, 2018). To adjust to these changes teaching staff should not only be competent in their subject field, but also competent with regard to the latest developments and trends in pedagogy (West, 2007). In this research study I investigated one such development by studying the outcomes of introducing Science teachers to Inquiry-based Education (IBE).

It is often erroneously believed that IBE simply involves the teacher doing a demonstration and asking closed ended questions, not developing learner ability to conceptualise. “If urban teachers implement Inquiry-based instruction, they are likely to do a demonstration for the class while asking fact-based questions prefaced by ‘what’ and ’how’ rather than asking probing questions that help students build conceptual understanding” (Diaconu, Radigan, Suskavcevic & Nichol, 2012:856). However, IBE is much more than what is described above. Inquiry is central to Science learning, and a key aim of IBE is not only to develop inquiry, investigative and process skills in learners, but also to develop the learners’ understanding of Science by combining knowledge of Science with reasoning and thinking skills (National Reseach Council, 1996). When applying IBE to specifically Science teaching and learning it  referedis to Inquiry–Based Science Education (IBSE). Studies have shown that learners remain interested and become motivated to put more effort into their studies when Science is taught using an Inquiry-based approach (Gibson & Chase, 2002).

Since I started this study I also had the opportunity to attend the La main à la pâte 8th International Seminar on Science Education in School at the Centre International d'Etudes Pédagogiques (CIEP) (translated: International Centre of Pedagogical Studies) in Sèvre, France in June 2017. This gave me the opportunity to engage with both IBSE experts and practitioners from around the world. We could share our experiences and challenges from our specific contexts, and so learn from one another. The highlight was to see IBSE in action in a school in France, and to visit and experience a ‘House for Science’, one of the centres set up all over France to act as a resource and support base for teachers who are interested in implementing IBSE. From this experience, I learnt that IBSE can work well within the classroom, but I also learnt that meticulous and careful planning is required in order for IBSE to be effective.

My work with SUNCEP has also given me the opportunity to visit and observe a number of Science classes in action in the Western Cape. In most instances, I found myself in a learning environment that was  largely teacher-centred, with the teacher doing most of the talking and learners only following instructions without being given the opportunity to question or disagree. I remain convinced that the downward spiral Science education is currently finding itself in, could be turned around if Science is offered to the learners in a way that is more learner-centred. A more learner-centred approach will give learners a chance to follow their inquisitive nature, to ask questions, and to test and construct their own knowledge of Science. I also realised that such a change needs to start with a change in approach by the teacher, as the teacher sets the tone in the classroom.

In the United States (USA) the National Science Education Standards (NSES), which have been designed to guide that country toward becoming a scientifically literate society, makes some recommendations with regard to implementing IBE (National Reseach Council, 1996). NSES suggests that both the ability to do scientific inquiry and to understand scientific inquiry should be developed in Science classrooms (National Reseach Council, 1996). These recommendations are relevant to South Africa (SA) as well, as scientific inquiry skills are also given priority in the South African school science curriculum. The Curriculum and Assessment Policy Statement (CAPS) for FET Physical Sciences, describes scientific inquiry skills expected of Grade 10-12 learners, and in so doing mentions ‘inquiry’ four times and the related term ‘investigate’ 76 times (DBE, 2011). Even though the NSES also sees inquiry-based instruction as a powerful vehicle of learning scientific content, it does not prescribe how to conduct inquiry in the classroom (Anderson, 2002). This is to allow for multiple modes of inquiry-based teaching that match the beliefs and the teaching styles of participating teachers. This flexibility could invite an openness to and acceptance of IBE as it is necessary to take into account cultural factors and possible constraints to inquiry such as time and resources (Keys & Bryan, 2001).

In post-Apartheid SA, there have been some improvements with regard to ensuring access to free basic education, but results from national and provincial assessment studies in Mathematics and Science continue to reflect low achievement scores (Reddy, Van Der Berg, Van Rensburg & Taylor, 2012). In this regard, a recent Centre for Development and Enterprise report states that “irrespective of which subject or grade one chooses to test, most South African children are performing significantly below the curriculum” (Spaull, 2013). While South Africa’s Trends in International Mathematics and Science Studies (TIMSS) score shows a steady improvement over the years from 2003 through to 2015, SA still remained at the bottom end of the international TIMSS table in 2015 (Alex & Juan, 2017). For instance, the TIMSS scores of 372 for Mathematics and 358 for Sciences for Grade 9 South African learnersare way below the TIMSS benchmark score of 500 (Reddy, Visser, Winnaar, Arends, Juan, Prinsloo & Isdale, 2016). Furthermore, the findings indicate that SA fared poorly compared to both developed and developing countries, including countries in Africa and Asia. The debate in South African education is no longer about policies and access, but rather about quality of teaching, learning processes and inputs at a local level, namely the classroom (Reddy *et al.*, 2012). Research has shown that traditional, teacher-centred Science lessons are not as effective as hands-on, inquiry-based Science lessons (Gibson & Chase, 2002). A shift to inquiry-based Science lessons could therefore be embarked upon to assist in enhancing the quality of Science education.

Effective implementation of IBE would necessitate on-going Teacher Professional Learning (TPL). This can result in improvements in teacher professional knowledge, confidence and self-esteem, and will be associated with higher quality instruction, which in turn has a positive effect on student learning (Kunter, Klusmann, Baumert, Richter, Voss & Hachfeld, 2013). Teacher efficacy, defined as teachers' confidence in their ability to promote students' learning, has been identified as one of the few teacher characteristics related to student achievement (Hoy & Spero, 2005). On-going TPL plays a significant role in increasing teacher efficacy. Thus, it makes sense to guide Science teachers in the inquiry-based pedagogy together with improving their content knowledge in order for a significant impact to be made on the quality of Science teaching.

SUNCEP serves the broader Mathematics and Science teaching and learning community. The centre offers learning opportunities to both learners and teachers primarily within the Western and Northern Cape provinces, but it does have a growing footprint in all the provinces of SA. SUNCEP aims at improving the quality of teaching and learning in schools mainly in previously disadvantaged communities. One of the ways SUNCEP does this is by providing, amongst others, practice-based TPL opportunities in the field of Mathematics and Science. These learning opportunities do not only focus on preparing teachers to implement the new curriculum, like many other workshops do, but there is a strong emphasis on strengthening subject content and pedagogy. The TPL component of SUNCEP aims at making a difference in the quality of teaching at the chalkface and beyond. This provided me, as a Sciences facilitator at SUNCEP, with an ideal opportunity to introduce teachers to and offer learning opportunities in IBE and more specifically Inquiry-based Science Education (IBSE).

Much research has been done with regard to IBE at primary school level, but very little at secondary school level (Keys & Bryan, 2001) and so results from my study could also make a useful contribution to this strategy of teaching and learning at secondary school level.

## 1.3. Statement of the problem

As indicated above, schools worldwide are struggling to produce good results in Mathematics and Science. South African schools lag even further behind. Science education in parts of Europe has moved away from traditional methods of teaching to IBE. This shift had a positive effect on the understanding and knowledge of the learners who have been exposed to IBE (Harlen, 2004; Minner, Levy & Century, 2010).

The poor results, in both Mathematics and Science faced by South African schools (Reddy *et al.*, 2016; Spaull, 2013), have led to the evaluation of current teaching and learning practices in these subjects, and the introduction of alternative, innovative pedagogies in training provided for Science teachers. This includes professional learning initiatives such as those offered by SUNCEP.

My position as a Physical Sciences facilitator with the SUNCEP TPL team allowed me to introduce the IBE approach to teachers and to give teachers an opportunity to implement IBE in their lessons. It also offered me the opportunity to gather data to do research on the effect that IBE can have on the teaching and learning of Science in schools.

In order to investigate the effect of IBE on Science teaching and learning, my central research question was, 'What are the effects of guided training in, and implementation of, IBE on Science teaching in the South African secondary school context?' In order to answer this question, I specifically investigated whether introducing Science teachers to the IBE approach affected the teachers'

(i) perceptions of Science and Science teaching, and
(ii) teaching practice in the Science classroom.

## 1.4. Research methodology

Action research methodology was used in order to answer the above research question. Action research addresses practical problems, in this case the poor performance by learners in Science, in a positive way (Ebersohn, Eloff & Ferreira, 2007). Action research has a cyclical nature and is focussed on change (Ebersohn *et al.*, 2007). Other characteristics of action research, such as involving active participation and developing knowledge in an interactive way (Ebersohn *et al.*, 2007; Zuber-Skerritt, 2012) make it an attractive approach for this project as it allows one to draw on the teachers' context specific insights to inform the research as well as make a meaningful contribution to the participants' professional learning needs. Action research is described as "a personal enquiry, but done collaboratively which involves individuals working together to achieve commonly agreed goals" (McNiff & Whitehead, 2010). In this project I saw myself as the individual researcher working together with my colleagues as well as the teachers to whom we provided professional learning opportunities. A benefit of collaboration is that it enhances ownership and partnership of all parties involved (Piggot-Irvine, 2012). The overarching goal of my research project was to shift teachers' identities and conceptions of the teaching of Science to become more reform-oriented and inquiry-based and, in so doing, enhance the quality of Science teaching to promote learner interest and learning.

Furthermore, the practical nature of action research which is focussed on change, is well-suited to the classroom environment. The project gave me an ideal opportunity to help teachers develop new science teaching and learning practices, and investigate the effects of the implementation of those practices.

Another characteristic of action research which makes the methodology ideal for this project is that it is a process which consists of a number of stages linking with one another in a way that makes the research both layered and cyclical in nature (Ebersohn *et al.*, 2007). For the purposes of this project I made use of three cycles as indicated by Figure 1.1.

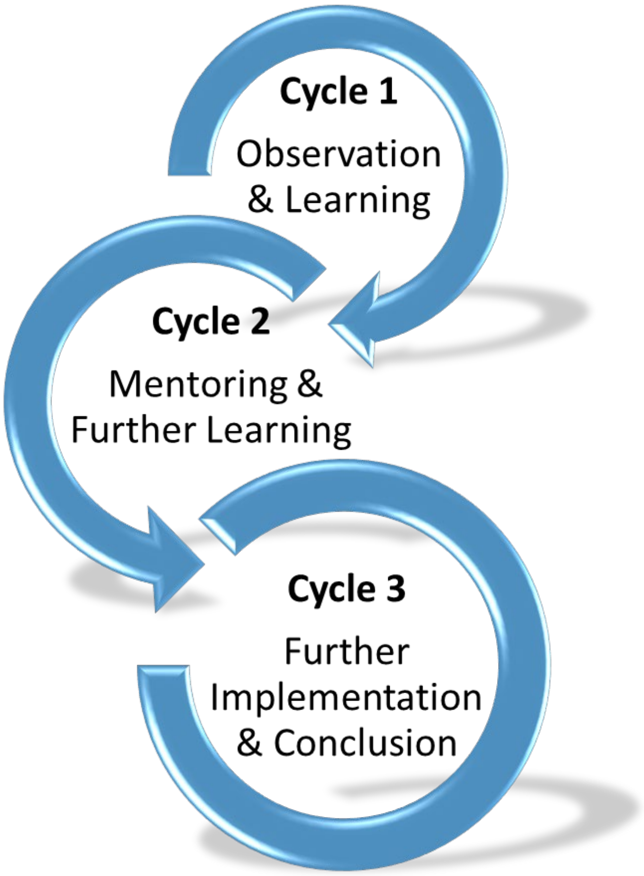



**Figure 1.1: Cycles in an action research process**

In cycle one I focussed on observing the teachers before they have been introduced to IBE followed by doing the first face-to-face learning session in this introductory TPL programme to IBE. In cycle two the teachers were given a chance to introduce what they have learnt into their lessons and mentoring was offered in the form of focus group discussion as well as a follow-up learning session. In cycle three teachers were given a further opportunity to implement IBE into their lessons and another round of observations were made to determine if the introductory programme had an effect on the teachers' perception and practice.

I used the information from Ebersohn et al. (2007) to identify the stages in each cycle of my action research project. These stages included research and reflection, specific planning, and taking action as shown in Figure 1.2 below. Each cycle of my research project included these stages.


**Figure 1.2: Stages in each cycle of the action research methodology**

At the start of each cycle I would gather information both about IBE as well as the participants as Science teachers and use the information gathered to plan activities for the programme. This was then followed by executing the plan. Below follows a more detailed description of each cycle.

### 1.4.1. The challenge

The problem in Science education which led to this study is the lack of learner interest in Science and the generally poor performance of learners in Science at secondary school level. In this action research project the challenge was to consider how to effectively introduce teachers to using a different teaching approach with the aim of influencing teachers' perceptions about the subject, themselves as Science teachers and their teaching practice, as a first step to address the problem concerned.

### 1.4.2. The overall plan

I decided to do an action research project as in this way I did not only do research, but I was able to present new ideas to, and share a journey with the teachers participating in the project. I henceforth refer to the teachers who participated in the research project as the Research Participating Teachers (RPTs), in order to distinguish them from teachers in general.

Over the course of this project, I presented TPL workshop sessions to the RPTs to introduce them to IBE and encouraged them to implement IBE principles in their lessons. The TPL workshop sessions had a face-to-face contact component as well as an e-learning component. I observed and interviewed the RPTs for the purpose of gathering data for this study, before as well as after the TPL workshop sessions. The project was carefully located and executed within three cycles of the action research process.

### *Cycle 1 – Observation and Learning*

After I had done extensive reading on teaching practices in Science and the IBE approach, I set up appointments with each RPT. This was prior to any TPL session I offered. The purpose thereof was to observe one of their lessons and to conduct my first interview with them to establish their current perceptions of Science teaching and their teaching approach. I used the information I had gathered from both the literature and this initial engagement with the teachers to plan the TPL sessions. I then facilitated a TPL opportunity in the form of an introductory face-to-face workshop session as well as an e-learning session in IBE for the RPTs.

### *Cycle 2 - Mentoring and Further Learning*

After these initial TPL sessions I encouraged the teachers to implement the IBE approach in their lessons. I then set up a focus group session with the aim to get feedback on the RPTs' experience of implementing IBE and to answer questions they had. The information from this feedback session was used to plan and set up another TPL face-to-face learning session. This was done with the intention to give further input and guidance regarding the IBE approach to teaching and learning.

### *Cycle 3 – Further Implementation and Conclusion*

In this cycle I gave the RPTs the opportunity to implement what they have learnt over a period of at least three months. Thereafter, I again met with them individually to observe their lessons and to conduct a second interview. These interviews were conducted after the TPL sessions and the period of implementation of IBE. The primary purpose of the interviews was to gather RPTs' thoughts about their experiences as they applied IBE in their teaching. In order to draw conclusions I carefully analysed these findings and compared them to the information I had gathered prior and during the TPL sessions.

## 1.5. Thesis structure

This thesis includes the following chapters:

### *Chapter 1: Introducing the study*

This chapter provides the background to my research. I firstly introduce myself and give my thoughts into why I decided to proceed with this study. Then I proceed to give some background into IBE and then state my research questions. This is followed by a description of my research methodology and listing the chapters in this thesis. I end with a brief reference to my ethical considerations.

### *Chapter 2: Trends in science education globally and locally and the need for continued reform in education*

In Chapter 2 I give background to education in South Africa and the educational reform that has taken place to date. I also discuss trends in Science education globally and locally and make a case for the need for continued reform. I then discuss the experience of the South African Science teacher, and the importance to consider the role that the teacher can play in reform in the classroom.

### *Chapter 3: Inquiry-based Education within the context of learning theory*

In this chapter IBE is discussed. I firstly look at constructivism as a theoretical basis for IBE before I give an overview of IBE and IBSE and examples of its implementation. I proceed to give an in-depth description of its features, requirements and the need for teacher preparation to ensure successful implementation of IBSE. I then propose a framework for teacher learning about IBSE and discuss the relevance IBSE has for the South African curriculum.

### *Chapter 4: Research Methodology*

It is important to position ones research within an appropriate paradigm. In this chapter I discuss various research paradigms and motivate my choice of paradigm which is action research. I then proceed to describe the features of action research and outline the action research process specifically for this study. I also look at the methods of research that I will use and so describe the type of data collected. For my research aims, the data which I used to address my research questions were of a qualitative nature and included the following forms:

- Interview responses from two interview sessions. The first interview session took place before the RPTs received TPL learning sessions in IBE. The second interview session was held after the course had been completed and the teachers had had an opportunity to implement the IBE approach in their Science lessons.
- Two sets of observation data about the RPTs' teaching were also gathered. The first observations took place prior to TPL sessions in IBE, and the second set of observations were done post learning, mentoring and implementation.
- Focus group discussion responses gathered at a focus group session that was held after the first round of implementation, were also used to inform my research.

I also discuss how the data will be analysed and how trustworthiness will be ensured. Finally I will look at ethical considerations, limitations and challenges to the study.

### *Chapter 5: Research data and findings*

In Chapter 5 the data is presented and findings from the data gathered are discussed. By analysing and comparing the different sets of data, I was able to come to conclusions about the effect of TPL in IBE on the perceptions of Science teachers and their teaching of Science. By comparing initial data with later data, I was able to ascertain whether there had been a shift in perceptions, conceptions, attitudes, identities and teaching practices. I could also identify what these changes were, and could so ultimately answer my research questions.

### *Chapter 6: Interpretation of findings & Conclusions*

This chapter holds my concluding remarks where I discuss the outcomes of my research regarding the effect an introduction to IBE had on the RPTs' perceptions of Science as a subject and the teaching of Science. I also reflect on the process of this action research study to identify any transformational relationships made and to evaluate the TPL framework. I end by looking at the implications the findings hold for teachers and the educational arena.

## 1.6. Ethical considerations

This study lent itself to certain ethical concerns, and thus required various protocols to be put in place to ensure that all participants were treated fairly and with respect. Permission for the research was sought from the Western Cape Education Department (WCED) and school management authorities since the research was done in public schools. Permission from the WCED was granted; the permission letter can be found as Appendix 1. The letter used to seek permission from each school principal is provided as Appendix 2. I then proceeded to submit a proposal for this study for ethical clearance from the appropriate bodies at Stellenbosch University. The ethical clearance letter with REC clearance number, REC-050411-032, for research proposal SU-HSD-001886 can be found as Appendix 3.

Since the perceptions and personal opinions of individual participants were gathered, the purposes and method of the study were clearly communicated to all participating in the research. All participants were requested to give written permission that their information could be used in the research project. The consent form, which was discussed with each participant individually, can be found as Appendix 4. No candidate was forced to participate in the study, and if a participant wanted to withdraw at any stage, he or she was free to do so. The RPTs also received the assurance that their anonymity would be protected at all times. As action research is cyclic in nature, communication was done and permission sought at the beginning as well as at key intervals of the research process.

In a research setting participants can easily feel that the researcher is in a position of power. Since I am a TPL facilitator at Stellenbosch University the RPTs could have seen me as 'lecturer' and be inclined to move into a student role. Ethically it is also important for the researcher to be aware of the balance required between the needs of the researcher and the obligation of the researcher to care and look out for the participant (Etherington, 2007). As researcher and especially in this action research process I have done my utmost to make the RPTs feel comfortable so that they would not see me as one holding a position of power over them, but as one who, together with them, would also want to learn from the research. This required establishing power equality within the researcher-participant relationship (Karnieli-Miller, Strier & Pessach, 2009). Establishing this relationship of equal power benefitted the processes of lesson observations and interviewing. I made certain that the RPTs were at ease so that they would be comfortable to share their perspectives openly and truthfully. This was achieved by ensuring that the RPTs were aware that the purpose of the process was not to evaluate them as teachers, but to come alongside them as a fellow colleague in education to allow both them and myself to learn in the process.

## 1.7. Conclusion

Our changing world, characterised inter alia by globalisation, advances in technology and the new generation of millenials, has made it necessary that we reconsider how we teach and educate (Kodrzycki, 2002; Sahlberg, 2011). SA has its own additional challenges of vast pockets of poverty where many schools do not have the adequate infrastructure, parental support and learner discipline for teaching to occur at an acceptable standard (Bantwini & Feza, 2017; Maarman & Lamont-Mbawuli, 2017; Modisaotsile, 2012; Reddy, Zuze, Visser, Winnaar, Juan, Prinsloo, Arends & Rogers, 2015; Spaull, 2013). These challenges however should not have to stand in the way of teaching learners in more effective ways, and could possibly partially be combatted by a different way of teaching.

To teach in a different way starts with empowering and supporting the teacher, and ensuring that teachers are included in the process of change (Aksit, 2007; Johnson, 2006; Msila, 2007; Polly & Hannafin, 2011; Pudi, 2006). In my study, I set out to introduce teachers to and support them in a new way of teaching. I attempted to work with teachers from various backgrounds, and I assessed whether this process had an effect on the teacher's perception of and on teaching the subject.

In my next chapter, I give a comprehensive overview of the current trends and practices in secondary school education internationally as well as in SA. With this, I aim to put forward a sound argument for the importance of the reconsideration of how we teach.

# Chapter 2: **TRENDS IN SCIENCE EDUCATION GLOBALLY AND LOCALLY AND THE NEED FOR CONTINUED REFORM IN EDUCATION**

## 2.1. Introduction

In this chapter I firstly consider the need for educational reform including the challenges to educational reform. I then proceed to discuss education and educational reform processes in South Africa (SA). In order to provide in-depth insight into the South African educational background and context, I spend a significant portion of this chapter painting a picture of the development and reform of education in SA post-apartheid. I also make use of results from Large-Scale Assessments (LSA) to highlight the efficacy of the reform processes in SA.

My focus then shifts to Science education, emphasising trends in Science education globally and locally. Trends in continuing gender inequality, trends in participation and trends in performance in Science education will be the foci. Global trends in performance of learners will also be used to demonstrate performance patterns and how they motivate ongoing education reform. In order to do so convincingly, I make use of data and findings from large-scale international tests.

Lastly I discuss the experience of the Science teacher in SA with specific reference to the effects of the South African educational milieu, the various curriculum changes and teaching qualifications on the teacher. I further discuss the pivotal role the teacher plays in educational reform.

## 2.2. The need for educational reform

Throughout the ages the field of education worldwide has been characterised by change (Aksit, 2007; Apple, 2004; Botha, 2002; Fataar, 2007; Garm & Karlsen, 2004; Liu & Dunne, 2009; Settlage & Meadows, 2002). These changes were, and still are, precipitated by the need to meet the demands of society and the market place, to improve the quality of education, to make education more accessible, to keep up with societal changes, and, in recent years, technological advances (Aksit, 2007; Apple, 2004; Botha, 2002; Fataar, 2007; Garm & Karlsen, 2004; Liu & Dunne, 2009; Settlage & Meadows, 2002). These changes in education are referred to as educational reform. In this section I look at the need for continual educational reform and focus on the role of globalisation in educational reform and the challenges to educational reform.

### 2.2.1. Quality education for all to meet societal needs

The ongoing quest to provide good quality, effective education is the main reason why education departments worldwide are engaged in continual education reform (Carney, 2008). More specific driving forces and motives for educational reform include globalisation, worldwide trends of low grades – especially in Mathematics and Science, learners not being fully prepared for tertiary studies, as well as the need to rectify the imbalances regarding gender and underrepresented groups' participation in tertiary education. The aim of educational reform is thus to strive for quality education for all (Carney, 2008).

At the 47th conference of the Federal Reserve Bank of Boston with the theme "Education in the 21st century: Meeting the Challenges of a Changing world", the focus was on how to change institutions and incentives to bring about better educational outcomes (Kodrzycki, 2002). Even though the conference was held with education in the United States of America (USA) in mind, it reflected trends and sentiments, which are echoed in educational spheres worldwide. Guest speaker Michael Barber, who oversaw educational reform in Britain on behalf of the Blair government, stated that the transformation of the education system must be directed at achieving two goals simultaneously: having the most talented workforce possible and improving the equity of educational outcomes. A well-educated nation is a strong nation, leading to a strong economy which will in turn again lead to the wellbeing of citizens (Kodrzycki, 2002).

Thus, to ensure progress and success governments constantly review their policies, including those on education. For instance, competence-based education, an example of educational reform, is an approach that specifically prepares persons for practice and is orientated towards graduate outcome abilities that will meet and address societal needs. Competence-based education is not focussed on graduating within a specific time frame, but rather on greater accountability, flexibility and learner-centred approaches (Frank, Mungroo, Ahmad, Wang, De Rossi & Horsley, 2010). Role players believe that competence-based education will narrow the gap between the labour market and education, the emphasis on education shifting its focus to developing capabilities, not on acquiring qualifications (Alake-Tuenter, Biemans, Tobi, Wals, Oosterheert & Mulder, 2012:2610).

### 2.2.2. Globalisation prompting educational reform

Globalisation is a term used to describe changes in global economics which affect production, consumption and investment, which can also be applied to political and cultural changes that affect common practices of large sections of people worldwide (Spring, 2008). Schooling is one such phenomenon with formal education being the most commonly found institution and shared experience worldwide (Spring, 2008). This means that globalisation and global competition also drive reform in education (Garm & Karlsen, 2004; Sahlberg, 2011). It is however, not easy to provide a single definition of globalisation due to a variety of views about it and it is therefore a term which, depending on which view one looks from, holds varying implication for education (Tikly, 2001). I align myself with Tikly's view of globalisation that the world is entering a truly global age which will lead to a global capitalism, resulting in new forms of global culture, governance and civil society (Tikly, 2001:153).

Educational reform in developed countries is often driven by advancement, globalisation and the effect globalisation has on markets and trade. Globalisation has led to an increase in the movement of resources, people and their ideas which had an impact on how people think about education (Sahlberg, 2011). For example, many developed countries around the world, face an influx of a diversity of people, which means that where a homogeneous culture had to be catered for in the past, educational departments have to more and more consider a variety of cultures, languages and socio-economic backgrounds.

What can further be recognised is the fact that educational change in Africa has been shaped by global forces both in the past, and currently. It has been argued that education can play a vital role in Africa's renewal because of the central importance of education for economic, political and cultural development (Tikly, 2001:169). Hence it is worthwhile to continue reviewing educational forms and striving for more effective strategies and approaches in education to meet the societal demands.

### 2.2.3. Challenges to educational reform

In many countries there have been constant review and attempts at improving how teachers teach (Shulman, 2011). This included experimentation with different presentation methods and pedagogical approaches. Yet, implementing new policy is more easily said than done.

> Implementing standards-based instructional practice in diverse urban school systems presents a particular set of challenges for educators and their partners in reform efforts. These challenges include lack of resources, high levels of poverty, low student achievement, below grade level English proficiency, high student mobility, attendance problems, and difficulty recruiting and retaining highly qualified teachers (Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway & Clay-Chambers, 2008:923)

Another hurdle which often stands in the way of educational policies that are aimed at making education more participatory and engaged are standardised tests (Liu & Dunne, 2009). For instance, in China, policies to transform education focussed on moving from a traditional examination-oriented education to a new quality-oriented and student-centred education system (Liu & Dunne, 2009). It has been more than 30 years since policy in China has been revised to prescribe a learner-centred educational experience. Yet, the aspirations of parents and schools for their learners to achieve top exam marks and systemic test scores drives teaching to be dictated and shaped by the examinations and thus delivered in a more traditional way (Liu & Dunne, 2009). Even in South Africa the preparation for the National Senior Certificate (NSC) exam, the national exit exam for learners on completion of their secondary schooling, dictates, to a large extent, teaching and learning interventions and strategies (Spaull, 2013).

Developing countries face different challenges within education, namely ensuring education for all its citizens. Most developing countries have a historical background which has left a grim legacy. India, for example, a country that was under British rule for many years, found itself in a dire position after independence with a large population of which only 9% of women and 25% of men were literate and thus had to make access to free education for all their main focus of educational reform (Kingdon, 2007). South Africa, with its legacy of apartheid, was also required to first attend to the issue of ensuring that all children have access to education.

Developed countries are not exempt from the challenge to reform with the aim of ensuring quality education for all. Tertiary institutions in developed countries are experiencing an increase in student aspirations to pursue further studies, with a particular interest in Science, Technology, Engineering and Mathematics (STEM) related fields (Eagan, Hurtado, Figueroa & Hughes, 2014). This in itself is a good indicator of improved Science education at school level. However, a fairly low percentage of these students complete their studies (Eagan *et al.*, 2014). In the USA, for example, only 40% of incoming students complete their degrees with less than 25% of underrepresented groups like Hispanics or African-American completing their studies (Eagan *et al.*, 2014). This points to a need for continued reform in school education, and unequal access to both good quality school education and resources even in developed countries.

> While education deficits are obviously greater in developing countries, this is a major issue in developed countries as well. In many industrialized countries there is a persistent problem of illiteracy and low skills, which is an important source of social exclusion. Unequal access to education also fuels growing wage inequality and worsen the income distribution. The uneducated and unskilled in industrialized countries face severe disadvantage in an increasingly competitive global market (Bakhtiari & Shajar, 2012:97).

As society and societal needs are constantly in flux, it is clear that there is a global need for continued educational reform to ensure that quality education is made available to all and in so doing these societal needs are addressed. In many of these countries reform is not easy as the usual challenges of implementing new, especially more learner-centred, educational approaches are exacerbated by high levels of illiteracy as well as high numbers of learners and high incidence of poverty. This challenge is made increasingly difficult by the lack of school resources and high costs, but mostly by an absence of qualified teachers especially in Science and Mathematics (Kingdon, 2007; Reddy *et al.*, 2012; Spaull, 2013).

## 2.3. Education and educational reform in the South African context

As with other countries worldwide, education in South Africa, is also affected by many of the challenges mentioned in the previous section, as well as its own unique set of challenges. In this section I discuss general education in SA and focus more specifically on Science education in SA in Section 2.5.

### 2.3.1. Background to educational governance in SA

After apartheid the new democratic South Africa demanded a new Constitution and new policies in order to place the country onto a new trajectory. During the apartheid period in South Africa education was largely colonial and nationalist in nature. During this era education governance in SA was located in 19 different entities (DoE, 2002). These entities were racially divided, with each entity responsible for its own curriculum and assessment policies. After 1994 a single administrative body, the Department of Education (DoE), was formed to set policies and standards for all children in education in South Africa. This body was tasked to develop a single national core syllabus, which replaced the former syllabi which differed according to race, geography and ideology and which played a powerful role in reinforcing inequality (DoE, 2002). By developing and implementing a single national core syllabus post 1994, education legislation and policy reform were used to redress the inequalities in and between schools for different population groups (Bantwini & Feza, 2017). Education policies have been devised to ensure free and equal education, at least up to secondary level, with the aim to develop critical thinkers and active citizens.

In 2009, the DoE was split into two departments, namely the Department of Basic Education (DBE) which is responsible for education from early childhood development to secondary school level, and the Department of Higher Education and Training (DHET) which guides and oversees tertiary education. The focus in the next section is on curriculum reform in SA under the guidance of the various administrative bodies in education.

### 2.3.2. Reform of the South African school curriculum

#### *a) Various reform strategies*

After 1994, the former National Education curriculum, NATED 550, became the first reform policy document and proposed an interim school curriculum. It was the guiding document for education in South Africa during the period in which a new Constitution was being drafted. It was known as 'A

Résumé of instructional programmes in schools' (DoE, 2005), and it aimed at eliminating racist language and ideas as well as outdated content (Chisholm, 2005a; DoE, 2002; Frederick, 2012). According to NATED 550 the exit exam for learners from secondary school was the Senior Certificate (SC), also known as the Matriculation exam. Subjects at this exit level at secondary school could be taken and examined at the higher or standard grade level, with achievement at the higher grade level providing learners with access to tertiary education (Grussendorff, 2010; Potgieter & Davidowitz, 2010).

The new Constitution became the foundation which informed policies in the new democracy. With this in place, the next reform in the field of education was the National Curriculum Statement (NCS) which was launched in 1997 (Chisholm, 2005a). The NCS was more widely referred to as Curriculum 2005 (C2005), and the methodology of instruction prescribed by the NCS was Outcomes Based Education (OBE) (Frederick, 2012). The aim of OBE was to move away from the rigid, nationalist education where very little opportunity was given for independent thought or questioning (Chisholm, 2005b; Jansen, 1998). OBE moved away from rote learning which is largely passive, and intended to promote new teaching styles to encourage creative learning and problem-solving through active learner participation (Jansen, 1998; Msila, 2007). The OBE methodology is a learner-centred one. It potentially allows learners to learn in a way that suits them best. It was premised on the idea that there could be many ways to solve a given problem. OBE also allows for teachers to decide what they would teach and how they would teach it (Du Plessis, 2015). The DoE believed this would be a good vehicle to develop the critical thinkers and active citizens as envisaged by the new Constitution (Botha, 2002). OBE did not provide teachers with a fixed content structure but rather focussed on learners developing skills with the teacher being a facilitator of learning (Chisholm, 2005b). Since this methodology was new to all teachers a host of training programmes were launched to orientate teachers and provide the much-needed guidance to implement the NCS using OBE as methodology. Due to the flexible nature of the OBE methodology teachers quickly felt they were lost when implementation commenced, and many concluded that even though the NCS as policy document was good, implementation was challenging (Frederick, 2012). This led to the DoE reviewing C2005, and the development of the Revised National Curriculum Statement (RNCS) which became official policy in 2002, thus replacing the NCS (Chisholm, 2005a). One of the main features which was retained from the NCS was OBE. The motivation to retain OBE was that it represented change (Chisholm, 2005b). In 2008 the first cohort of learners being taught according to OBE wrote the first National Senior certificate (NSC) exit exam (Potgieter & Davidowitz, 2010). The NSC does not include the higher and standard grade levels as was the case with the SC format, but all learners now write an exam on the same level.

The RNCS endeavours to embody a democratic vision of the nation and the citizens that our school system should develop (DoE, 2002). The RNCS lists the critical and developmental outcomes which were derived from the Constitution and are contained in the South African Qualifications Act (1995). The purpose of critical outcomes, which underpin the new curriculum, is to integrate all learning (Jansen, 1998; Pudi, 2006). Together, these outcomes describe the kind of citizen the education and training system should aim to create. The RNCS critical outcomes envisage learners who will be able to:

- Identify and solve problems and make decisions using critical and creative thinking;
- Work effectively with others as members of a team, group, organisation and community;
- Organise and manage themselves and their activities responsibly and effectively;
- Collect, analyse, organise and critically evaluate information;
- Communicate effectively using visual, symbolic and/or language skills in various modes;
- Use Science and Technology effectively and critically showing responsibility towards the environment and the health of others; and
- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

The RNCS developmental outcomes envisage learners who are also able to:

- Reflect on and explore a variety of strategies to learn more effectively;
- Participate as responsible citizens in the life of local, national, and global communities;
- Be culturally and aesthetically sensitive across a range of social contexts;
- Explore education and career opportunities and
- Develop entrepreneurial opportunities.

Even though these desired outcomes are commendable, they have not yet led to the desired effect. Feedback from different groups in education, as well as trends in systemic test results, indicate that the implementation of NCS through OBE as well as the RNCS has not been effective in reaching its aims and goals and that the quality of education remains poor (Modisaotsile, 2012). For instance, in 2009 when candidates of the 2008 cohort of first NSC learners entered tertiary education at Universities of Cape Town and Pretoria, test results of these learners indicated that they had not been adequately prepared for tertiary education, with as few as 17% of the Chemistry class passing this first year course (Potgieter & Davidowitz, 2010).

The overall low performance in tests scores and concerning trends continuing beyond RNCS were a motivation for further educational reform in SA. This together with teachers indicating a need for better guidance regarding content, resulted in the development of the Curriculum and Assessment Policy Statement (CAPS). This latest guiding document in SA school education is organised per learning area or subject, as well as per learning phase. The result is that the current South African schooling system is divided into five phases namely:

- Early Learning Development (ELD) – preschool phase which culminates in Grade R with learners at the age of 6 years
- Foundation Phase (FP) – Grades 1 – 3 with learners from ages 7 to 9 years
- Intermediate Phase (IP)– Grades 4 to 6 with learners from ages 10 to 12 years
- Senior Phase (SP) – Grades 7 to 9 with learners from ages 13 to 15 years
- Further Education and Training (FET) – Grades 10 – 12 with learners from ages 15 to 17 years.

Clear guidelines as to what must be taught per grade and per subject, as well as which teaching resources are to be used, are stipulated within CAPS. This made it easier for teachers to know what to teach and when to teach it. On the other hand, it can also be experienced as too prescriptive and thus restrictive for teachers who would like to use their own creativity.

### *b) Outcomes of educational reform in SA*

Since the 1960's a number of international large-scale assessments (LSA) have been used worldwide to measure learners' achievement levels; these assessments provide valuable country-level achievement data for policy makers (Klieme, 2016). Such assessments are done in many countries across the world at regular intervals with learners of different age levels (DBE, 2012; Mullis, Martin & Loveless, 2016). In many developing countries, international and national learning assessments have become the preferred tool of educational policy makers (Kamens & Benavot, 2011). One example of LSA tests is the Trends in International Mathematics and Science Study (TIMSS) (Foy, Arora & Stanco, 2013; Mullis *et al.*, 2016). South African TIMSS performances and the national standardised tests are used by DBE to measure learner progress to inform educational direction and policy. The national standardised tests in SA include the Annual National Assessment (ANA) tests in Literacy and Mathematics for learners up to Grade 9, and the NSC exam, which is the exit exam after twelve years of formal schooling (DBE, 2012).

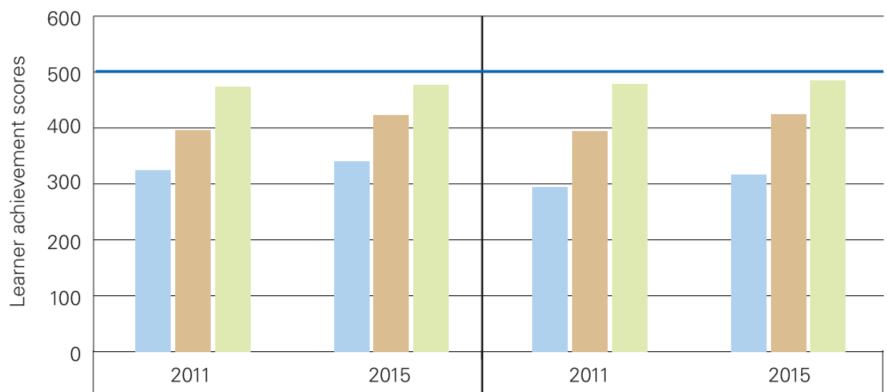
Results from TIMSS studies provide indications of which countries are the leading figures in education worldwide, as well as current shortcomings in education (Kamens & Benavot, 2011; Liu & Dunne, 2009; Spaull, 2013). Data from these tests can be used to pick up educational patterns across the world as well as highlight the state of education in various contexts. It is also used by education policy makers of participating countries to inform their decision-making and reform initiatives. TIMSS is a project of the International Association for the Evaluation of Educational Achievement (IEA) which provides information on trends in learner achievement in Mathematics and Science of learners in Grades 4 and 8 (IEA, 2017). TIMMS have participating countries from all continents including Africa, Asia and the Middle East, thus providing a wide international coverage. Since my study focusses specifically on Science at the secondary school level, I mainly refer to data from TIMSS assessments in Grade 8 Science. The benchmark score for TIMSS is set at 500 (Provasnik, Kastberg, Ferraro, Lemanski, Roey & Jenkins, 2012). Obtaining a mean score of 500 or above is a good attainment. TIMSS scores are also further categorised as advanced, high, intermediate and low as indicated in Table 2.1 below.

**Table 2.1: TIMSS score categories**

| Category | TIMSS Score |
|---|---|
| Advanced | 625 and above |
| High | 550 – 624 |
| Intermediate | 475 – 549 |
| Low | 400 – 474 |

**(Source: Own table; information from Provasnik et al., 2012)**

Since the implementation of CAPS, which started in 2012 (Du Plessis, 2015), South African TIMSS scores have started to take a turn for the better. This is displayed in Figure 2.1.




| | Mathematics | | Science | |
|---|---|---|---|---|
| | 2011 | 2015 | 2011 | 2015 |
| Public (No-fee) | 324 | 341 | 294 | 317 |
| Public (Fee-paying) | 397 | 423 | 394 | 425 |
| Independent | 474 | 477 | 479 | 485 |

**Figure 2.1: Attainment in Science and Mathematics per school type in SA, 2011 and 2015 (Source: Zuze, Reddy, Visser, Winnaar & Govender, 2017)**

The 2015 national report on TIMSS in Grade 9 showed a slight improvement in the mean scores for Science as well as Mathematics, particularly in public schools (Reddy *et al.*, 2016; Zuze *et al.*, 2017). Figure 2.1 gives the average attainment of South African learners per type of school in both 2011 and 2015. From the figure it is also evident that the increase was present across all school types.

The TIMSS 2015 report also includes a comparison of results per country from 2003 to 2015. Changes in South African scores in Science from TIMSS 2003 and TIMSS 2015 are displayed in Figure 2.2 together with the changes in scores of a selection of 25 other countries that also participated in TIMSS for the same period.

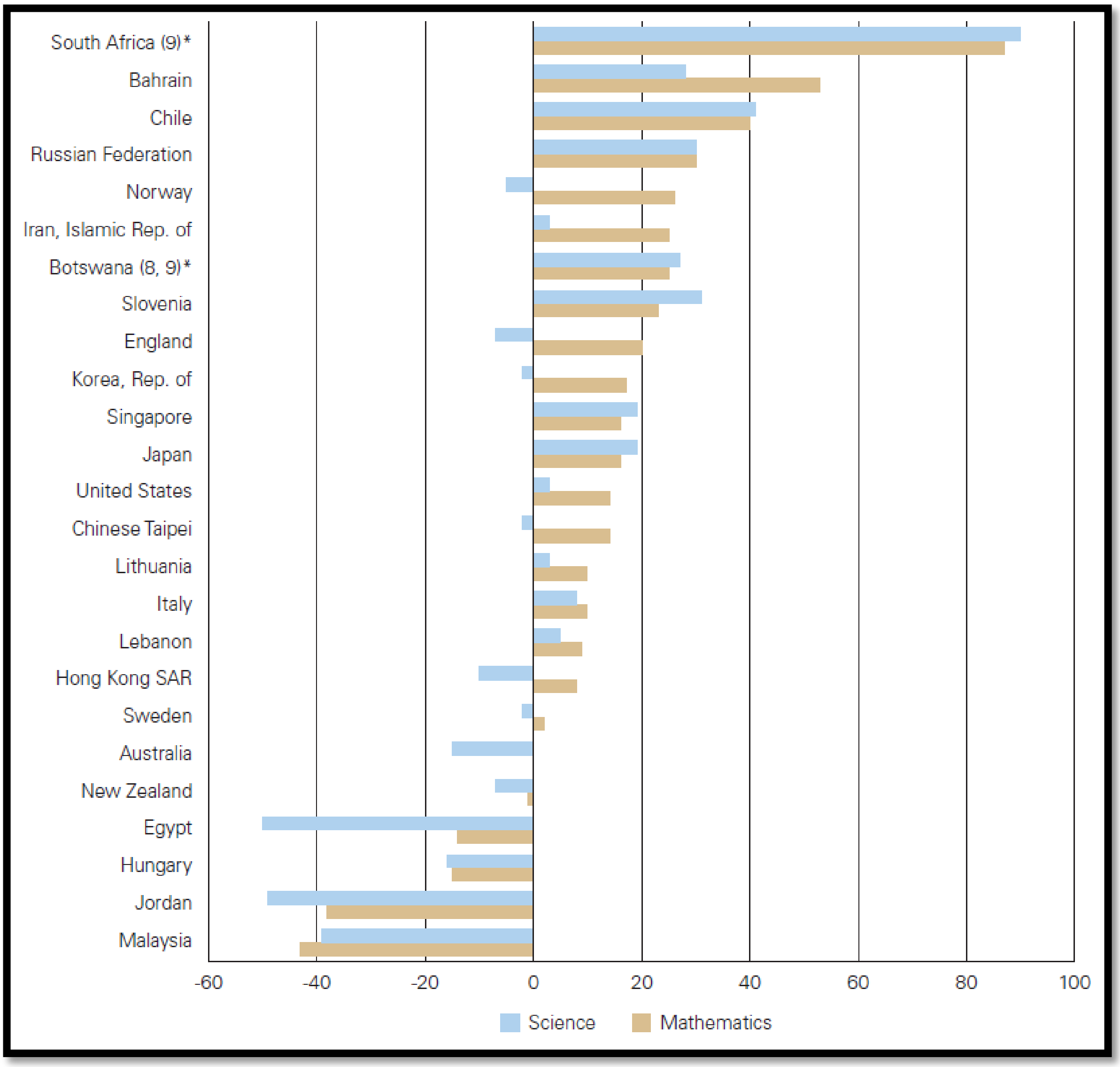



**Figure 2.2: Change in average Science and Mathematics TIMSS scores per country, 2003 and 2015**

**(Source: Zuze et al., 2017)**

Bars to the right in Figure 2.2 show an improvement in scores from TIMSS 2003 to TIMSS 2015, and bars to the left show a decrease in scores. The length of the bar represents the extent by which a country's score has changed. Of the 25 countries included in the analysis, 13 countries showed an improvement while 12 countries showed a decline in the Science achievement scores. It is important to note that of the 25 countries South Africa has achieved, admittedly from a very low base, the biggest positive change, with an improvement of 90 points in Science.

Even though this increase was from a very low base, it still underscores the substantial improvement that took place during this period, where many other countries showed little change or even negative trends (Zuze *et al.*, 2017). This is encouraging and can imply that educational reform efforts have been fruitful; however, with South African scores still quite low and as a country in the second last place, further educational reform strategies are still clearly needed.

***c) Conclusions drawn from educational reforms in SA***

This section gave a brief overview of the process of curriculum reform post 1994 in SA, and the accompanying educational performance. Given our history of a highly fragmented and unequal education dispensation before 1994, trying to forge a unified education system set to provide access to education for all and bring about equity, as well as to develop critical thinkers and active citizens, is a tall order. Data shows some positive trends in terms of access and providing resources to schools, yet education in SA still continues to face many challenges. Measured against international benchmarks South African learner results remain low across all school types in SA, and so educational reform must continue. The South African democracy is still relatively young and one can therefore expect that education at school level would continue to undergo reform as the Department of Basic Education will continue to strive to effectively reach the aims and goals as set out by the new Constitution for an improved, quality education for our nation.

### 2.3.3. South Africa - still a divided nation

The legacy of apartheid affecting South African schools is evident in our divided nation. The groupings and boundaries set up during apartheid, with an unequal distribution of resources and access, still largely remain. On the educational front it is no different. In the apartheid era schools were classified and resourced differently along racial lines. After more than 20 years of a democratic South Africa a fair degree of integration has occurred in certain schools which currently display a more diverse learner population. The schools in which this integration is evident, are mainly those in more affluent areas that draw learners from families who can make a financial contribution to their schooling (Hall & Giese, 2009). However, learner demographics in schools in the lower socio-economic areas have remained largely unchanged. Parents from these communities are unable to make significant financial contributions to the education of their children and hence learners from these communities lack adequate educational resources (Bantwini & Feza, 2017; van der Berg, 2014).

I will now proceed to explain the quintile system that the government in SA implemented to address the inequilities among South African schools, and then show that by 2017 the system still could not bring about an equal playing field, by considering resouces in schools and progress by learners across the quintiles.

### *a) The quintile system*

One way in which the government attempted to address the inequalities which existed between various schools was to categorically group schools. The categories are called quintiles and schools are assigned to a quintile based on their physical condition, resources available to them and the funding available within the school community (Hall & Giese, 2009). This quintile system has five levels with quintile one, two and three being the least resourced schools and classified as no-fee paying schools (Hall & Giese, 2009; Van Wyk, 2015). These are predominantly the schools within black and coloured[1] communities which were greatly under-resourced and under-developed during apartheid. Being a no-fee school means that parents do not have to pay school fees and that the government will fully subsidise such schools (Hall & Giese, 2009). Yet, poor communities are at a disadvantage in terms of lacking a sufficient number of schools and the schools which are available are still inadequately resourced (Van der Berg, 2014).

Some of the features of quintile four and five schools are that they are housed in sturdy brick buildings with flushing toilets. These schools are fee paying schools as quintile four and five schools are not fully subsidised by the government. These schools have a strong base as they were privileged during apartheid, and are categorised as schools where the learners have access to ample resources (Reddy, Zuze, Visser, Winnaar, Juan, Prinsloo, Arends, 2015). Government funds will cover only the basic educational costs for these schools whilst parental financial contributions are used to cover any further needs. All schools in previously white-only areas have been classified as quintile five schools and generally continue to be well resourced, both in terms of infrastructure and a financially strong parent community.

Schools in quintiles one, two and three, which pay no fees, are still in a predicament. During the apartheid era these schools did not have a good infrastructure. Currently the subsidy paid by the government is not adequate to provide high quality education and with parents being unable to make

[1] Apartheid race classifications are still used in South Africa to track transformation. I acknowledge that these terms are problematic.

financial contributions, the backlogs in infrastructure and educational resources have largely remained. Data analysis provides evidence that even though the quintile system was deemed a useful way to redress inequality, it is failing to do so and hence failing to ensure educational improvements across the board (Hall & Giese, 2009).

### *b) Resources in schools across the quintiles*

Data sets from the main quantitative report of the 2017 School Monitoring Survey done by the DBE gives an indication of the degree of progress made or not made across quintiles in four categories, namely allocated teaching posts filled, financial capacity, infractructure standards and access to library resources. I briefly discuss the four categories below and Figures 2.3 to 2.6 indicate the data per category as bar charts. Each chart gives a comparison of schools across quintiles and present data in 2011 and 2017 as a combined percentage of primary and secondary schools. I firstly consider the category teaching posts filled. Figure 2.3 below gives the data as a bar chart.

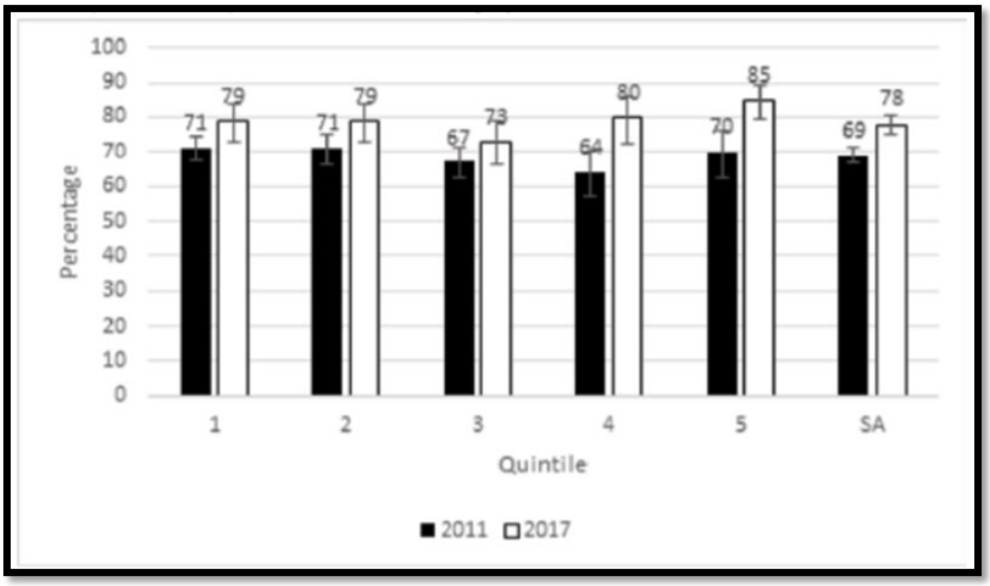



**Figure 2.3: Allocated teaching posts filled**
**(Source: DBE, 2018)**

In this category there has been an improvement from 2011 to 2017, with schools,on average, having close to 80% of posts being filled, leaving 20% of allocated posts still vacant. The next category looks at financial responsibilities. The data, as shown in Figure 2.4, displays a decrease in financial capacity across all the quintiles from 2011 to 2017. The last set of columns in Figure 2.4 shows us the average percentage of financial capacity in South African schools across the quintiles. This average declined from 74% in 2011 to 57% in 2017 which is an indication that the financial capacities of schools across board has declined over the years.

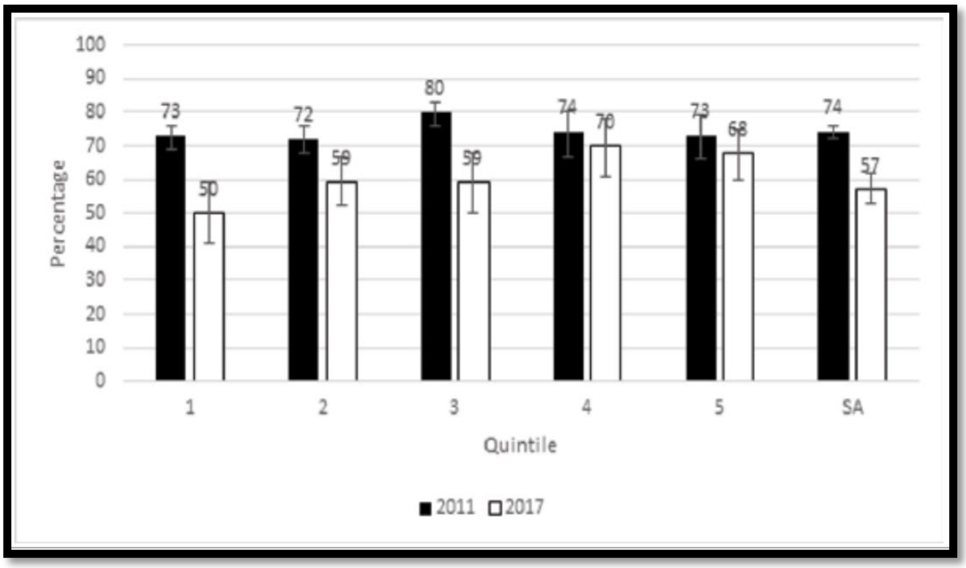



**Figure 2.4: Required financial capacity**
**(Source: DBE, 2018)**

One can only assume that schools are finding it increasingly difficult to function optimally as the lack of finances at the school will have an impact on its daily operations. What is notable is that even though quintile four and five schools also displayed a decrease in financial capacity from 2011 to 2017, they are still, on average, about 10% better off than quintile two and three schools in 2017, and by 20% better off than quintile one schools in this regard.

Another category, adherence to minimum standards in infrastructure, paints a dismal picture. What is quite obvious is the low level of adherence to minimum standards in the lower quintiles and hence in SA overall.

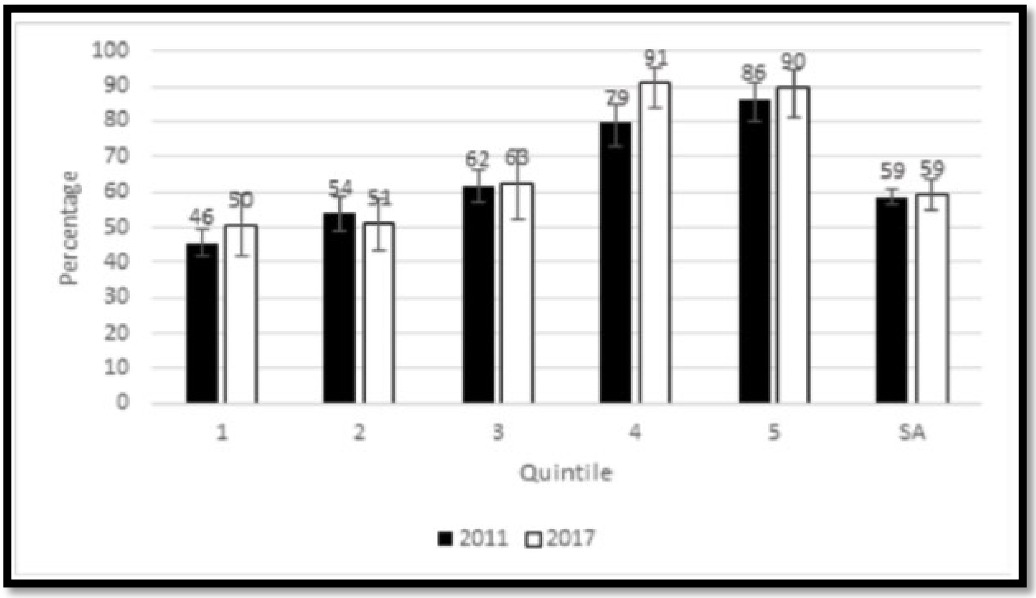



**Figure 2.5: Adhering to the minimum physical infrastructure standards for 2016**
**(Source: DBE, 2018)**

On closer look, Figure 2.5 shows that for quintile four and five schools the adherence in 2011 was at an acceptable standard, and displays a further increase bringing the adherence up to 90% in both quintile four and five schools in 2017. Quintile one and three schools does show an increase, however slight, but quintile two schools show a decrease in adherence to minimum physical infrastructure from 2011 to 2017. This is very concerning as it is from an already low position. It is a well-known fact that some schools in rural areas still use pit toilets, while many schools operate in dilapidated buildings.

In the fourth category, access to library resources, the picture worsens. Even though there has been a definite increase in access to librabries to learners across the board, as indicated by the rise in percentage for all five quintiles in Figure 2.6, the difference between the quintiles are vast with less than 50% of quintile one learners having access to libraries in 2017, while on the other hand 78% and 86% of quintile four and five learners respectively have access to librabry facilities.

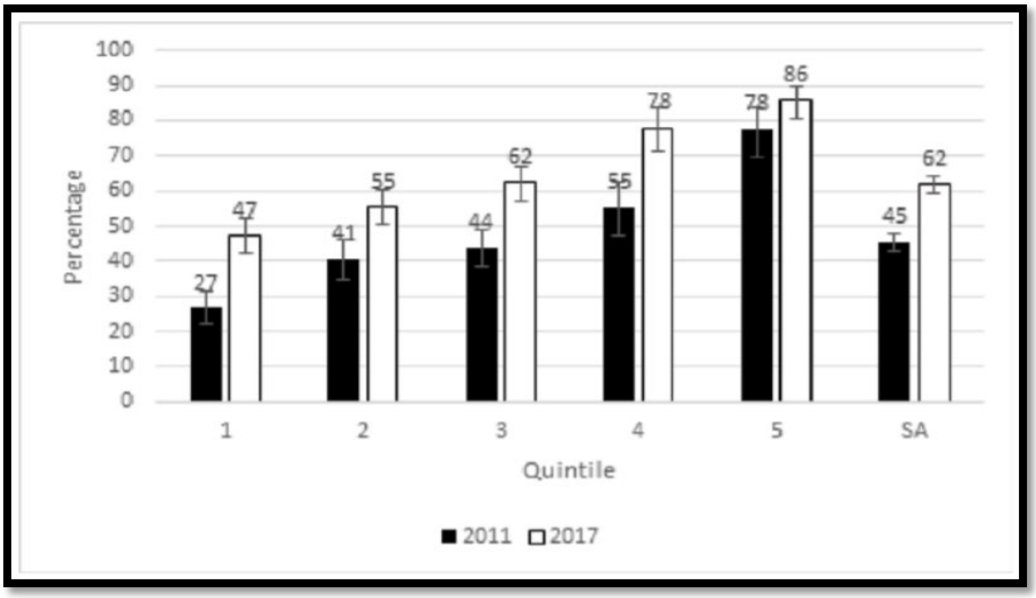



**Figure 2.6: Learners with access to school or mobile library facilities (Source: DBE, 2018)**

The four categories discussed here is an indication of gaps in resources, which affects the education of learners and particularly highlights the differences between the schools from differing quintiles. I will now proceed to look at the patterns in academic performance according to quintile.

### *c) Patterns in academic performance according to quintile*

These differences in educational resources across the quintiles have a direct effect on academic performance and this is evident in performance data. In this section I make use of data indicating the effective enrolment of Grade 6 learners of ten African countries, including SA. Effective enrolment refers to enrolled learners who are functionally literate (Spaull, 2013). The data has been categorised according to gender, location and wealth quintiles as displayed in Table 2.2. This data allows me to show trends per quintile not only in SA, but also how SA is faring in comparison to other African countries. From this table one can deduce the following about enrolled Grade 6 learners in South Africa:

- Female learners are more functionally literate than males;
- Urban learners are much more functionally literate than rural learners;
- There is a wide range in functional literacy across the quintile system with quintile one learners in South Africa lagging far behind those in quintile five;
- The average in functional literacy across quintiles one to three, the no fee-paying schools, is only 63,0% and in quintile four and five, the fee-paying schools, it is 84,1%; and
- A number of African countries such as Kenya, Namibia, Swaziland, Tanzania and Zimbabwe out perform South Africa at this level.

**Table 2.2: Effective enrolment rates of the Grade 6 aged population**

| | Gender | | | Location | | Wealth quintiles | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Total | Male | Female | Urban | Rural | Q1 | Q2 | Q3 | Q4 | Q5 |
| Kenya | 87,3 | 85,8 | 88,9 | 88,4 | 85,8 | 80,2 | 85,5 | 87,8 | 91,9 | 91,4 |
| Lesotho | 70,1 | 62,6 | 76,8 | 82,7 | 65,2 | 63,1 | 64,2 | 70,1 | 74,0 | 79,9 |
| Malawi | 54,4 | 59,0 | 49,7 | 69,9 | 50,4 | 44,2 | 49,5 | 57,2 | 56,3 | 64,0 |
| Namibia | 80,1 | 76,4 | 83,6 | 89,0 | 74,9 | 70,1 | 77,2 | 78,4 | 86,4 | 91,4 |
| South Africa | 71,2 | 67,1 | 75,4 | 84,5 | 57,8 | 56,1 | 63,4 | 69,5 | 76,6 | 91,5 |
| Swaziland | 88,2 | 87,7 | 88,6 | 89,7 | 87,8 | 87,5 | 84,4 | 86,1 | 91,2 | 93,1 |
| Tanzania | 82,3 | 81,1 | 83,6 | 87,8 | 80,5 | 74,9 | 79,8 | 85,6 | 84,4 | 87,2 |
| Uganda | 71,0 | 73,1 | 68,8 | 79,6 | 67,2 | 57,9 | 67,7 | 70,5 | 78,8 | 78,0 |
| Zambia | 49,3 | 51,9 | 46,6 | 58,8 | 44,2 | 37,4 | 44,5 | 44,4 | 56,0 | 62,8 |
| Zimbabwe | 75,3 | 71,6 | 78,1 | 90,8 | 70,1 | 70,9 | 71,3 | 75,1 | 73,6 | 87,2 |

**(Source: Spaull, 2013)**

I made a further analysis of the data in Table 2.2 to show the countries in order of highest to lowest total effective enrolments by considering the total, rural location and urban location. This reveals that of the ten countries, SA is sixth. Some poorer countries, which spend less per capita on education than SA, fared beter than SA (Spaull, 2013). Table 2.3 displays this further analysis of the data given in Table 2.2. The order in Table 2.3 indicates that even though SA also takes sixth place for effective enrolment in urban areas, it moves down two places into eighth position for effective enrolment in rural areas. What is deeply concerning is the fact that South African scores show the biggest range difference in effective enrolment between urban and rural schools, as well as between quintile one and quintile five schools. Quintile five schools shows a high enrolment of 91.5% and quintile one schools only 56,1% enrolement. This again highlights the effect of inequalities amongst South African schools.

**Table 2.3: Ten African countries in order of highest to lowest effective Grade 6 enrolment**

| Country | Effective enrolment percentage | | | | Range difference from Quintile 1 to 5 in effective enrolment percentage |
|---|---|---|---|---|---|
| | Total | Urban | Rural | Difference between urban & rural | |
| Swaziland | 88,2 | 89,7 | 87,8 | 1,9 | 11,2 |
| Kenya | 87,3 | 88,4 | 85,8 | 2,6 | 5,6 |
| Tanzania | 82,3 | 87,8 | 80,5 | 7,3 | 12,3 |
| Namibia | 80,1 | 89,0 | 74,9 | 14,1 | 21,3 |
| Zimbabwe | 75,3 | 90,8 | 70,1 | 20,7 | 16,3 |
| **South Africa** | **71,2** | **84,5** | **57,8** | **26,7** | **35,4** |
| Uganda | 71,0 | 79,6 | **67,2** | 12,4 | 20,1 |
| Lesotho | 70,1 | 82,7 | **65,2** | 17,5 | 16,8 |
| Malawi | 54,4 | 69,6 | 50,4 | 19,2 | 19,8 |
| Zambia | 49,3 | 58,8 | 44,2 | 14,6 | 25,4 |

**(Own table)**

Analysis of TIMSS-SA 2011 shows that SA scores in Science remains among the lowest of the participating middle-income countries (Spaull, 2013). Even the top achievers in SA are still not globally competitive (Reddy et al., 2015). Figure 2.7 shows the average Grade 8 TIMSS 2011 scores for middle-income participating countries.

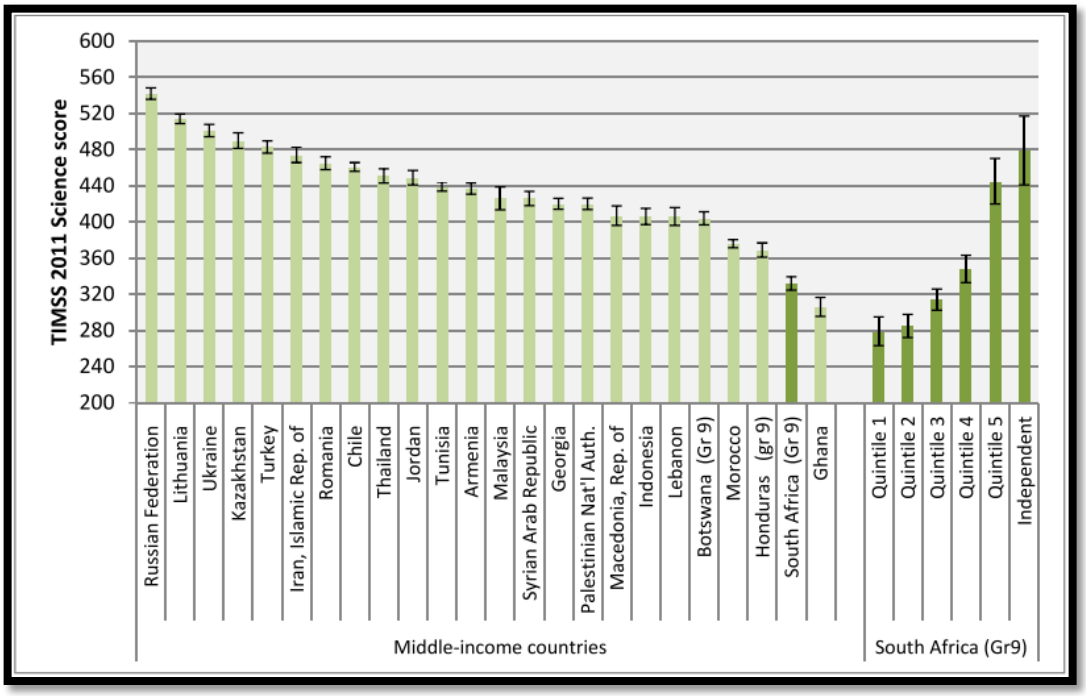



**Figure 2.7: TIMSS 2011 Average Grade 8 Science test scores (Source: Spaull, 2013)**

Do note that learners form South Africa, Honduras and Botswana who wrote the tests in 2011where in Grade 9 in their respective countries whereas the candidates from all other countries where Grade 8 learners. It also indicates the breakdown in average scores for SA according to quintile. Note that the average scores for the better performing South African school categories, i.e. fee-paying, quintile five and independent schools are still below the TIMSS benchmark score of 500. Fee-paying quintile four schools have an average score below 400, quintile three schools a score just above 300, and quintile one and two schools an average score below 300.

### *d) Unequal access to resources according to socio-economic status*

There are still stark differences between socio-economic groups, communities and schools in SA Figure 2.8 displays the school and home contexts by school type in South Africa during 2015.

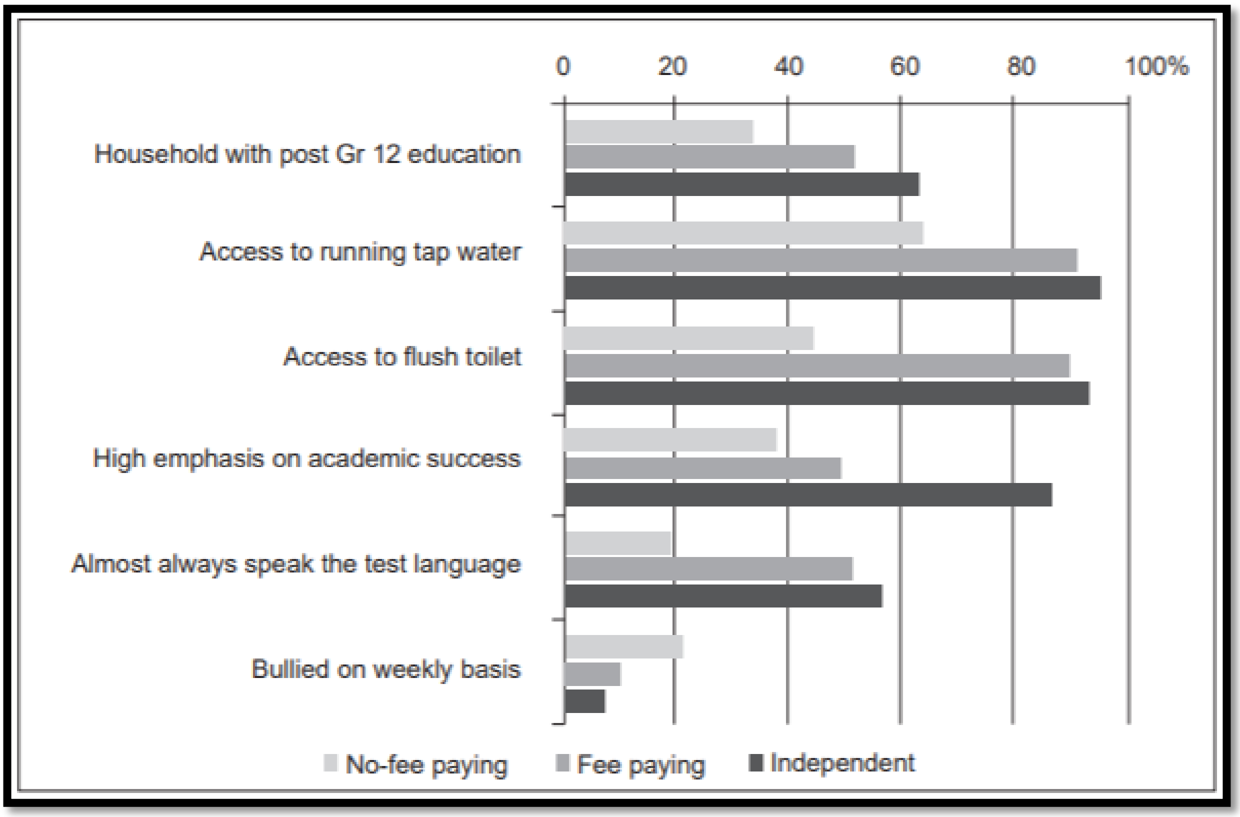



**Figure 2.8: School and home context of learners in South African schools, 2015 (Source: Alex & Juan, 2017)**

School types are a good indication of population groups, with learners attending no fee schools coming from the poorer communities, which are mainly found in the rural and informal settlement areas in SA. Most learners from these schools do not have access to good personal or educational resources.

Learners from fee-paying schools represent middle class communities. Most of these schools are also previously white schools and thus have good infrastructure. The learner demographics of fee-paying schools have changed over the past 25 years, and now display a more racially integrated school population. The learners attending the fee-paying schools also come from families who are financially better off, so they have access to better resources and most of which would have a good level of education. Learners attending independent schools are mostly from very wealthy communities who have access to very good personal and educational resources.

A fair percentage of learners from no-fee schools still encounter lack of water and flushing toilets in both their homes and schools. Households of learners from no-fee schools show the lowest incidence of having members with a post Grade 12 education or placing strong emphasis on academic success (Alex & Juan, 2017). A huge barrier for learners from no-fee schools is that these learners' home language is not the language in which they are taught and tested at school. Furthermore, households in poorer communities lack resources like dictionaries, books and landline phones, as well as computers and access to adequate internet at home (Alex & Juan, 2017).

So despite concerted efforts to provide wider access to schooling, SA still remains a divided nation gripped by high levels of poverty and displaying one of the most unequal distributions of income in the world (Reddy, 2006). Black South Africans in particular struggle with the consequences of apartheid and are the poorest group in South Africa. On the education front many predominantly black schools continue to endure backlogs in infrastructure, qualified teachers in subjects like Mathematics and Sciences, learning materials like books, stationery and apparatus, and more recently, access to ICT (Reddy, 2006; Maringe, Masinire & Nkambule, 2015; Modisaotsile, 2012).

All of the above is compounded by the home and living environment of the learners where provision of the basic needs like food, safety, and adequate clothing is inadequate. Such communities are often characterised by violence and substance abuse, and for a learner coming from this environment his or her chance of performing well at school and gaining a good education is largely compromised. Van der Berg (2014:216) highlights the important role of education to address the prevailing inequality in SA as follows:

> Inequality remains deeply imbedded in South African society and will not disappear of its own accord. Interventions are required to reduce income inequality, but most of these interventions (affirmative action and Black economic empowerment, fiscal redistribution) can have only limited effects. The one exception is education, although solutions to the dilemma of poor educational performance and quality are not easy to find. Yet this remains the crucial requirement for the creation of a less unequal society. Whilst reducing poverty requires more jobs, reducing inequality requires better education.

In the light of the above, it is no surprise that the morale of many teachers and learners in SA is low and that many learners have little or no interest in schoolwork. Needless to say, SA has struggled post-apartheid to ensure good quality, high standard, and free education for all up to the secondary school level. This has been affected by a number of factors. As illustrated above, the combination of large class sizes, unfulfilled teachers, often not adequately prepared for what they need to teach, and a lack of resources are only some of the factors which hamper quality education. The most significant of them all is the socio-economic profile of the population with the huge gap between rich and poor. From this broad overview of education, I now continue to focus on Science education specifically. I describe trends in Science education worldwide and in South Africa, in terms of learner participation and performance, as well as teacher practice and current approaches to teaching.

## 2.4. Trends in school Science education globally and locally

Issues pertaining to specifically Science education both globally and locally will now be considered. I will do this by placing the continuing underrepresentation of women in Science (Blickenstaff, 2005; NASAC, 2015), and the decline in interest and participation in Science education worldwide under the spotlight (Trna, Trnova & Sibor, 2012). Furthermore, the trends in performance in Science education globally and locally will also be considered. All three matters must be highlighted as a matter of great concern as qualified scientists are needed across the world to ensure, that not only current scientific operations and processes continue and run effectively, but also to find scientific responses or solutions to the many new challenges that we face worldwide.

### 2.4.1. Inequalities in gender representation in Science education

The trend of gender inequality in both Science related fields and Science education still persists with women and girls still underrepresented in STEM educational programmes and careers (Blickenstaff, 2005). The National Centre for Science and Engineering Statistics in the USA found that females remain in the minority in STEM related fields compared to males (Henderson-Rosser & Sauers, 2017). Statistics show that as cohorts of learners progress through high school the girls’ interest in STEM subjects decline and so it is not surprising that 82% of engineering degrees in the USA are still earned by men (Henderson-Rosser & Sauers, 2017).

This is no different in Africa. In 2015, a workshop was held by the Network of African Science Academies (NASAC) in Kenya. “NASAC is a consortium of merit-based science academies in Africa and aspires to make the ’voice of science’ heard by policy and decision makers within Africa and worldwide” (NASAC, 2015:42). The focus of the workshop was the importance of mainstreaming gender in Science education. Most of the workshop participants alluded to the low level of inclusion of women in Science, and the prevailing need to achieve gender equity in Science (NASAC, 2015). Thus, the participation of women scientists in the activities and processes of national academies should be increased (NASAC, 2015). Ms Dorothy Ngila, a member of the Academy of Science of South Africa (ASSAf) presented a strong case for the use of practical science education and the role of Inquiry-based Science Education (IBSE) to get the interest of the 'girl-child' at an early stage and, in so doing, realise gender mainstreaming in Science (NASAC, 2015).

In the USA, the achievement gap and underrepresentation by females and minorities in STEM related fields have led educators to consider pedagogical approaches to STEM instruction which will increase learners' deep understanding of STEM subjects. Educators argue that this can be achieved by moving away from traditional pedagogical approaches to Inquiry-based instructional approaches where the learner is at the centre (Henderson-Rosser & Sauers, 2017). Similarly, in Europe the main agenda is to increase innovation, creativity, imagination as well as engagement with Science and Mathematics, hence the interest in a more flexible and productive education system (Bolte, Holbrook & Rauch, 2012). European policy makers realised that this will require a "paradigmatic shift in attitudes and capacities across the entire population, from a passive to active mode of education, based on the capacity for inquiry and democratic participation" (Bolte et al., 2012:12).

### 2.4.2. Global trends in learner participation in Science education

There is a global trend of a decline in learners and students pursuing Science and Science related fields (Garg & Gupta, 2003; George, 2006; Henderson-Rosser & Sauers, 2017; Lyons & Quinn, 2010). A study by Kennedy, Lyons and Quinn (2014) discusses such trends in Australia and indicates trends of declining participation within various Science disciplines. Results of this study, which was done from 1992 to 2012, indicate a decline in participation in Biology, Multidisciplinary Sciences, Physics as well as Chemistry (Kennedy *et al.*, 2014). An earlier national study in Australia, 'Choosing Science', attempted to understand the decline in Science enrolment. It was found that the principal factor was the wider array of options students have when choosing subjects. This also strengthened the influence of three other contributing factors, namely:

- the difficulty many students have in picturing themselves as scientists;
- the decrease in the utility value of key science subjects relative to their difficulty; and
- the failure of school Science to engage a wider range of students (Kennedy *et al.*, 2014).

Many other countries, both developed and developing, such as the UK, USA, India, Nigeria, Qatar and South Africa, report similar trends and concerns (Cleaves, 2005; Garg & Gupta, 2003; Jacob Kola, 2015; Said, 2016; Spaull & Taylor, 2015). Studies in America found that there was a deterioration in learners' attitudes towards Science from middle to high school (George, 2006). This led to high attrition from Science classes from middle to high school which resulted in many learners leaving high school without the necessary background in Science (George, 2006). The National Science Board in the USA found that learners in the USA lack knowledge in Science, Technology, Engineering, and Mathematics (STEM) (Henderson-Rosser & Sauers, 2017). This has caused the USA to focus their recent reform initiatives strongly on STEM which resulted in an 'Educate to Innovate STEM' campaign. This campaign's main focus was to raise average performing secondary school STEM learners' achievement into the category of top performing STEM graduate achievement, and ensuring more opportunities for girls and underrepresented groups (Henderson-Rosser & Sauers, 2017).

### 2.4.3. Trends in global school level Science achievement and South Africa's ranking

Large gaps continue to exist between current and desired levels of educational attainment. Low average scores on standardized tests are evidence of a mediocre quality of schooling (Kodrzycki, 2002). Kodrzycki (2002) argues that the existing educational system has been effective, at most, in moving elementary and middle school students from substandard to basic levels of achievement. However, it has not been effective in raising children's performance to proficient levels, in making progress in high schools, or in closing the gap between white learners and underrepresented groups particularly African-Americans and Hispanics in the USA. In SA mostly black learner groups are still lagging behind (Kodrzycki, 2002; Modisaotsile, 2012; Spaull, 2013).

One way to measure trends in attainment in education, and to make comparisons both internationally and nationally, is through large-scale standardised testing (Foy *et al.*, 2013). Below I compare TIMSS data sets from Grade 8 level Science for the years 2011 and 2015 to highlight some trends in Science scores worldwide. It must be mentioned that for a handful of countries, including SA, it was Grade 9 learners and not their Grade 8 learners who took this Grade 8 level Science test. It must also be noted that not all countries participated in both 2011 and 2015 TIMSS tests. This explains why the lists of countries will differ. Figure 2.9 gives the mean scores of all the participating countries in 2011. In 2011 a total of 45 countries participated in the Science test round. The figure shows that only 40% of the participating schools obtained a mean score above the TIMSS benchmark score of 500 which means only 40% of the participating schools obtained a good score. (See section 2.3.3, Table 2.1) Figure 2.9 also indicates that SA obtained a score way below the benchmark of 500 and had the second lowest score of all the countries in 2011.

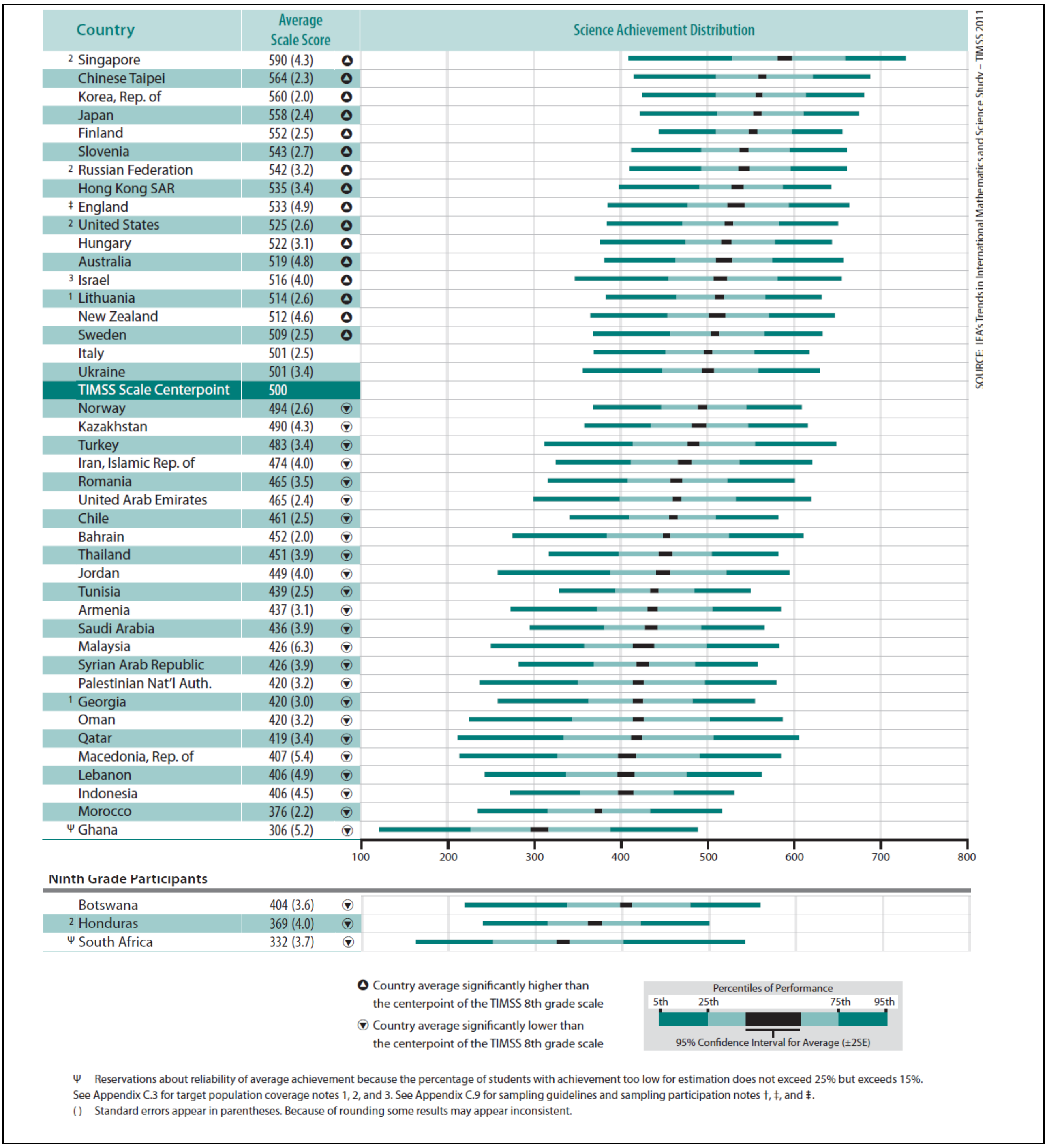



**Figure 2.9: Performance of Grade 8 science learners in TIMSS, 2011 (Source: Martin et al., 2012)**

Figure 2.10 below shows that while only 39 countries took part in the TIMSS test in 2015, 49% of the total number of participating schools in 2015 had a mean score above the TIMSS benchmark score of 500. This was an improvement of 9% from 2011. Even though there has been an overall improvement with more countries, including SA, this time round faring better in 2015 than in 2011, SA was the country that had the lowest score.

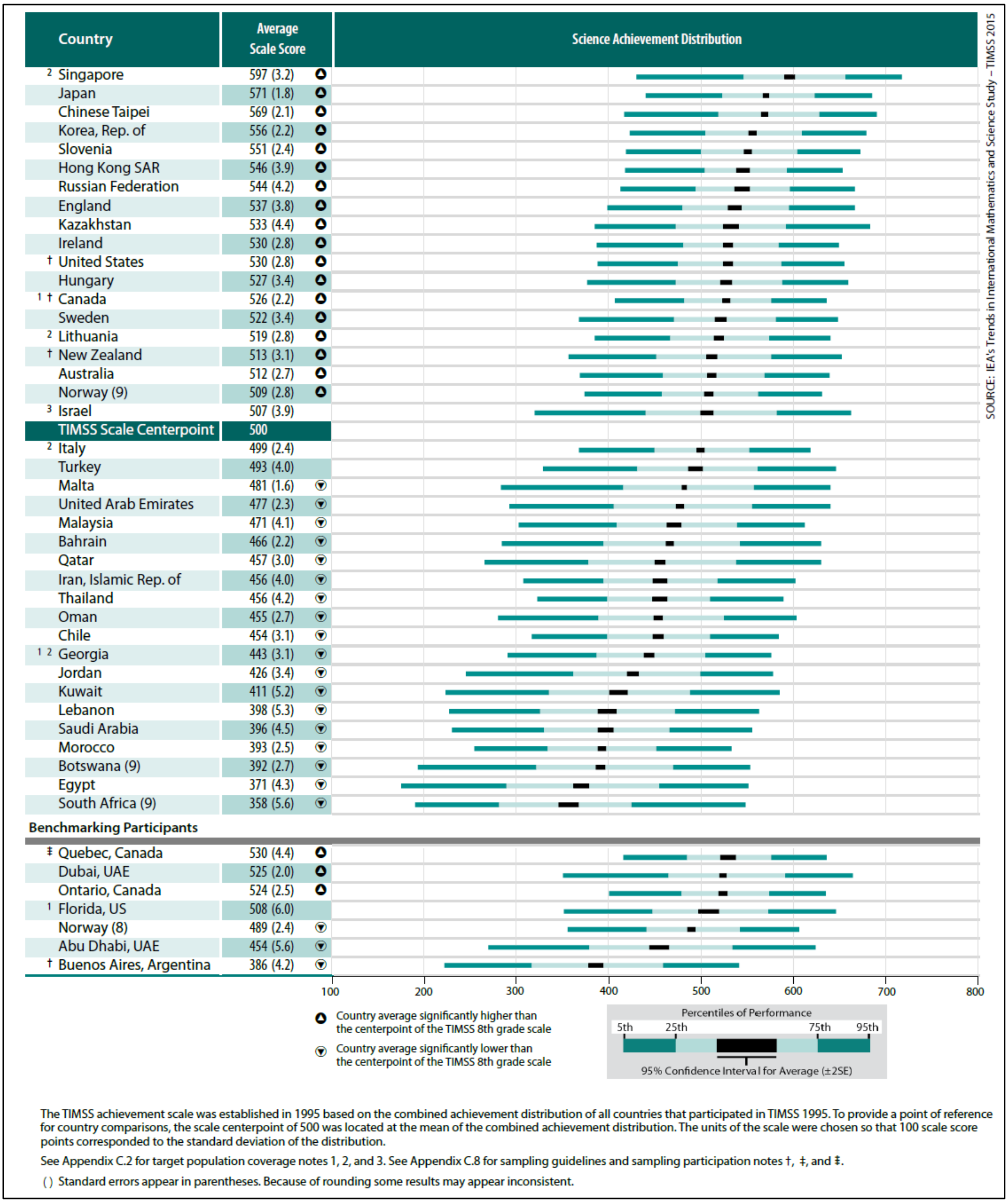



**Figure 2.10: Performance of Grade 8 science learners in TIMSS, 2015 (Source: Martin, Mullis, Foy, & Hooper, 2016)**

Table 2.4 below further summarises the trends from Figures 2.9 and 2.10, per attainment category from 2011 and 2015 by indicating the percentage of the countries per category for each of the years.

I also include the same breakdown by considering only the 34 countries, which participated in both 2011 and 2015.

**Table 2.4: Percentage distribution according to TIMSS attainment categories for years 2011 & 2015**

| Category | TIMSS Score | All TIMSS participating countries in the indicated years | | The 34 participating countries who took part in both TIMSS 2011 & 2015 | |
|---|---|---|---|---|---|
| | | **2011** | **2015** | **2011** | **2015** |
| **TIMSS benchmark score**[2] | 500 | 40 | 49 | 47 | 50 |
| Advanced | 625 and above | None | None | None | None |
| High | 550 - 624 | 11 | 13 | 12 | 15 |
| Intermediate | 500 - 549 | 29 | 36 | 35 | 35 |
| | 475 - 499 | 7 | 10 | 9 | 9 |
| *(Intermediate)* | *(549 – 475)* | *(36)* | *(46)* | *(44)* | *(44)* |
| Low | 400 - 474 | 44 | 26 | 38 | 26 |
| | Below 400 | 9 | 15 | 6 | 15 |

**(Own table; Information obtained from Martin et al., 2012, 2016)**

Considering all score sets, from 2011 as well as 2015, it is evident that over 50% of countries achieved a mean score below the TIMSS benchmark of 500, and that performance levels fall mainly in the intermediate and low categories in both years (Martin, Mullis, Foy, & Stanco, 2012; Provasnik et al., 2012; Reddy et al., 2016). When comparing only the 34 countries that participated in both years, it is clear that in this group more than 50% of the countries obtained a mean score lower than the TIMSS benchmark of 500. Another observation is that for the 34 countries there has been no difference from 2011 to 2015 in the percentage of countries obtaining a score equal to or higher than the benchmark of 500. The majority of the 34 countries achieved a score in the low and intermediate categories. Further comparison of 2011 and 2015 raw mean scores does indicate some good news, which is an overall average increase in achievement by countries, however the mean scores still remain low. What is concerning is the fact that the percentage of participating countries obtaining a mean score below the minimum cut off mark of the low category has more than doubled from 2011 to 2015. From the table one can also see that none of the groups, neither in 2011 nor in 2015 have had countries attaining the advanced category. This is an indication to me that there is still much work required to lift the

[2] The benchmark score includes all schools who obtained a score of 500 and above, i.e. adding advanced, high and part of intermediate scores. These scores are highlighted in blue in the table.

level of attainment in Science worldwide. The TIMMS results make a case to reconsider the practices used in Science teaching on a global level, and, when considering the results of SA as displayed in Figures 2.9 and 2.10, especially so in schools in SA.

Even though results for learner performance in both Science and Mathematics remain poor, data does show some upward trend in many countries (Juan, Hannan & Namome, 2018; Klieme, 2016; Reddy *et al.*, 2016). As early as 1999, TIMSS results identified that the countries outperforming the USA were Japan, Australia, the Netherlands and the Czech Republic. In an attempt to investigate the factors that influence the performance of learners in Science, researchers explored the teaching methods and approaches used by countries that outperformed the USA in the TIMSS in 1999. The study made an interesting finding that the common thread in the approaches used by these countries, except for the Netherlands, is a strong focus on learner engagement through practical activities and engagement with peers (Roth & Garnier, 2007). One has to note further that these countries linked the activities to science ideas and concept building and did not perform the activities as loose standing, interesting classroom discoveries (Roth & Garnier, 2007). These findings build a strong case for the use of a more learner-centred approach to address the declining performance trends in Science.

### 2.4.4. Trends in South African school level Science achievement

In Section 2.3, I discussed education in SA and factors influencing it, in a more general sense. With my study situated within the secondary school, Science classroom I now take a closer look at trends in Science education in SA. Analysis of TIMSS data also display trends of inequality according to geographic location in SA. Figure 2.4 indicates the 2015 TIMSS mean scores per province in SA in Science and Mathematics for Grade 9 learners (Reddy *et al.*, 2016).

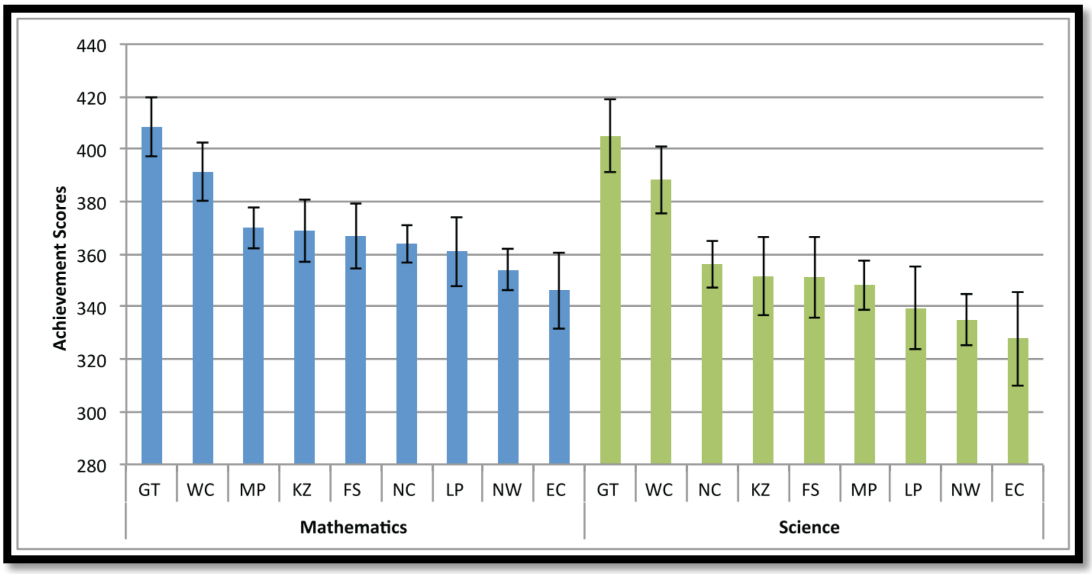



**Figure 2.11: TIMSS 2015 provincial Science and Mathematics performance (Source: V Reddy et al., 2016)**

The results show that not one of the provinces reached a mean score equal to or above the TIMSS benchmark score of 500, which indicates an overall low performance. Furthermore, it also displays a concerning pattern of large differences in mean scores from province to province with the more rural provinces like the Eastern Cape (EC), Limpopo (LP) faring worse than the more urbanised provinces Gauteng (GT), Western Cape (WC) and Kwazulu-Natal (KN).

I have already indicated that by looking at the 2015 Grade 8 TIMSS Science test scores there was an increase across all countries, including SA, since 2011. Also to be noted is that SA displayed the largest degree of increase from an average of 332 in 2011 to 358 in 2015. However, SA still remains at the bottom of the ranking even when compared to countries of similar standing. This is reflected in Figure 2.12.

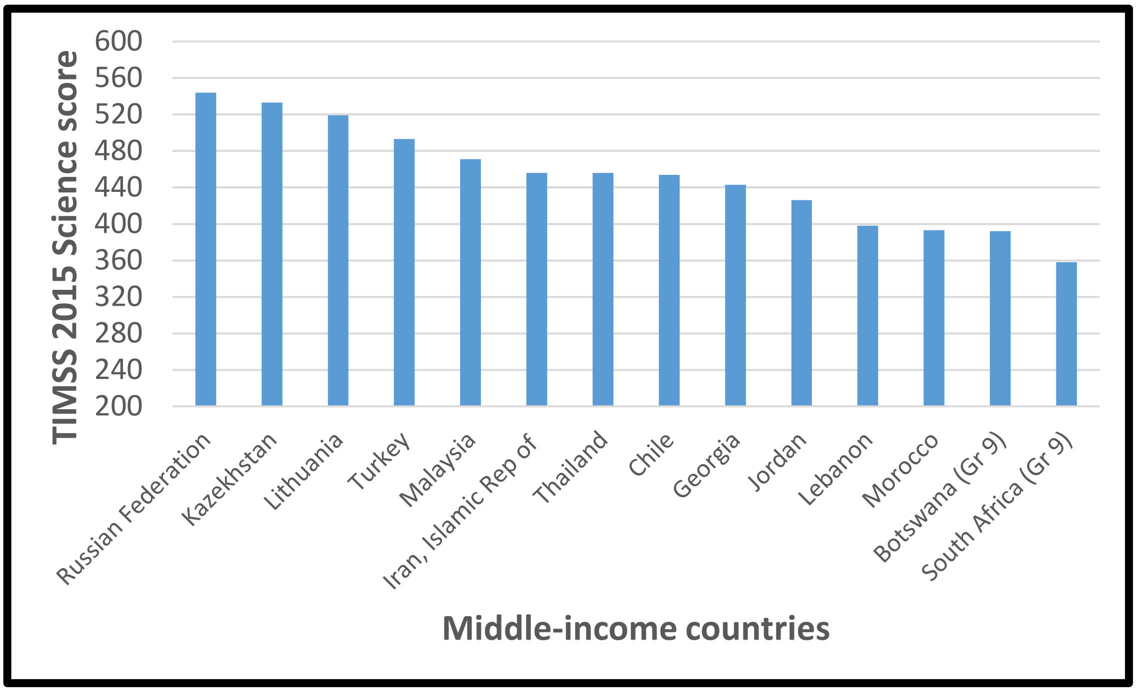



**Figure 2.12: TIMSS 2015 Average Grade 8 Science test scores (Source: Martin et al., 2016)**

Figure 2.12 displays results of the TIMSS 2015 average Grade 8[3] Science test scores for the middle-income countries only, and how SA compares. From this figure, one can clearly see that SA is at the bottom of the list with the lowest average Science test score.

Another example of South African learners' performance in Physical Sciences is the NSC data from

[3] Grade 9 learners from South Africa and Botswana wrote the Grade 8 level TIMSS Science tests in 2015, whereas the candidates from all other countries where Grade 8 learners

2014 to 2017 as displayed in Table 2.5. I use the average over these years to show the level of participation and performance in Physical Sciences over these years, and include the data per year to display the variations across the years.

**Table 2.5: Physical Science NSC candidate statistics, 2014 - 2017**

| Year | Total number of candidates who wrote NSC Exam | No. candidates who wrote NSC Physical Science (PS) | No. achieved at 30% and above in PS | No. achieved at 40% and above in PS | % of Total candidates who wrote PS | % of PS candidates achieved at 30% and above | % of PS candidates achieved at 40% and above | % of total candidates who achieved PS at 40% and above |
|---|---|---|---|---|---|---|---|---|
| 2014 | 537 570 | 167 997 | 103 348 | 62 032 | 31.3 | 61.5 | 36.9 | 11.5 |
| 2015 | 652 808 | 193 189 | 113 121 | 69 699 | 29.6 | 58.6 | 36.1 | 10.7 |
| 2016 | 627 918 | 192 710 | 119 467 | 76 068 | 30.7 | 62.0 | 39.5 | 12.1 |
| 2017 | 558 189 | 179 561 | 116 862 | 75 736 | 32.2 | 65.1 | 42.2 | 13.6 |
| **Average** | **594 121** | **179 561** | **114 992** | **70 884** | **30.95** | **61.8** | **38.7** | **11.98** |

**(Source: Own table; Information obtained from DBE, 2017b)**

The data indicates that over a four-year period from 2014 to 2017, an average of only 31% of the total NSC candidates wrote the Physical Sciences exam. Furthermore, even though there is an average of 62% of learners who attained the pass mark of 30% for the exam, an average of only 38% of the Physical Sciences candidates achieved a mark of 40% and more. A mark of 40% or more is significant in terms of access to and success at a tertiary institution. When calculating the average number of candidates who passed Physical Sciences with a score of at least 40% and more as a proportion of the total number of NSC candidates, a very low average percentage of 12% is obtained.

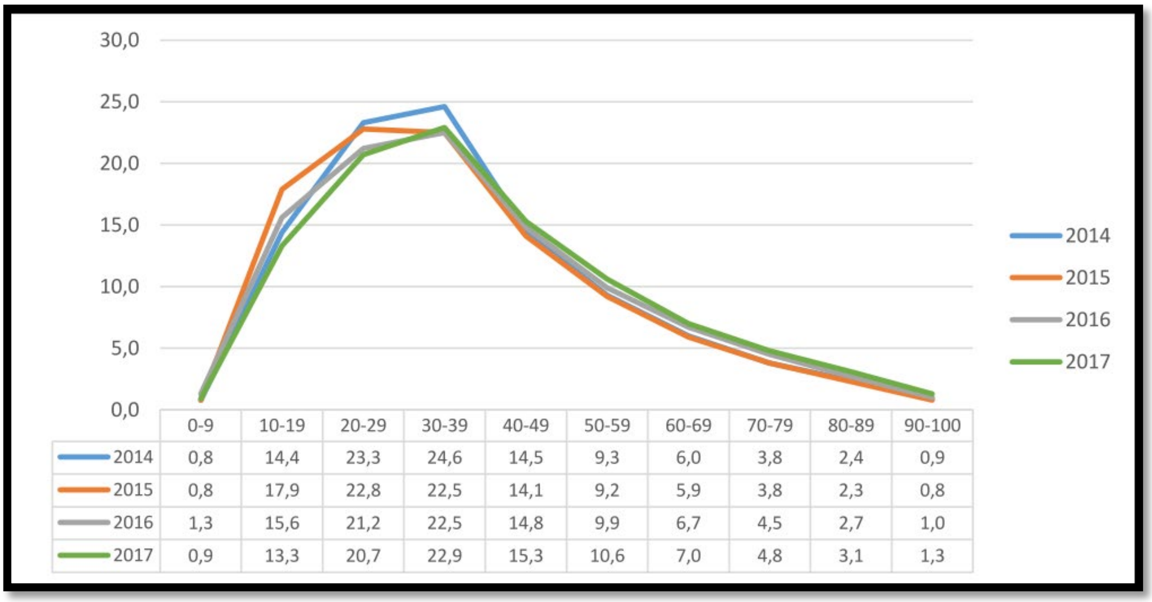



**Figure 2.13: Performance distribution curves in Physical Sciences (percentage), 2014-2017**
**(Source: DBE, 2017b)**

The graph in Figure 2.13 displays the performance distribution curves in the Physical Sciences NSC results over the same four year period. The first observation is that the curves are identical for every year over this period. It clearly shows that the largest percentage of learners reached a mark below 40%, and indicates that year after year a low number of learners, only about 5%, qualify adequately enough to attain entry requirements to continue with further studies in Science at tertiary level.

These trends are concerning to say the least. One of the primary objectives of the DBE is to improve the quality of STEM education by providing learner and teacher support to STEM focussed schools so that the matric Mathematics and Science passes will increase (DBE, 2010). It is believed that schools can and should play a role in influencing learners' attitudes positively to ensure more scientifically literate and engaged citizens in society (HSRC, 2012).

Data from the 2013 South African Social Attitudes Survey (SASAS) and the 2011 SA TIMSS results were used to examine South Africans' attitudes towards Science. An infographic summarised the following findings:

Beliefs about school science of the general public:

- 41% - Science learnt at school was not useful in daily life;
- 30% - Science learnt at school was not useful in jobs; and
- 23% - Studying Science will not necessarily get one a good job.

Views of Grade 9 learners in 2011

- 41% Enjoyed Science;
- 57% Valued Science;
- 17% Felt confident in their ability in Science; and
- Only 21% of those who enjoyed Science read Science outside of school. (HSRC, 2012).

The TIMSS-SA 2015 report mentions the following as to why it is important for learners in South Africa to do Science and Mathematics at school:

- Training in these subjects is rewarded in the work environment;
- The demand for low-skill labour is declining;
- It can improve the country's global competitiveness;
- Doing these subjects has benefits beyond employment opportunities as it improves critical thinking and problem-solving abilities (Zuze *et al.*, 2017).

The above motivates how taking Science and Mathematics will not only benefit the individual, but also address the needs of the country. These trends all point towards the need to continue with educational reform in Science. The Boston conference agreed that emphasis should firstly be on how to improve the performance of the average student, secondly on how to raise the educational attainment of low-income and underrepresented learner groups, and thirdly on greater attention on developing high-end talent (Kodrzycki, 2002).

In terms of education, the 2015 analysis of the TIMSS results points towards the importance of focussing on the enjoyment of Science, learners having a positive attitude towards Science and building self confidence in learners to ensure improved achievement in Science (Juan *et al.*, 2018; Zuze *et al.*, 2017). This will strengthen the learner's ability to learn Science and so raise learner performance in Science (Juan, Reddy & Hannan, 2014). This is achieved not only through access to resources. In countries with similar challenges as experienced in South Africa, a shift in the pedagogical approach to teaching Science, largely from teacher-centred to learner-centred, has led to better outcomes. A pedagogical shift like this requires, firstly, a paradigm shift on the side of the teacher, as the teacher is the one who sets the educational scene in the classroom. This requires ongoing intensive learning opportunities, accompanied by constant support, for teachers.

## 2.5. The South African teacher's current experience in education

### 2.5.1. Effect of the South African educational milieu

In SA, poverty, lack of resources, poor discipline in schools, and having to deal with backlogs in infrastructure, to mention but a few challenges, have a big influence on teachers. These societal factors do not only impede teaching and learning on a practical level, but also affect the teacher personally. A study done by Kunter and others argue that socio-emotional and motivational characteristics play a large role in building supportive teacher-learner relationships which are vital for effective classroom management, and which foster learners' learning (Kunter *et al.*, 2013).

According to South African education policy the teacher-learner ratio, should be 40:1. However, statistics indicate that in many classes across SA this is not the case. Classes of over 50 and even up to 80 learners are a common occurrence (Chisholm, 2005c; Maringe *et al.*, 2015; Onwu & Stoffels, 2005). This is the case, especially for schools in poorer communities, where teachers have to contend with large numbers of learners in their classes.

Teaching in environments fraught with constant daily challenges can negatively affect teachers' morale and their belief in their own ability which in turn impacts on the quality of teaching and thus hampers effective education.

### 2.5.2. Effect of curriculum changes

In education, policy changes often lead to curriculum changes. This means that teachers have to adjust what they teach as well as how they teach, accordingly. Even though changes to curriculum are piloted before they are accepted and implemented, the feedback from such pilots is often not discussed with significant role players, namely teachers as well as higher education institutions who train teachers (Aksit, 2007). Hence, a situation arises where the curriculum change pilot is immediately followed by implementation in schools (Aksit, 2007). This situation can lead to failure, as often teachers are not adequately prepared, which results in the teachers feeling insecure and inadequate.

An example is Outcomes-based Education (OBE) discussed earlier. In short, the OBE approach implied that "the teacher would disappear in a classroom plan where learners and learning became the central focus of policy change under the new curriculum" (Jansen, 2001:243). Ideas like the teacher becoming the 'guide on the side', and facilitating the learner who now is taking charge of his or her own learning, further implied that the teacher had to give up their centre position and allow teaching and content to make way for learning and competencies (Jansen, 2001). Needless to say, this has led to much uncertainty and feelings of incompetence among teachers. However, with the implementation of CAPS, which has specific content guidance, a level of structure was restored.

### 2.5.3. Effect of the level of teacher qualifications

Even though statistics show that SA has a high rate of qualified teachers, and teachers also view themselves as competent and effective, many teachers are unhappy in their profession (Reddy et al., 2015). This problem is further compounded by the fact that between 18 000 and 22 000 teachers leave the teaching profession in SA annually while only 6 000 to 10 000 newly qualified teachers graduate annually (Modisaotsile, 2012). Many of the newly qualified teachers opt against teaching in SA due to the challenges faced by education currently (Modisaotsile, 2012). Apart from overcrowded and poorly equipped schools, it is frequently found teachers are either underqualified or even unqualified for the positions that they hold (Modisaotsile, 2012). Whilst statistics show that the majority of South African teachers currently in the profession are qualified teachers, a further dissection reveals that many teachers have a low level of qualification (Spaull, 2013). This shows that there is an urgent need for more highly qualified teachers.

It is not unusual that teachers are teaching a subject which they were not trained in. It must be borne in mind that many teachers were trained to teach a particular subject, but are then often required to teach another subject. Since Mathematics and Science teachers are scarce, teachers trained in subjects other than Mathematics and Science are called upon and placed in positions at schools where they are requested to teach these critical subjects. This means that a number of teachers in Science posts are unqualified to teach Science (Ramnarain, 2016; Rogan & Gray, 1999). Subsequently, this has led to many teachers who currently are in Science posts with a weak content knowledge in the subject, which makes it difficult for these teachers to interpret curricula and to be innovative around teaching Science (Lelliott, Mwakapenda, Doidge, du Plessis, Mhlolo, Msimanga, Mundalamo, Nakedi & Bowie, 2009). Once again, poorer and rural communities are the groups that are mostly affected by this phenomenon. The teacher is therefore a qualified teacher on paper, but often not qualified to teach Mathematics and Science. This impacts greatly on the quality of teaching in Mathematics and Science classrooms.

In the light of what is happening in education in SA today, with specific reference to the state of education and the profile of its teachers, it is necessary to put a strong focus on teacher training (Modisaotsile, 2012). After the TIMSS 2011 analysis, recommendations were made for teachers to evaluate their professional knowledge and pedagogical practices and for an improvement in teacher subject knowledge and pedagogy (Reddy et al., 2015). This calls for much needed in-service teacher training in especially Mathematics and Science. Figure 2.14 shows the time spent in hours per year in 2011 and 2017, by teachers in SA on professional development. In most cases it does show an increase from 2011 to 2017; however, we again see a difference between lower quintile and higher quintile schools.

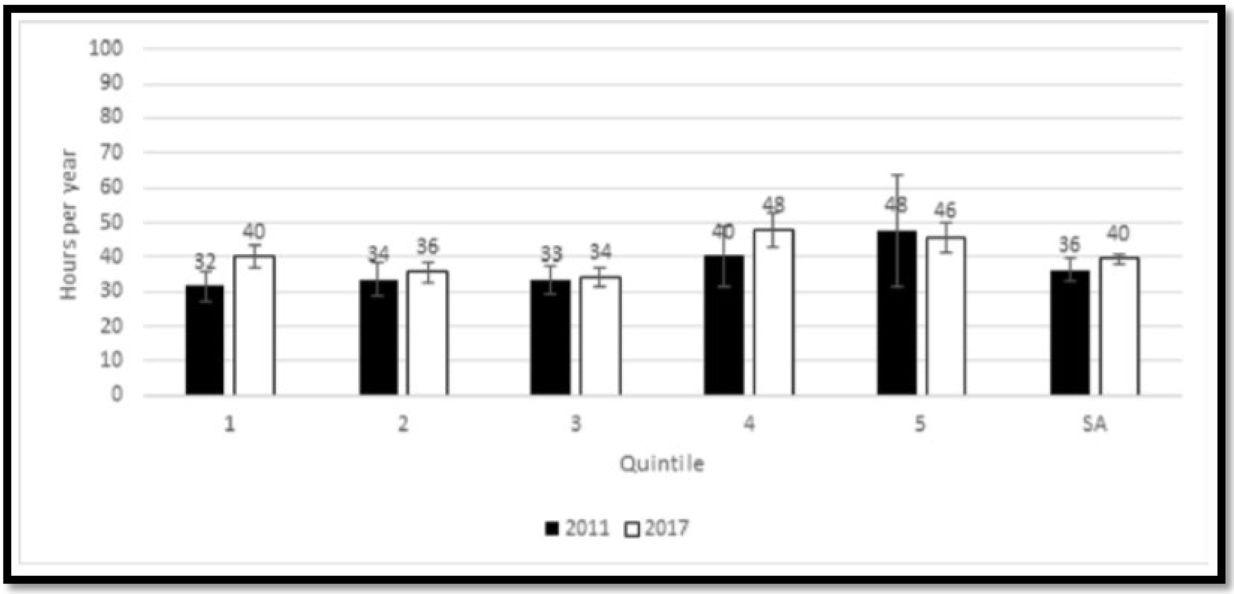



**Figure 2.14: Average hours spent by teachers on TPL per school quintile, 2011 and 2017 (Source: DBE, 2018)**

Table 2.6 indicates a breakdown of the ways in which teacher professional learning (TPL) opportunities attended by teachers were initiated. The table shows the number of hours spent on TPL in 2017 in the categories of how the learning opportunity was initiated. It is encouraging to see that in all quintiles the 'self-initiated' category is the highest. This is a good pattern as it indicates that teachers are willing to give up personal time to learn more.

**Table 2.6: Categories of TPL initiation & time spent, in hours, by teachers on TPL in 2017**

| Quintile | Self-initiated | School-initiated | Externally initiated - Departmental | Externally initiated - Professional associations | Externally initiated - Other | Total |
|---|---|---|---|---|---|---|
| 1 | 15.3 | 11.0 | 11.8 | 3.1 | 2.2 | 43.4 |
| 2 | 12.4 | 9.0 | 10.1 | 2.5 | 2.3 | 36.3 |
| 3 | 10.8 | 9.4 | 9.8 | 2.6 | 2.9 | 35.5 |
| 4 | 19.9 | 14.4 | 11.0 | 3.0 | 3.4 | 51.7 |
| 5 | 23.0 | 11.4 | 8.0 | 2.6 | 2.9 | 47.9 |
| SA | 15.4 | 10.6 | 10.1 | 2.8 | 2.7 | 41.6 |

**(Source: DBE, 2018)**

Regular TPL will not only give the teacher an opportunity to improve his or her content knowledge, but also to learn of new pedagogical approaches. Teachers with improved pedagogical content knowledge (PCK) is the key to more effective teaching and learning (Kunter *et al.*, 2013). This will lead to quality education, which ultimately leads to success for learners, as well as schools. Spaull echoes this when he says that "(t)he quality of a country's teachers is intimately related with the quality of its education system" (Spaull, 2013:24).

### 2.5.4. From teacher-centred to learner-centred

Science education should enhance the capacity of citizens, particularly in developing countries, to find ways to address developmental challenges in ways that are environmentally sound, socially equitable, and economically affordable (Kyle, 1999). This requires qualified scientists who are able to think out of the box, reason effectively, and strategise. A passive approach to Science teaching is not the most effective way to achieve this. Therefore, Science education has undergone significant change in recent years with the aim to combat the declining trend in interest. Over the last decades the field of Science teaching has made a concerted effort to move away from passive textbook style instruction to make way for a more active, practical approach (Villani, Pacca & Valadares, 2012a). Another feature in Science education renewal has been the creation of Science centres. These have been used to train Science teachers as well as for the promotion of innovation in Science education (Villani et al., 2012a). Traditionally educational reform has placed most of the focus on what the teacher does in the class and not on the learner. However, the breakthrough of cognitivist and constructivist approaches to learning gradually shifted the focus of educational reforms from teaching to learning (Sahlberg, 2011).

It should be borne in mind that the times, the learners, the needs of learners and society have changed. We live and work in a world, which operates in a completely different manner to 30 years ago when many of the current teachers were learners themselves. Technology has made huge strides and continues to develop at a tremendous rate. While in the past the teacher was the main source of information the role of the teacher has shifted from providing information to equipping learners with tools to gather and process information. All of the above are indicators that educators cannot continue to operate as before. It is vital that educators adjust to these changes and new demands. In order to bring about changes and improvement in educational performance a shift from teacher-centred to learner-centred teaching is crucial. In many countries changes in the area of curriculum, with the intention of curriculum reform, already include shifting from a teacher-centred to a learner-centred didactic model (Aksit, 2007:133).

Teachers are the main driving force in what happens in the classroom. Yet, teachers often approach teaching in the way they have been taught. A teacher's background and own schooling experience play a large role in shaping the teacher he/she eventually becomes and so his/her teaching (Onwu & Stoffels, 2005). Teachers cannot be expected to independently unlearn teaching habits or gain PCK in a subject they have not been qualified in. In order to improve practice, many ingrained ways of thinking and doing of teachers need to be undone. The shift from a teacher-centred to a learner-centred approach therefore demands continuous TPL. What is required is rigorous guidance, regular collaboration for the sharing of ideas and mentoring. This can be provided through TPL opportunities.

Educational reform necessitates leadership, personal transformation and collaboration amongst teachers (Aksit, 2007). Whilst the challenge for educational reform in developed countries is to improve the quality of education, developing countries, including SA, have the challenge of both making up huge historical backlogs and providing quality education. Essential to the educational transformation process is moving to a system of informed professional judgement, whereby teachers have access to high-quality data on student performance and teaching practices, and where their teaching is driven by what these data tell them. Under such a system, the process of teaching would be re-engineered, with time reallocated toward activities such as professional growth, planning, and mentoring (Kodrzycki, 2002). Instead of continuing to focus on individual school performance, reform should concentrate on systemic improvement in the education system (Kodrzycki, 2002).

## 2.6. Conclusion

In this chapter I could point out how the need for educational reform is guided by changes in society and by the needs of society. I discussed how in SA ongoing educational reform over the past twenty plus years has been used to redress educational inequalities from the past and how efforts have been made to provide education for all.

Besides the plight of gender inequality, low participation and low performance in Science the world over, the stark reality in SA was highlighted that showed the ongoing societal inequalities and that the good efforts and significant change in the South African educational realm, has not yet brought about the desired outcomes. This coupled with the statistical evidence of Science performance of South African learners, indicates the need for and benefits that change in the Science classroom could hold.

Teachers remain a very important cog in the machine of education and the drivers of educational reform in the classroom. Teachers need to translate the curriculum and be the link between policy and the learner. Teachers are the ones that shape the teaching and learning environment in the classroom. This requires that teachers carry an extensive body of knowledge in the subject they teach as well as having good insight into various pedagogical options.

In the next chapter, I introduce a teaching and learning methodology or approach, which is learner centred and could possibly be a tool to bring about a desired change within Science education. I also propose how to guide teachers in this new approach.

# Chapter 3: **INQUIRY-BASED EDUCATION WITHIN THE CONTEXT OF LEARNING THEORY**

## 3.1. Introduction

From the evidence provided in the previous chapter there is no doubt that continuous reform is needed to bring about a positive change in the performance of learners in Science. The prevailing educational, social and economic changes and challenges require a shift away from what is currently happening in classrooms where the transmission mode continues to be the order of the day.

I, therefore, devote this chapter to consider Inquiry-based education (IBE), an alternative way to teaching, within the context of learning theory. I start by considering various learning theories and how they relate to teaching and learning Science. I will discuss the learning theories of Dewey, Piaget, Ausubel and Vygotsky as the main proponents of constructivism, which forms the basis of IBE. I then explore IBE by considering what would be required to make the shift away from the transmission mode of teaching in order to adopt this alternative teaching and learning approach.

Thereafter, I consider IBE, more specifically inquiry-based science education (IBSE), in detail, by looking at how it is promoted in various educational systems. I also present examples from around the globe of implementation of IBSE before I consider IBSE in South African education. Features of IBSE and requirements to implement IBSE effectively with the emphasis on teacher learning programmes are presented thereafter.

## 3.2. Transmission: The conventional way of teaching and learning

One of the challenges faced by teachers in schools today are disinterested learners. I would argue that this challenge is exacerbated by the methods used by teachers in the transmission approach to teaching and learning. In this approach, which can also be described as a teacher-centred approach, teachers use teaching methods where learners are told facts which they have to believe as the truth and are not allowed to question. The majority of the practices followed when using the transmission approach stem mainly from two theories of learning and development, namely behaviourism and maturationism, which posit that learners should gain access to information in order to alter behaviour, and they should do so in stages applicable to their level of maturity (Fosnot & Perry, 2005).

Classical behaviourism, proposed by, amongst others, Pavlov, Thorndike, Watson and Skinner, considers what can be seen, namely the behaviour and the modification of behaviour of the learner, but it ignores the hidden mental processes (Pritchard, 2009). This theory focuses on the effect of reinforcement, practice and external motivation on a network of associations and learned behaviour (Fosnot & Perry, 2005; Scheurman, 1998). Classical behaviourist theory holds implications for changing behaviour and not necessarily for a cognitive change (Brown, 1994; Fosnot & Perry, 2005). The prevalent traditional educational practices, focusing on mastery of skills or knowledge transfer, stem from behaviourist psychology (Fosnot & Perry, 2005). Educators who use a classical behaviourist framework organise the content of a subject into parts and arrange them in a hierarchical order (Scheurman, 1998). They believe that activities such as observing, listening, experiencing and practising will lead to learning and development. Learners are viewed as passive, in need of external motivation and affected by reinforcement (Scheurman, 1998). The classical behaviourists see progress as linear and learners are assessed to determine where they fall on this linear scale (Fosnot & Perry, 2005). Even though former proponents of transfer, like Thorndike, have renounced this approach, elements of transfer are to a large extent still present in the schooling system (Brown, 1994; Levy, Lameras, Mckinney & Ford, 2011).

Psychologists like Granville Stanley Hall, Gesell, James, Hull and McDougall are the leading figures of the developmental theory, maturation (White, 1968). Educators working within the framework of maturationism regard conceptual knowledge as dependent on the age and developmental stage of a learner with age being regarded as a predictor of behaviour (Fosnot & Perry, 2005). Learners are viewed as meaning-makers who interpret experience through cognitive structures as they mature, and therefore educators following this theory will prepare an environment which is developmentally appropriate (Brown, 1994). Maturationism claims that the stage of development determines how and what one knows (Fosnot & Perry, 2005). In maturationism, as with behaviourism, the goal of instruction is the acquisition of skills according to developmental stages. Within the framework of maturation the curriculum is analysed for its cognitive requirements on learners and matched to the learner's stage of development, while assessment of learners is according to developmental milestones (Fosnot & Perry, 2005).

Classical behaviourism and maturationism are the main driving forces behind the transmission mode of teaching. The transmission mode is characterised largely as a teacher-centred approach which holds the perception that the teacher is the expert in the field (Smyth, 2003). Learners, on the other hand, are seen as empty vessels that should be filled with knowledge (Pardjono, 2002). The processes of teaching in this manner mostly consist of the teacher transferring knowledge to learners by telling them or handing out material while learners are passive (Carney, 2008; Dewey, 1933; Lourenço, 2012). Learners are discouraged from questioning and are required to accept what they are told. They are rarely given an opportunity to think for themselves, probe or construct knowledge. According to Piaget, the transmission approach is one which promotes memory or retention rather than developing intelligence and which cultivates individuals who will not challenge conventional truths compared to individuals who are creative and critical (Lourenço, 2012). Instead of allowing the learner to question facts or to reshape or remodel facts and their presentation, the transfer of facts is usually followed by learners engaging in activities which will assist them to memorise the facts, practice procedures and reproduce them in a test or exam. Learners' level of progress and attainment will then be determined by how well they regurgitate information and facts (Pritchard, 2009; Smyth, 2003). The transmission approach is not without value, yet its strong focus on the transfer of information makes the exclusive use of this educational approach very limiting as it does not provide sufficient opportunity to develop a variety of skills like problem solving and communication, nor does it challenge learners to think or reason. Taking into account the relative ease with which information in this day and age can be accessed, this type of learning becomes insufficient as it no longer adequately prepares learners for the future. Education should focus on teaching learners to identify problems, followed by how to access and use information to solve those problems.

The transmission mode has a critical limiting effect in Science classes, which include experiential and practical components. Science lessons which are embedded within the context of the transmission mode do not give learners the opportunity to come up with their own investigative processes or solutions to problems. In such Science classes, learners are expected to follow the investigative processes and procedures dictated to them by the teacher (Levy *et al.*, 2011; Munby, Cunningham & Lock, 2000; Ramnarain, 2014). One finds that the scope of experiential learning has been reduced to where the learners are given a 'recipe' to follow in order to do an experiment. Learners are then expected to make observations which are mostly obvious. Only thereafter learners may be asked to put on their thinking caps to draw conclusions. This undemanding approach to Science investigation and learning, which has a strong procedural slant, hampers the development of thinking processes and understanding, and hinders deep learning (Roth & Garnier, 2007). All of the above leads to learners becoming disinterested as they are simply recipients of information through activities such as long presentations, too much writing and very little practical work which is often presented in a routine-like manner (Shamsudin, Abdullah & Yaamat, 2013).

Current education policies, including assessment systems, are also driving forces behind applying the transmission mode. This is because of the strong emphasis on recall of discrete facts which demands wide topical coverage, but which leads to less demanding teaching strategies (Minner *et al.*, 2010). Teaching is therefore focussed on factual level information and verification laboratory work, rather than investigative activities which provide for learner responsibility and decision-making opportunities (Minner *et al.*, 2010).

Another factor which plays a significant role in the predominance of the transmission mode is teachers' own learning experiences when they themselves were learners. As a teacher, one is often inclined to be guided in one's pedagogical thinking and to approach one's practice in a way that is similar to what has been modelled to you (Smyth, 2003). In most cases, the transmission mode is the way teachers had been taught when they were at school. Even in many current teacher training courses the transmission mode prevails. The combination of these factors leads to the transmission mode being the primary approach that teachers are conversant with, resulting in it strongly guiding their practice (Munby *et al.*, 2000; Seimears, Graves, Schroyer & Staver, 2012; Smyth, 2003).

To change deep seated teaching beliefs and habits is not easy. It requires both emotional and intellectual engagement which will lead to transformation through changed conception (Smyth, 2003). It is for this reason that practice-based continuous teacher professional learning (TPL) takes on such importance to ensure educational reform.

## 3.3. Constructivism as an alternative mode of learning

As IBE is embedded within the learning theory of constructivism, this learning theory and its main proponents are discussed in some detail below.

### 3.3.1. Introduction to constructivism

Brown (1994) describes the dawn of constructivism as a learning theory as a cognitive revolution. According to this theory leaners are no longer regarded as passive recipients of information but as individuals who actively construct knowledge. Constructivism developed from the work of John Dewey, Jean Piaget and Lev Vygotsky (Fosnot & Perry, 2005). Unlike maturationism, which suggests that development determines what and how one knows, constructivism defines development as a process of learning (Fosnot & Perry, 2005; Ültanır, 2012). More so, constructivism is based on an understanding of the mental processes involved, and unlike behaviourism which is focused on just acquiring of knowledge and skills (Dewey, 1933; Pritchard, 2009). Theorists like Dewey, Piaget, Vygotsky and Ausubel each hold their own views of learning. Therefore broader constructivist theory has more than one interpretation of knowledge and learning, with learning being perceived as complex and non-linear (Fosnot & Perry, 2005). I now proceed to discuss some of the main proponents of constructivism. Thereafter I present the main ideas about the constructivist way of learning and link them to IBE.

### 3.3.2. Dewey's progressive education

Almost 100 years ago Dewey first communicated his concepts of how people think (Dewey, 1933). These concepts include mode of thought and belief, imagination and reflection (Rodgers, 2002). Dewey's integrated social theory of education evolved from his work in psychology and his work on intelligence and pursued what would be best for children in educational endeavours. Dewey's constructivist approach focusses on learning opportunities and conditions which would allow learners to follow their own objectives as guided by their experiences, interests and concerns (Hyslop-Margison & Strobel, 2007). For Dewey the main aim was that learners must learn how to learn (Weber, 2008). This theory can benefit every individual child or person, and does not focus on subject matter, but on the process of inquiry. According to Dewey, knowledge is a form of activity, and so knowledge, truth and meaning are the consequences of actions. When considering knowledge and education, learners are seen not as spectators but as actors (Weber, 2008).

The term 'active learning' was coined by Dewey (Dewey, 1933; Hyslop-Margison & Strobel, 2007). With active learning, Dewey implied that the learner does not passively receive and accept knowledge, but that s/he will learn by engaging with his or her environment whilst doing something (Hein, 1991). Dewey's model places the teacher in the role of facilitator who helps learners to design their own learning experiences according to the learners' own objectives and priorities (Hyslop-Margison & Strobel, 2007). Dewey called this process of learning 'inquiry', and saw this process of constructing knowledge as one of constant development and growth (Weber, 2008).

### 3.3.3. Piaget's scheme theory

Together with Dewey, Piaget is seen as one of the main proponents who developed this specific interpretation of constructivism (Ültanır, 2012). Piaget's theoretical model of cognitive development is also known as scheme theory (Ültanır, 2012). Piaget refers to already held knowledge and concepts which learners have as schemes (Cakir, 2008; Pritchard, 2003; Ültanır, 2012). Von Glasersfeld (2005) shares Piaget's view that people only reconsider concepts and constructs and accept new ones due to an event which disturbs already held concepts. This points to the importance of prior knowledge (Von Glasersfeld, 2005).

When learners encounter new knowledge or information that fits their prior knowledge or scheme, such knowledge or information will be taken up into this already held 'bank of knowledge' (Cakir, 2008; Pritchard, 2009). This is known as assimilation. If the new knowledge does not fit prior knowledge nor makes sense to the learner, disequilibrium results (Cakir, 2008). Piaget describes disequilibrium as a process whereby existing cognitive structures and prior knowledge are disturbed, resulting in cognitive conflict. The learner will then undergo a process whereby new cognitive structures and schemes are developed until a point of equilibrium is reached, i.e. until balance is restored to the cognitive structure (Cakir, 2008). Piaget sees this process as the process of learning and calls reaching this point of equilibrium 'accommodation' (Cakir, 2008; Pardjono, 2002; Pritchard, 2009). According to Piaget, people will understand information that fits their current view of the world (Seimears *et al.*, 2012:266). Therefore, inundating learners with information that holds no relevance to them, often the case when following the transmission mode of teaching and learning, is like throwing puffs of smoke at them and hoping they would catch it.

Another theory of learning, one which is held by Piaget, is the developmental stage theory (Pritchard, 2009). This significantly resembles the concept of maturation as it suggests that learners grasp concepts of increasing complexity as they mature biologically, and therefore only concepts applicable to the stage of development should be introduced to learners (Pritchard, 2009). However, while levels of biological maturity, and so developmental stages, can be associated with a particular age, Piaget's stage development theory, is not restricted to age groups as maturationism does (Pritchard, 2009).

For Piaget, knowledge arises from actions and the learner's reflection on these actions (Von Glasersfeld, 2005). This ties in with another way of interpreting Piaget's theory of learning, namely, learning by assimilation and accommodation (Pardjono, 2002). Piaget states that children learn through being active and operating as lone scientists. Piaget does not see knowledge as a state, but as a process (Confrey, 1990). If a child is shown how to do something rather than being encouraged to discover it for themselves, understanding may actually be inhibited. Hence, the role of the teacher shifts to that of facilitator who is also the provider of 'artefacts' needed for the child to work with and learn from (Pardjono, 2002; Ültanır, 2012).

### 3.3.4. Ausubel's meaningful learning

Ausubel's views on learning are embedded in the theoretical framework of meaningful learning (Villani *et al.*, 2012). This framework strongly rejects rote learning, and regards learning as depending largely on differentiation and integration (Cakir, 2008; Confrey, 1990). For Ausubel, the presence of prior knowledge is a most important prerequisite for learning. This is where Ausubel's theory strongly corresponds with that of Piaget. He describes prior knowledge or meaningful information as networks of connected facts or concepts, which he called 'schemata' (Cakir, 2008). According to Ausubel cognitive development is stage independent, and happens within these existing schemata. This means that for Ausubel, learning occurs when the learner incorporates new information into prevailing schemata of information (Cakir, 2008). The importance of the prior knowledge that the learner possesses is demonstrated clearly by Ausubel when he said:

> 'If I had to reduce all educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him/her accordingly' (Ausubel, Novak, & Hanesian, 1978:p. iv).

Ausubel's conditions for meaningful learning therefore include the use of appropriate materials, the ability of learners to relate old and new ideas, and preconceptions with which to make these relations (Confrey, 1990). Terms used by Ausubel to describe his ideas on cognitive structure include subsumption, progressive differentiation and integrative reconciliation. This means that general concepts will be used to gain and organise new concepts (subsumption), followed by the establishment of new linkages between related concepts (progressive differentiation). Within these newly formed linkages, conflicts in meaning are then resolved by relating previously discrete concepts with one another (integrative reconciliation). From this description it is clear that Ausubel conceived of cognitive structures being hierarchically organised (Cakir, 2008; Confrey, 1990).

### 3.3.5. Vygotsky's theory of knowledge acquisition

Lev Vygotsky, a Russian psychologist, was a strong proponent of social constructivism as a theory of knowledge acquisition (Hyslop-Margison & Strobel, 2007). Social constructivism maintains that knowledge is not solely generated through individual cognition, but is largely socially negotiated and created. This supports the view that knowledge and understanding are generated in collaboration with others (Hyslop-Margison & Strobel, 2007; Pardjono, 2002). Vygotsky was also a proponent of the notion that children learn through being active (Lourenço, 2012). Congruent with his social constructivist theory, he sees learning as a socially facilitated activity. Vygotsky emphasises that language plays a significant role in cognitive development, since one must be able to communicate in order to interact and ultimately learn socially (Cakir, 2008; Lourenço, 2012; Vygotsky, 1978).

Vygotsky considers knowledge to consist of two sets of concepts, namely spontaneous and non-spontaneous concepts (Cakir, 2008). Spontaneous concepts are characterised by the absence of a system and includes one's own thought processes and everyday experiences, while non-spontaneous concepts entail scientific systems and facts (Moll & Greenberg, 1990). Vygotsky understands learning and the developmental process as an interaction between these two sets of concepts, where new non-spontaneous concepts can be embedded and assimilated into existing spontaneous concepts and *vice versa*.

Vygotsky believes that each learner has a zone or region within which s/he develops. This zone has boundaries on either side: on the one side the boundary is the developmental threshold necessary for learning and on the other side it is the learner's own capacity to learn (Vygotsky, 1978). Vygotsky coined this region the zone of proximal development (ZPD). It is regarded as "a theoretical space of understanding which is just above the level of understanding of a given individual" (Pritchard, 2003:25).

The ZPD is that gap between what the student is currently capable of doing independently, and what is currently out of the learner's reach. "The central Vygotskian notion of zones of proximal development is one of learning flowering between lower and upper bounds of potential, and depending on environmental support" (Brown, 1994:9). Figure 3.1 indicates these bounds. Beyond the lower bound border of the ZPD is the achieved zone. This zone characterises what learners know and are familiar with. Learning here is easy, but if the learner stays there it can also lead to boredom as here the learner is not challenged. Beyond the upper bound border of the ZPD is the unattainable zone. In this zone the learner is unable to do anything new, even with help. It takes the learner into the unknown and this can lead to anxiety and panic on the part of the learner.

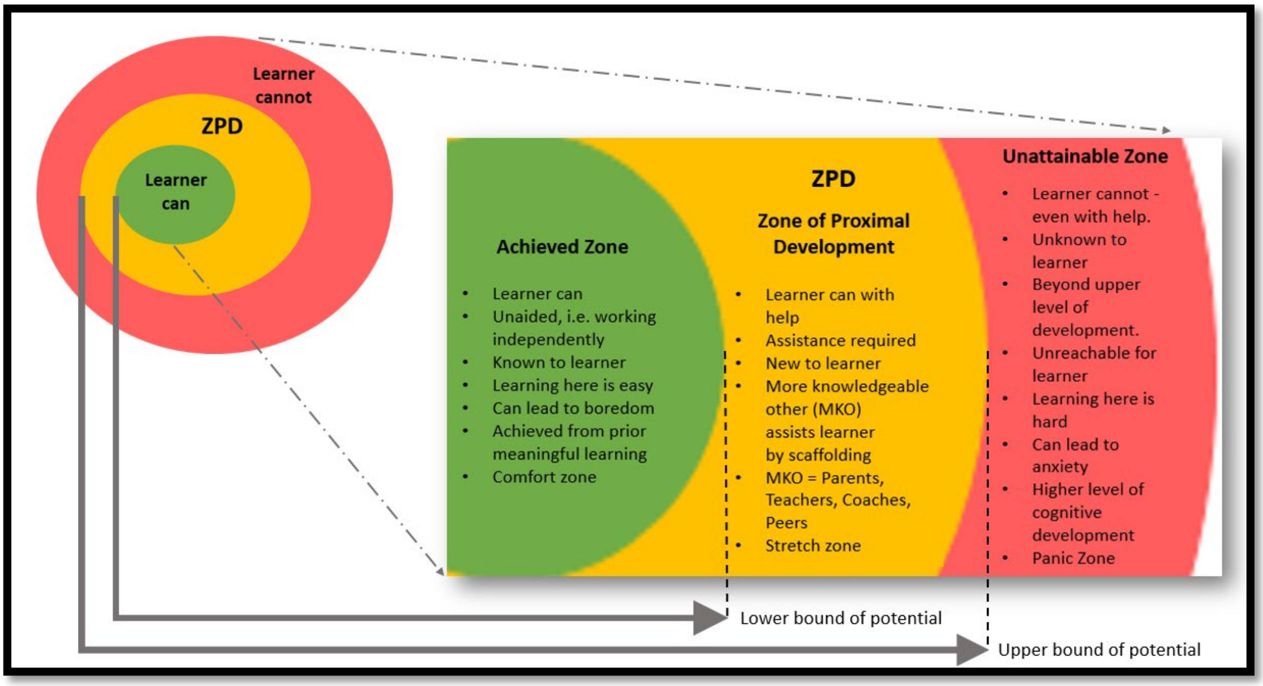



**Figure 3.1: Vygotsky's Zone of Proximal Development (Own diagram)**

In the ZPD, the learner can acquire new knowledge and skills with the help of a 'more knowledgeable other', for example the teacher (Cakir, 2008; Lourenço, 2012; Pritchard, 2009; Sewell, 1990; Škoda, Doulík & Procházková, 2013). This is the zone where the learner will be stretched, i.e. it is new to the learner and just beyond what the learner is fully comfortable with. It is also the zone where the learner will learn and grow as the teacher or any 'more knowledgeable other' acts as a 'scaffolder' of knowledge (Pritchard, 2009). Lourenço refers to the term scaffolding, a term originally coined by Wood, Bruner and Ross, which fits with Vygotsky's theory about active learning (Lourenço, 2012). Scaffolding is a tutorial action between the learner and an adult (Lourenço, 2012). This corresponds with Vygotsky's view that action, which leads to learning, should be mediated with carefully scaffolding activities. Scaffolding should guide the learner's thinking. The teacher layers the process of learning through lessons and activities and by using guiding questions and prompts to allow for knowledge to build up (Hitt & Smith, 2017). As a facilitator, the teacher provides the challenges that the learner needs for achieving more. Development is fostered in the zone of proximal development by collaboration, and is not strictly age or stage related (Cakir, 2008).

Vygotsky argues further that "development is an internalisation of social experience where children can be taught concepts that are just beyond their level of development with appropriate support. What the child can do with an adult today, they can do alone tomorrow" (Pritchard, 2003:115). In this manner the zone of proximal development progressively expands.

### 3.3.6. Comparison of constructivist theorists

There are a number of areas of overlap and similarity amongst the constructivist theories of Dewey, Piaget, Ausubel and Vygotsky. The one common thread which runs through their theories is the importance of prior knowledge, i.e. that learners already hold a body of information and ideas and that this forms the basis for learning. The process of learning involves new information being embedded into the existing knowledge. A second similarity is the importance of learners being actively engaged in a process of learning. Thirdly, they all agree on the role of the teacher changing from one of only imparting information to one where the teacher facilitates a process of the learner him-/herself building knowledge.

The overview of the main ideas of each theorist in the preceding section provides evidence of, on the one hand, elements of overlap and commonality embedded within constructivist thinking, and on the other hand, own conceptualisations of how learning occurs, and own interpretations of constructivism. Table 3.1 provides a synopsis of the four theorists' ideas on learning.

Constructivists view learning to be the result of mental constructions (Pritchard, 2009). Another way of looking at it is to say that cognitive change is a structural change in the understanding of a person (Fosnot & Perry, 2005). Therefore, the goal of instruction, according to the theory of constructivism is cognitive development and deep understanding as a result of constructions of active learner reorganisations of information (Fosnot & Perry, 2005). The fundamental principle of the constructivist model is that knowledge and understanding are built up by individual learners (Dewey, 1933; Pritchard, 2009; Von Glasersfeld, 2005). As we acknowledge the presence of prior knowledge held by learners, we are required to actively engage learners with objects, concepts, ideas and events in their process of learning (Fosnot & Perry, 2005; Levy *et al.*, 2011; Lourenço, 2012; Ültanır, 2012; Von Glasersfeld, 1995).

When considering the comparison, the question remains: should the emphasis in the discussions around constructivism be placed on individual cognitive structuring or on the social and cultural effects of learning? Constructivism is not only an underlying philosophy or way of seeing the world, including the nature of reality and knowledge, but it also has views on human interaction and science (Cakir, 2008). Hence, the terms cognitive constructivism and social constructivism are both encountered in education literature.

**Table 3.1: Comparison of main premises of four prominent constructivists**[4]

| | Dewey | Piaget | Ausubel | Vygotsky |
|---|---|---|---|---|
| **Theory** | Progressive education[5] | Scheme theory. Assimilation & Accommodation | Meaningful learning[6] | Social context of learning and constructivism. |
| **Cognition** | Knowledge is a form of activity [7] | Schemes: The mental patterns people use to guide behaviour and cognition. | Schemata: Networks of connected facts and concepts which store meaningful information | Two types of concepts exist, namely spontaneous and non-spontaneous |
| **Learning** | Process of inquiry; Learners must learn how to learn [4] | New information causes disequilibrium of current schemes. This leads to accommodation whereby old schemes are modified and new schemes form. Thereafter, balance is restored to the cognitive system and equilibrium is reached. | Meaningful learning occurs when new information is subsumed into existing information | Concept formation and knowledge can either be spontaneous – as picked up through everyday experiences and is unorganised, or non-spontaneous – as formally taught and is hierarchical. |
| **Requirement for learning** | Sensory input; Engagement with the world[8] | Learning is stage dependant | Learning is dependent on existing schemata and not stage dependant | Language is important in the development of thought |
| **Prior knowledge** | Learners' experiences [9] | Prior cognitive structures are important. Without them disequilibrium cannot occur. | New information must be incorporated into current information | Spontaneous, unorganised knowledge picked up through everyday experiences |
| **Approach to instruction** | Active learning [3] | Bottom up | Top down | Scaffolding |
| **Type of constructivism** | Socially integrated [10] | Cognitive constructivism | Cognitive constructivism | Social constructivism |

**(Source: Cakir, 2008)**

Constructivism regards opportunities for interaction with others, in the form of collaboration and discussion, in the process of knowledge construction as vital. According to Dewey, an open and public system of inquiry, to which each member can contribute, is required for knowledge to be

[4] Main source Cakir (2008). Information from other sources is indicated by means of footnotes.
[5] Pardjono, 2002
[6] Villani, Dias & Valadares, 2010
[7] Weber, 2010
[8] Hein, 1991
[9] Barrow, 2006
[10] Weber, 2008

formed in community (Weber, 2008). Progressive education, as promoted by Dewey, emphasises that there is a social component integral to learning which uses conversation, interaction with others and application of knowledge (Hein, 1991). This points to the need for interaction with others to more effectively bring about cognitive development in individuals. This is supported by Vygotsky's argument of development being an internalisation of social experiences. Hyslop-Margison and Strobel (2007) explain it well when they state: "Social constructivism avoids the idea that individual cognition is the sole generating force in knowledge construction and espouses the view that knowledge is a cultural or negotiated artefact generated in cooperation and understanding with others" (Hyslop-Margison & Strobel, 2007:81).

Therefore it is not so much a question of which of the two, cognitive or social constructivism, should be given priority, but rather the interplay between them (Fosnot & Perry, 2005). In the next section the focus is on how constructivism underpins IBE.

### 3.3.7. Constructivism as the basis of IBE

In the 1970s constructivist approaches in the form of inquiry started to become apparent in educational activities and in particular in Science instruction (Minner *et al.*, 2010). The work of the theorists Piaget, Vygotsky and Ausubel was blended into the philosophy of learning known as constructivism and used to shape constructivist-based material which is commonly branded as inquiry-based resources (Minner *et al.*, 2010). IBE is embedded within a number of educational theories, however, it is strongly connected to the constructivist paradigm (Škoda, Doulík & Procházková, 2013).

What is well known is the fact that it was the enduring dialogue about the nature of teaching and learning that gave rise to inquiry-based instruction (Minner *et al.*, 2010). One can deduce that the principles of the four theorists which were used to form the basis for IBE are the following: active learning, individual process, reflection, importance of prior learning, scaffolding, the teacher as facilitator and social interaction.

In Table 3.2 below I present the guiding principles of constructivist thinking as presented by Hein (1991) and link them with the main features of IBE. This shows how deeply IBE is embedded within constructivism. I then continue to discuss IBE in more detail.

**Table 3.2: Connections between constructivist thinking principles and IBE features**

| Constructivist thinking principles[11] | Features of IBE[12] |
|---|---|
| Learning is an active process | Inquiry-based instruction techniques engage learners actively in the learning process which is more likely to increase conceptual understanding (Minner, Levy & Century, 2010). |
| People learn as they learn | Through inquiry "ideas become modified as students use them to try to explain new experiences" (Artigue, Dillon, Harlen & Lèna, 2012:5). |
| The action of constructing meaning is mental | One of the most important outcomes of IBE is developing higher order thinking by allowing the learner to make meaning of his or her experiences (Minner *et al.*, 2010; Ramnarain, 2016). |
| Learning involves language | Language, alongside other tools, plays a central role in building knowledge collaboratively, as is often the case in IBE settings (Artigue *et al.*, 2012; Keys & Bryan, 2001; Levy *et al.*, 2011). |
| Learning is a social activity | IBE recognises that students are introduced to scientific thinking through discussion with others (Artigue *et al.*, 2012; Levy *et al.*, 2011). |
| Learning is contextual | Inquiry is a pedagogy which is flexible allowing teachers to shape the process to their specific outcome and classroom circumstances (Levy *et al.*, 2011). |
| Knowledge is required for learning | IBE recognises the prior knowledge learners hold and builds on it. To attempt to induce changes in the learners' ways of thinking one must have some insight into the learners' "domains of experience, concepts, and the conceptual relations that the learners possess at that moment" (von Glasersfeld, 2005:7). |
| Learning is not instantaneous, but a process | Inquiry-based teaching and learning includes a scaffolding process (Bell, Smetana & Binns, 2005). |
| Motivation is a key component in learning | In inquiry-based education teachers are also regarded as motivators of the learning process (García, 2013) |

**(Source: Hein, 1991)**

# 3.4. Inquiry-Based Education (IBE)

## 3.4.1. Introduction to IBE and IBSE

In order to discuss IBE, clarity on what is meant by 'inquiry' first needs to be established. 'Inquiry' refers to the work scientists do when they study the natural world and propose explanations that include evidence gathered from the world around them (Anderson, 2002). The National Research Council (NRC) - an organisation involved in Science education reform in the USA - states that:

[11] This list of guiding constructivist thinking is taken from Hein (1991)
[12] Corresponding constructivist thinking principles

> "Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" and elaborates further to say that, "inquiry in education is 'a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions; and communicating results" (García, 2013:2).

In Inquiry-Based Education (IBE), the term 'inquiry' implies a process of gaining information through investigation by involving learners voluntarily in a form of active learning that is multifaceted and which emphasizes questioning, predictions, data analysis, critical thinking and communication (Anderson, 2002; Bell *et al.*, 2005; Čeretková, Melušová & Šunderlík, 2013; Ramnarain, 2016; Shamsudin *et al.*, 2013). So, inquiry-based learning refers to an active learning process where learners do something, and not where learners have something done to them. In more traditional educational environments the focus is strongly on the content or subject material that must be learnt. However, IBE places the emphasis on how the learner learns and not so much what must be learnt (Škoda *et al.*, 2013).

In the Science classroom context IBE is more specifically referred to as Inquiry-Based Science Education (IBSE). The purpose of a Science classroom should be to encourage a deeper understanding of the workings of the physical world. To achieve this understanding requires investigation and articulation of one's own ideas as well as the ideas of others (Julyan & Duckworth, 2005). This is why IBE and IBSE place such a strong emphasis on learner participation, active learning and collaboration. It was Dewey who first encouraged Science teachers to use a prototype of inquiry-based teaching emphasising the importance of learner involvement and the teacher taking on the role as a guide and facilitator of the inquiry process (Levy *et al.*, 2011).

IBE and IBSE approaches recognise that the learner is not an empty vessel. IBE acknowledges that learners have had experiences and opportunities whereby they could have come into contact with a particular topic, subject or object, and in doing so, carry some knowledge about it. Also, learners have informal and common sense knowledge which has been acquired through interaction with the world around them, including others who assisted in their social constructions of their world (Driver *et al.*, 1994). This prior knowledge of a learner forms a basis to work from, and so IBE includes processes which will acknowledge learners' own current knowledge and understanding of a subject. This is in line with the constructivist approach which allows learners to actively construct new meaning as they connect it to previous knowledge.

Following an IBE or IBSE approach holds a variety of educational benefits. It is believed that if teachers allow learners to engage in constructivist inquiry, the learners' views about the nature of science will improve (Bell & Linn, 2000). For instance learners then have a more dynamic view, and an enhanced understanding of the nature of Science (Bell & Linn, 2000). Also, an inquiry approach achieves significant cognitive development. For example, active engagement with topics increases conceptual learning, and the retention of concepts is better for learners who experienced discovery teaching (Shamsudin *et al.*, 2013). Since learners often work in groups when following the IBE approach, they are constantly sharing ideas and arguing their case. This means that learners have the opportunity to further develop reasoning, verbal and team skills, which is not the case when following a traditional approach to learning (Muianga *et al.*, 2018). The active learning processes of IBSE which include investigation and discussion are therefore key elements in reaching the objectives of current reform in Science education. From here onwards I focus on and refer specifically to IBSE as my study is situated in Science education.

### 3.4.2. Policy promoting IBSE

Policy makers and researchers recognise that nurturing positive attitudes of learners toward Science could be a critical element in developing their Science ability (George, 2006; Juan, Reddy & Hannan, 2014). Science instruction worldwide has included hands-on, practical and experimental activity, but in a way which often is prescriptive and routine-like and which does not encourage formulation of scientific thought (Kang, Windschitl, Stroupe & Thompson, 2016). Learners merely following a laboratory 'recipe' actually constitute rote scientific study. Therefore, many educational authorities around the globe have shifted towards IBSE in an attempt to make teaching and learning more effective, more relevant and to improve the progress of learners, making inquiry teaching one of the central concerns in educational reform (Bell *et al.*, 2005). There are clear attempts to open Science teaching to more varied teaching methods and topics (Bolte, Holbrook & Rauch, 2012). This is evident within policies in developed countries like France, England, Denmark, Finland, USA and Australia (Anderson, 2002; Euler, 2013; Fitzgerald, McKinnon, Danaia & Deehan, 2016; LAMAP Foundation, n.d.). A number of developing countries like the Czech Republic, Slovakia, South Africa, Brazil, and India have also started looking into IBSE (Cline, 2015; Jansen, 2001; Ramnarain, 2016; Škoda *et al.*, 2013).

In Europe educational reform promotes IBSE to encourage growth in innovation, creativity, and imagination, as well as improved engagement with Science and Mathematics (Bolte *et al.*, 2012). In the USA the National Science Education Standards (NSES) claims that "inquiry into authentic questions generated from learner experiences is the central strategy for teaching Science" (Anderson, 2002:1). In 2015 the Network of African Science Academies (NASAC) held a workshop with a focus on women for science, addressing the topic of mainstreaming gender in the African Science education curriculum. The term gender referred to both men and women, with gender mainstreaming meaning to bring fairness and equal opportunity for both men and women. The recommendation made by NASAC to ensure this mainstreaming, was to promote IBSE as best practice in teaching Science as well as in training Science teachers (NASAC, 2015).

The South African curriculum too leans towards the inclusion of IBSE. The development and reform of the South African school curriculum post 1994 has been discussed in some detail in Chapter 2. There it was explained how the post-apartheid unified curriculum for all South African children, the National Curriculum Statement (NCS), which strongly promoted Outcomes-based Education (OBE), has been revised and adjusted to the current national curriculum namely the National Curriculum Statement Grades R-12 (NCS Grades R-12) (DBE, 2011). Details of principles, aims, objectives and content are clearly set out in separate per subject documents known as the Curriculum and Assessment Policy Statement (CAPS). One of the principles of the NCS Grades R-12 reads as follows:

> "Active and critical learning: encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths" (DBE, 2011).

It proceeds to further state that the NCS Grades R-12 "aims to produce learners that will be able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively as individuals and with others as members of a team;
- organise and manage themselves and their activities responsibly and effectively;
- collect, analyse, organise and critically evaluate information;
- communicate effectively using visual, symbolic and/or language skills in various modes;
- use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation" (DBE, 2011).

Furthermore, it is worth mentioning that the principle of Science investigation is emphasised strongly in the CAPS document. The word 'investigation', another important component in the IBSE approach, appears 32 times in the Further Education and Training (FET) Physical Sciences CAPS document.

The principles highlighted above, and each one of the aims of the NCS Grades R-12, hold a strong correlation and are congruent with what IBE and IBSE promote. This is in line with the worldwide trend amongst educational policy makers and institutions of increasingly leaning towards the use of inquiry-based pedagogies in the teaching and learning of Mathematics and Science (Wake, 2011). The next section highlights some programmes from around the world which actively implement IBSE.

### 3.4.3. Examples of practical implementation of IBSE

American schools have seen an intense focus on Science, Technology, Engineering and Mathematics (STEM) in an attempt to achieve the outcomes set by the American National Science Education Standards (NSES) (Alake-Tuenter, Biemans, Tobi, Wals, Oosterheert & Mulder, 2012; Anderson, 2002; Lieberman, 1995). Guided by the Kindergarten to Grade 12 (K-12) policy, this led to the development and implementation of a host of programmes focused on promoting innovation and developing science resources and inquiry activities (Penuel & Means, 2004). Examples of such programmes are Comer School Development Program, Success for All, and the New American Schools scale-up, Full-Option Science System (FOSS), Science Education for Public Education Program (SEPUP), GLOBE, LeTUS and various regional and nationwide 'river watch' programmes[13] (Geier *et al.*, 2008; Penuel & Means, 2004).

Multiple federal agencies, which are concerned with science and education, namely the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Environmental Protection Agency (EPA) and the Departments of Education and State, joined forces to provide funding to establish the GLOBE programme in 1995 (Penuel & Means, 2004). This international environmental science programme places emphasis on both development of scientific skills and science education. In the years 1998 to 2001 Detroit and Chicago saw the LeTUS project which had the mission of creating capacity within these districts to ensure success in their science reform programmes (Geier *et al.*, 2008). When standardised tests scores were compared the results showed that learners who participated in the project outperformed those who did not participate (Geier *et al.*, 2008). Further benefits of implementing these programmes were a heightened interest in learning Science by urban minority boys who are generally out-performed by urban girls. The inclusion of varied instructional methods and learning experiences like inquiry, peer collaboration, interaction and the use of technology made the process of learning more appealing and so contributed to gender equity in a situation where boys could be left behind (Geier *et al.*, 2008). Yet, studies suggest that there is still

[13] A high school based student activity in the USA through which teams of high school students are trained on basic river water quality data collection and reporting procedures using Minnesota Pollution Control Agency protocols.

much room for scaling up the extent of exposure learner groups in the USA have to Inquiry-based activities (Geier *et al.*, 2008). The GLOBE programme, too, found that learners benefited educationally from the inquiry approach and developed key scientific skills, but that more work was required to support teachers and to ensure that all have the required resources and equipment for implementation (Penuel & Means, 2004).

The Australian National Science Curriculum also calls for investigative, inquiry-based science, which led to a "large-scale astronomical high school intervention project" being rolled out in New South Wales (Fitzgerald *et al.*, 2016). Even though research results show that this project led to content knowledge gains, challenges in implementing it more widely throughout Australia were also highlighted. For example, huge investment for carefully designed programmes is required for sustained teacher professional learning (Fitzgerald *et al.*, 2016).

European policy makers and educational institutions have made great strides in moving to IBSE. The numerous projects made possible through government support in terms of policy and funding provide evidence thereof. Some of the earliest work in IBSE in Europe was done by the La Main à la Pâte (LAMAP) operation which was launched in 1996 by the Academy of Science in France (LAMAP Foundation, n.d.). LAMAP is an inquiry based education model which was developed in France and which is, to date, still used as a form of instruction in many French primary schools (Onwu, 2015). LAMAP is an approach consisting of a variety of pedagogical features. It is adaptable and can therefore be customised to suit a variety of contexts. Besides being implemented across France, it has also been piloted and implemented in various countries worldwide including a number of African countries namely Morocco, Cameroon, Egypt, Tunisia, Mali and in recent years, South Africa (Onwu, 2015).

Similar to LAMAP was the PRIMAS project, a united venture of 14 institutions from 12 European countries, developed and rolled out from 2010 to 2013 across Europe (Euler, 2013). PRIMAS is an acronym for Promoting Inquiry-based learning in Mathematics And Science education, and the project focussed on developing material for inquiry-based teaching as well as providing support to educators making the shift to inquiry-based teaching (Artigue *et al.*, 2012; Euler, 2013). Other IBSE focused projects in Europe include PROFILE, Pathway, SAILS, ESTABLISH and STEAM (Bolte *et al.*, 2012) in which various educational institutions across Europe participate. They have moved closer to a shared understanding of the role of IBSE projects, and work towards informing the practice and processes of IBSE in Europe as a joint effort (Bolte *et al.*, 2012). However, in European countries it was found that while the concept of IBSE has been included in Science curricula, implementation thereof has been slow and infrequent (Levy *et al.*, 2011; Wake, 2011). Each of these projects picked up that there are definite educational gains to implementing IBSE, but that it is complex and effective implementation demands careful design, strategy and support.

From the above I can conclude that the commonalities across the countries regarding IBE and IBSE adoption include the importance of education policy supporting the inclusion of inquiry into education at large, as well as making national funding available for teacher training or retraining programmes and the implementation of IBSE.

### 3.4.4. IBSE in South African schools

The South African school curriculum policy, which provides a foundation for inquiry-based teaching and learning, is centralised and prescriptive and therefore provides a clear pathway towards the desired results as set out by the aims, yet the sustainability of achieving these results is challenging (Du Plessis, 2015). In reality, learners' exposure to inquiry in Science is still quite limited (Gaigher, Lederman & Lederman, 2014). Teachers never even came to a full understanding of OBE which was the teaching and learning methodology prescribed by teaching policy in SA post 1994 (Jansen, 2001). Further research has shown that even after policy and curriculum adjustments, Science inquiry in better resourced schools was still restricted to experiments which confirmed theory or were teacher-controlled investigations, while in disadvantaged schools learners were not even given an opportunity to take part in laboratory work, let alone design investigations (Gaigher *et al.*, 2014; Ramnarain, 2016).

A number of factors have prevented the NCS Grades R-12 aims to be reached. This includes factors like physical condition of schools and access to resources, level of teacher qualifications and support of teachers by district offices (Bantwini & Feza, 2017; Spaull, 2013). Many schools in SA, especially township schools, remain under-resourced which results in curriculum reform and implementation of inquiry being constrained (Ramnarain, 2016).

The implementation difficulties are not confined to South Africa. This implies that educators should continue to look for solutions for the challenges that exist. For instance, using household implements where schools face a lack of resources would not only make inquiry possible, but would also make Science more authentic and part of daily life, and less abstract (Ramnarain, 2016). Ongoing in-service TPL programmes could also address the difficulty of low qualification levels of some teachers, and at the same time provide opportunities for training in IBSE by teachers.

One attempt to implement IBSE in SA has already shown positive results. In 2012 the La Main à la Pâte-Inquiry Based Science Education (LAMAP-IBSE) pilot project was launched in the Gauteng province in South Africa (Onwu, 2015). This was one of the first concerted attempts made in South

Africa to provide training in IBSE to teacher trainers as well as teachers. Lecturers from several tertiary teacher training institutions in Gauteng received intensive training by international experts in order for them to train and provide ongoing support to teachers from 10 schools in the Tshwane South district of the Gauteng Department of Education. The implementation of LAMAP-IBSE as a result of this project has led to definite improvements in Science teaching and learning (Onwu, 2015). Teachers involved reported that their approach to Science instruction was enriched to such an extent that they have gained more confidence, and that they have found learners to become more enthusiastic, and assuming ownership of the learning process (Onwu, 2015). This is a positive start to IBSE in SA, and a good indication of the guaranteed benefits for Science teaching and learning in South African schools.

The next section looks at IBSE in further detail to provide a broader picture of what it entails and requires, as well as to explain the considerations that must be taken into account should this be implemented in schools.

## 3.5. Features and requirements of IBSE

### 3.5.1. IBSE: A learner-centred approach

Conceptions of being a learner have seen major change lately in that a learner is now seen as an "active constructor rather than passive recipient of knowledge" (Brown, 1994:6). IBSE places emphasis on the learner, and not the teacher, being the one that is doing (Anderson, 2002). In a teacher-centred approach the teacher shares information in various forms to make it accessible and to transfer it to learners. In contrast, features of a learner-centred approach include:

- Learners being responsible for their own learning;
- A responsiveness by educators to the needs of individual learners;
- The stimulation of the learner's learning potential; and
- A cooperative style within learner groups (Muianga *et al.*, 2018).

Much benefit can be derived from following a learner-centred approach. Besides the fact that it allows for a wide range of learning modes and caters better for individual learning needs, it also increases learners' retention of knowledge and skills (Minner *et al.*, 2010; Muianga *et al.*, 2018). Furthermore, growth in conceptual learning is found when educational instruction allows for more learner responsibility and collaborative work with peers compared to working independently (McNeill, Pimentel & Strauss, 2013; Minner *et al.*, 2010; Muianga *et al.*, 2018). With such an approach learners are encouraged and given space to make their own decisions and do not just blindly have to follow what they are told. There is now room for their ideas to be implemented which validates learners and builds their self-confidence (Muianga *et al.*, 2018). Ultimately, the learner-centred setting which the IBSE approach ensures, gives learners ownership of their learning, encourages them to become independent learners and in turn breeds more interest and willing participation by the learners (Levy *et al.*, 2011; Muianga *et al.*, 2018).

### 3.5.2. Role of the teacher in the IBSE approach

With the learner being the focal point of the learning process when following the IBSE approach, one could ask where this leaves the teacher. The teacher, still an expert in the field, should now act as a facilitator of the learning process. In inquiry-based teaching teachers should aim to encourage learners to take responsibility for their own learning (Levy *et al.*, 2011). Therefore, teachers need to be re-positioned as instructional designers who work to create various forms of learning opportunities, rather than as passive consumers of pre-developed curricula (Kang *et al.*, 2016). In inquiry-based learning the idea is that the learners are the ones who make the connection between what is already known and what they newly discover in a meaningful way for themselves and it is those connections that should interest the teachers (Julyan & Duckworth, 2005). Teachers should use the connections to further guide and lead learners in the process of constructing knowledge. IBSE requires good learner support and this should be provided by the teacher in the form of teaching environments and teaching strategies uniquely designed to support learning through an evolving process of exploration and discovery (Levy *et al.*, 2011).

Therefore, the main functions of teachers in the IBSE setting is to firstly create an environment conducive to inquiry-based teaching and learning where learners can construct knowledge (Von Glasersfeld, 2005). This includes providing them with suitable learning tasks, making available the necessary resources, equipment and apparatus, ensuring discipline in the classroom and making use of suitable assessment methods. What is further required from teachers is to guide learners by asking leading or counter questions to make them think even more deeply and helping them to produce rather than consume knowledge (Muianga *et al.*, 2018; Ültanır, 2012). Teachers must not only create opportunities for learners to work actively by themselves, but also provide opportunities for the learners to work in collaboration and interaction with one another (Cakir, 2008; Smyth, 2003). Understanding the various inquiry components, as well as understanding how inquiry can be designed with increasing learner involvement, will enable teachers to enhance inquiry-based learning further.

### 3.5.3. Form and levels of inquiry

Even though there is a firm belief that an inquiry-based approach can enhance learning, it is the one approach that means many different things to different people (Ramnarain, 2016). IBSE is an approach that is difficult to visualize and one that is difficult for many teachers to put into successful practice (Levy *et al.*, 2011). There is no set format for IBSE due to the fact that a number of factors play a role in the interpretation of what IBSE is. These factors include policy, cultural context, teacher ability, teacher values and beliefs, teacher willingness and learner ability and willingness. Teachers need to adopt different strategies according to different intended learning outcomes, the needs of students, and the specific circumstances of their own, diverse classrooms. Hence, an understanding of different types of inquiry-based learning and teaching will help teachers to create learning activities that are appropriate for the context (Levy *et al.*, 2011).

The NRC has developed a framework for schools in the USA describing inquiry-based Science instruction which includes essential characteristics of inquiry-based Science instruction. The essential characteristics indicated by this framework are access to science content, learners engaging with science content, and employing key elements of inquiry namely:

- learners taking responsibility for learning;
- learners thinking actively; and
- learner motivation (Minner *et al.*, 2010).

Inquiry instruction includes various components, namely questioning, design, data, conclusion, or communication, and the framework further stipulates that the key elements of inquiry should be present within at least one of these components. (Minner *et al.*, 2010).

What is required to initiate learning and for learning to occur in the inquiry-based learning way is a problem or phenomenon to investigate or a question to be answered (Artigue *et al.*, 2012; Levy *et al.*, 2011; Onwu, 2015; Škoda *et al.*, 2013). This problem or big question must lead learners to framing questions, designing and implementing procedures, and lastly, drawing conclusions and results from evidence. Mathematical and analytical tools to derive a scientific claim are also required (Keys & Bryan, 2001; Levy *et al.*, 2011; Ndlovu, 2015; Wake, 2011).

The participation and active involvement of the learner in his or her own learning process is the main focus of IBSE. NRC highlights this role of the learner in the following core components regarded as essential features of an IBSE classroom:

- Learners are actively engaged by scientifically oriented questions;
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions;
- Learners formulate explanations from evidence to address scientifically oriented questions;
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and

- Learners communicate and justify their proposed explanations (Minner *et al.*, 2010)

These core components are graphically illustrated in Figure 3.2.


**Figure 3.2: IBE and IBSE as a learner-centred approach (Own diagram)**

Effective IBSE is not achieved merely through hands-on activity. Learners must also be given the opportunity to explore, investigate and search for answers. Furthermore, IBSE requires that learners are given the opportunity to process these experiences for meaning through group work, to collaborate by sharing ideas within groups, and to engage in argumentation and class discussion (Minner *et al.*, 2010; Kang, *et al.,* 2016).

Inquiry-based teaching and learning can be implemented at various levels or types of inquiry. This allows for a wide spectrum of Inquiry-based Science activities which in turn accommodate the variety of learning outcomes, educational needs and contexts which teachers need to cater for (Levy *et al.*, 2011). Even though all the features of inquiry are present in each inquiry level, the levels are differentiated by the degree of responsibility given to the learner and the teacher respectively (Alake-Tuenter *et al.*, 2012; Bell & Linn, 2000). Table 3.3 summarises the various types and levels of inquiry as explained by Bell *et a*l. (2005) as follows. At level one, where the smallest degree of responsibility lies with learners, teachers would be providing the research question, as well as an already prepared plan to perform an investigation. The teacher will even perform the investigation and collect data him- or herself. This data will be given to the learners in order for the learners to do the analysis. This type of inquiry is referred to as confirmed inquiry as learners will only confirm already presented ideas. At level two teachers will also pose the question, but this time only provide instructions as to how to collect data.

**Table 3.3: Types and levels of inquiry**

| Type of inquiry | Level of inquiry | Features of inquiry | | | | |
|---|---|---|---|---|---|---|
| | | Frame research question | Design investigations | Perform investigation | Analyse data | Discuss & present findings |
| Confirmed | 1 | Z** | Z | Z | X* | X |
| Structured | 2 | Z | Z | X | X | X |
| Guided | 3 | Z | X | X | X | X |
| Open | 4 | X | X | X | X | X |
| | | *Where learner takes the lead (X)<br>**Where the teacher takes responsibility (Z) | | | | |

**(Source: Bell et al. 2005)**

Learners will have to perform an investigation and collect data to analyse themselves. The teacher, however, will provide the materials and equipment needed to perform the investigation. This is referred to as structured inquiry because a framework is provided to the learners. At level three teachers provide the research question, but now learners will be given the opportunity to design their own investigation, plan or procedure. Learners will then follow and perform their own investigation to collect and analyse data. With the teacher as the facilitator, this level of inquiry is regarded as guided inquiry. Level four presents learners with a problem. Learners are then expected to frame their own research questions, design their own investigative procedure, perform the investigation, analyse the data and present their findings. This level is known as open inquiry and gives the highest degree of responsibility to the learner. Teachers need to keep in mind that learners need to practice the processes of inquiry and gradually build up their inquiry skills from level one to level four. Learners would reap little benefit if they are thrown straight into level four inquiry activities. A gradual progression with appropriate scaffolding measures is more likely to lead to success in implementing high level inquiry teaching (Alake-Tuenter *et al.*, 2012; Bell *et al.*, 2005).

### 3.5.4. Proposed structure of IBSE at secondary level school

Constructivism and IBSE have major ramifications for the goals that teachers set for their learners, the instructional strategies teachers employ in reaching these goals and the methods of assessment used to document genuine learning (Fosnot & Perry, 2005). In the previous sections I have touched on various aspects which one has to consider to make a shift to IBSE. I now propose a structure for the various educational elements to fit and work together to incorporate IBSE in the secondary school setting. The elements include resources, classroom setting, the teacher, who takes the supporting role, and the learner who is the main actor. The learner should come ready to explore, engage with others, ask questions and design plans to find answers. The teacher, however, is the main determinant to ensure that IBSE takes place and therefore the teacher has to 'set the scene' in the classroom. Effective teaching through IBSE calls for a carefully designed process whereby the teacher should firstly be aware of what the learners already know, and then plan activities which will lead learners to knowledge that is new, but which links to their prior knowledge (Driver, Asoko, Leach, Mortimer & Scott, 1994). In Figure 3.3 I attempt to give a depiction of how all the elements fit together.

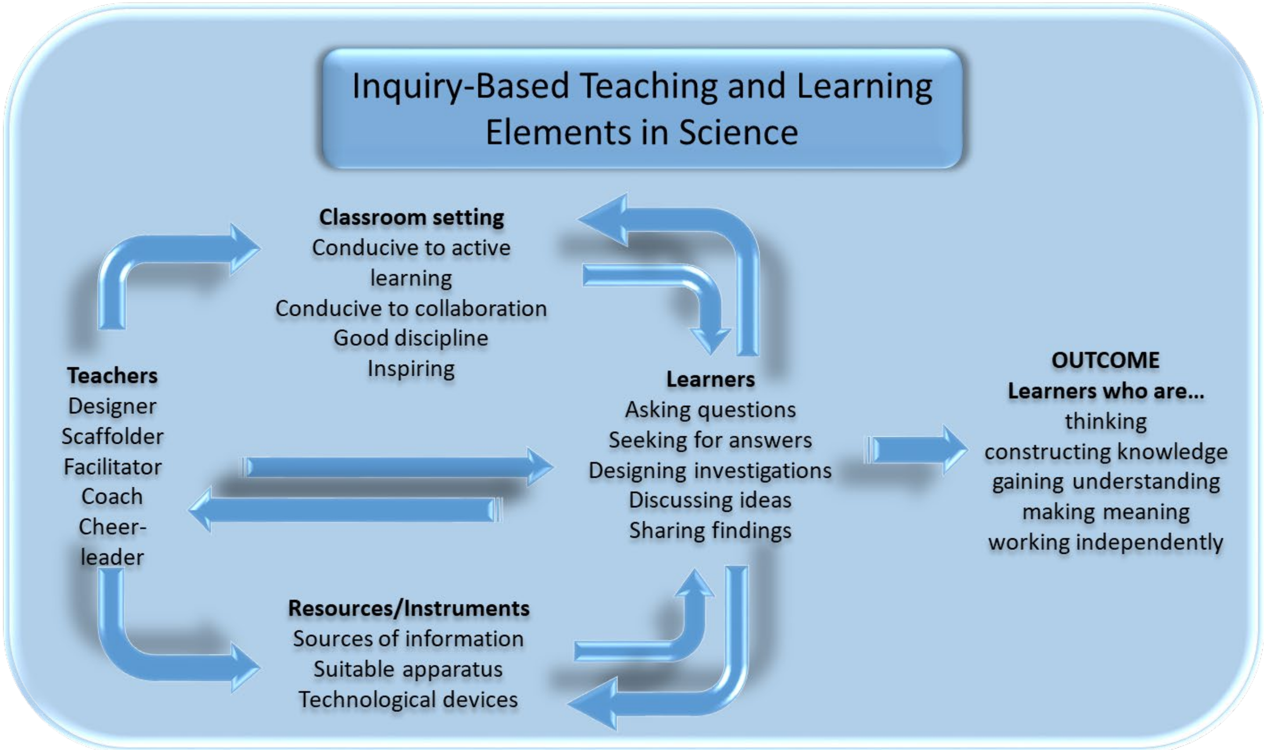



**Figure 3.3: A depiction of an Inquiry-based Science teaching and learning structure (Own diagram)**

IBSE requires the role of the teacher to shift from transmitter of knowledge to that of designer of knowledge construction (Hyslop-Margison & Strobel, 2007). S/he has to define the IBSE game plan and design a series of activities which will lead to effective inquiry-based learning. This includes choosing and providing suitable materials and resources as well as planning how these resources are to be used (Von Glasersfeld, 2005). The teacher is also the one who must determine the classroom set-up and ensure an environment conducive to learning in an active and collaborative way (Minner *et al.*, 2010). In this case, the teacher's knowledge and skill set must be employed to guide learners through the process, not by providing information, but with questioning. Throughout the whole process the learner who is actively engaged in activities carefully planned by the teacher, constantly interacts with the materials or resources, environment and the teacher him or herself. Lastly, the teacher must, at all times, be willing to encourage the learner (García, 2013). The figure indicates that the desired outcome is learners who are engaged, thinking to make meaning, constructing knowledge, sharing and collaborating, and gaining understanding (Fosnot & Perry, 2005; Julyan & Duckworth, 2005; Levy *et al.*, 2011; Minner *et al.*, 2010; Von Glasersfeld, 2005). Ultimately, they should become self-directed learners able to work independently from a teacher (Pritchard, 2009).

For teachers to shift from a transmission approach to IBSE could be quite challenging. I now look at the need for teacher professional learning (TPL) to equip and prepare teachers to follow and implement IBSE.

### 3.5.5. The need for TPL to equip teachers in IBSE

In my previous chapters I made a case for the need for educational reform. Educational reform will not take place unless teachers' attitudes and practices change (Anderson, 2002; Garm & Karlsen, 2004). Therefore, any change within the school educational arena must start with the teacher and preparing the teacher for that change. In order to get Science teachers to make a shift to IBSE, a clear process must be followed to bring about this change and TPL would be the best context in which to place such a process.

I make a case for the need for focussed TPL in IBSE by giving a short summary of the benefits of IBSE in the classroom, pointing out what is required for a shift to IBSE and highlighting the barriers to change that teachers have. I then proceed to consider the various aspects of TPL that are required to provide effective professional learning on IBSE to teachers. Lastly, I provide a framework for a TPL approach specifically for IBSE.

#### *a. Benefits of IBSE in the classroom*

IBSE in the Science classroom could bring about positive educational reform. In section 3.4.1. IBSE was discussed fully and below is a summary of the key benefits of IBSE:

- The Science classroom should encourage a deeper understanding of the workings of the physical world and through applying IBSE in the classroom, this can effectively be achieved (Julyan & Duckworth, 2005);
- IBSE also leads to significant cognitive development (Shamsudin *et al.*, 2013);
- IBSE recognises and build on learners' prior knowledge. When the learner makes such connections it can only lead to meaningful learning (Driver *et al.*, 1994); and
- IBSE includes cooperative learning styles like sharing ideas, debates and defending views allowing the learners an opportunity to further develop and sharpen communication skills (Muianga *et al.*, 2018).

Furthermore, teachers who have had some experience with inquiry-based teaching believe that it has great potential to overcome learning difficulties and motivate learners (Levy, Lameras, Mckinney, & Ford, 2011). Studies show that scientific inquiry-based teaching is effective in making learners more interested in studying Science (NASAC, 2015). IBSE can also be the catalyst needed to encourage more participation of girls in Science (NASAC, 2015). It would therefore be worthwhile for teaching and learning in the classroom to give Science teachers a learning opportunity in IBSE.

#### *b. Teachers need a framework for IBSE*

Maintaining that this approach to teaching has many educational benefits and emphasising its effectivity still does not inform the teacher on how to implement it. Most teachers, even though they would be proponents of inquiry in Science education, lack a framework to inform their inquiry instruction methodology (Bell, Smetana, & Binns, 2005). Over the years, studies reviewed the effectiveness of inquiry-based programmes in schools. It was concluded that inquiry-based approaches are difficult for teachers to implement as implementing IBSE require a departure from teachers' current practices.

#### *c. Teachers need to change their perspective and role*

Inquiry-based teaching must be addressed in relation to scientific inquiry, which includes the scientific method and inquiry-based learning, and therefore speaks to learning through curiosity. This means that teacher training should be focussed on both scientific skills required for scientific inquiry as well as teaching and learning skills to ensure that educational goals are reached (Penuel & Means, 2004). Whether teachers make a shift to inquiry-based teaching is largely dependent on the teachers' understanding of Science as inquiry and learning as inquiry (Anderson, 2002). This will require guiding teachers into learner-centred inquiry and learner-centred instruction, which demands an entirely new perspective on teaching Science and his or her role as a teacher.

### *d. The dual role of the teacher when implementing IBSE*

Primarily, teachers have been trained to transfer content knowledge, and therefore the focus of most TPL programmes have been largely placed on subject content and how to effectively transfer subject content. To prepare teachers for inquiry-based teaching they must learn how to engage with learners to both direct the learners' activity as well as maintain authority in the classroom. This, together with ensuring that the learner still acquires adequate content knowledge, will require careful planning and preparation (Shamsudin, Abdullah, & Yaamat, 2013). This means that when preparing teachers for inquiry-based teaching, the focus of TPL has to shift from filling knowledge and skills gaps, to a systematic process facilitating change in teachers' attitudes, beliefs and practices (McDonald, 2011).

### *e. Barriers to change – internal and external*

Teachers experience both internal and external barriers when confronted with change such as adopting new teaching approaches like an inquiry-based approach to teaching (Johnson, 2006). When considering the use of an inquiry-based approach, teachers will become aware of the fact that an entirely new set of teaching skills is required, and this could, for some, result in an internal struggle. One significant difference between transmission mode teaching and inquiry-based teaching is that inquiry-based teaching necessitates an element of social interaction between teacher and learner, which is often intimidating for the teacher (Shamsudin *et al.*, 2013). While internal barriers have their origin in the values and beliefs of teachers, external barriers to teachers adopting an inquiry-based approach to teaching arise in three categories, namely technical, political and cultural (Johnson, 2006). Some of the technical aspects include preparing teachers to take on a new role, designing new classroom activities and assessments, and guiding learners to take on a new role (Anderson, 2002). The political arena will include matters like inadequate in-service training, lack of resources, parent resistance and unresolved teacher conflicts, while the biggest barriers in the cultural category can be traced back to established values and beliefs (Anderson, 2002; Johnson, 2006).

Promoting changes to teaching practice must be supported by insight into the beliefs and values of teachers as this will pre-empt conflict and resistance to change which, if not avoided, could result in merely surface changes in practices and not the deep change that is desired (Smyth, 2003). Theory, beliefs, values and understanding shape what we do and how we do it. Teachers, both as learners themselves and in their training to become teachers, have not experienced Science education as inquiry. Their own experience was probably largely limited to the transmission mode and this leads to them to teach in a way that was modelled to them. Therefore, in order to move teachers towards an approach of inquiry in their classrooms, a shift in these four areas is required for change to follow (Anderson, 2002). To change the beliefs and approach of a teacher towards teaching and learning, one has to provide the teacher with frequent opportunities, within their own teaching context, to implement and practice the new approaches (Johnson, 2006). TPL programmes, which provide learning opportunities for teachers in inquiry-based teaching, must take cognisance hereof.

### *f. The way forward*

From the abovementioned it is clear that more specific training, support and mentoring for teachers are vital for effective implementation of IBSE (Alake-Tuenter *et al*., 2012; Fitzgerald, McKinnon, Danaia, & Deehan, 2016; Onwu, 2015; Penuel & Means, 2004; Ramnarain, 2014). Since the IBSE approach contains so many aspects to consider, it requires careful, detailed planning, and this demands that teachers are given or have access to continued support. This begs the question: what are the key considerations that must be included in TPL programmes which promote IBSE?

Creating opportunities for teachers to learn though first-hand experience can have far-reaching benefits in preparing teachers for instruction in IBSE. In order to promote conceptual change within teachers, TPL programmes must provide pedagogical experiences that will challenge and change the teachers' conceptions of teaching and learning in Science, as well as provide opportunity for self-reflection on their pedagogy. Reflection leads to teachers gaining conceptual understanding of their learners, and provides insight into how pedagogical adjustments can be used to address misconceptions learners might hold (Cakir, 2008). Where teachers have conceptual problems in areas of content, TPL programmes should also focus on refreshing and consolidating difficult Science topics by providing learning experiences for teachers (Cakir, 2008).

Another important element of TPL, which could greatly assist in bringing about a shift and ultimately lead to teaching reform, is collaboration. By encouraging and allowing the opportunity for collaboration among teachers in the school context, change in teaching practices are supported and ensured (Johnson, 2006). Teachers are inclined to be more disposed to practice than to theory, and they also tend to record and relay what they have learnt in practice as narratives and stories rather than as theories (Anderson, 2002). A collaborative setting provides good opportunities for teachers to interact with their peers so that they can share and learn from what happens in practice (Anderson, 2002). Practitioners striving to implement inquiry-based teaching find collaboration between teachers to be of great value as it gives such practitioners a support base as well as a context within which to reflect (Anderson, 2002:10; Bell *et al.*, 2005). This leads to the development of new understandings followed by the adoption of new classroom practices. Therefore, it would be beneficial for any TPL programme that specifically focusses on introducing new teaching and learning strategies and methods to make collaboration a key feature of the programme.

### 3.5.6. A framework for learning about the IBSE approach

Following on the above reasoning, I propose the following framework to introduce and start a process of learning about IBSE. The framework is made up of three distinct phases, namely Awareness, Learning and Growth. It is important for teachers to realise the following: firstly, that there is a need to consider change, and secondly, which alternatives are available. The first phase 'Awareness', will focus on presenting the facts that will indicate why change is required as well as information about available practices that could bring about the desired effect to teachers. The second phase 'Learning', will focus on teachers themselves making the necessary cognitive adjustments to accommodate new approaches in their teaching skill set. Since changing to IBSE requires such a big leap, learning about IBSE is best achieved by giving teachers an experiential experience. In this phase they will become the 'learners', and experience IBSE from a learning perspective. They will be taken through the IBSE process and with their prior knowledge of learners, their own practices and how learners respond to it, they will reflect on the feasibility of the new approach. In the third and final phase of my framework 'Growth', teachers will continue to learn about and experience IBSE, but this time from a teaching perspective. In the growth phase teachers will take their positions as teachers and attempt to implement the new approaches they have learnt. They will have access to assistance through mentoring and collaboration with one another. This component will be completely practiced-based as teachers will implement IBSE within their own classroom context. This will give them the opportunity to sharpen their IBSE skills. I present a visual representation of this collaborative, practice-based framework in Figure 3.4 followed by a summary of each phase.

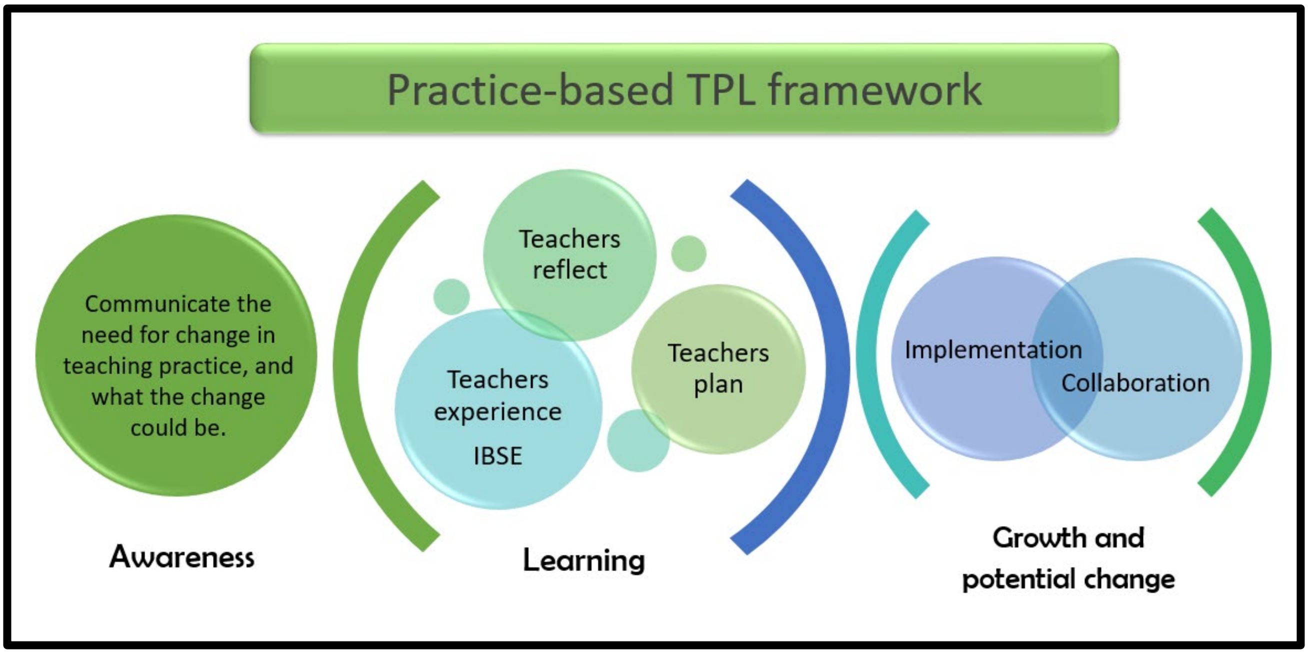



**Figure 3.4: Practice-based framework to introduce Science teachers to IBSE (Own diagram)**

Phase 1: Awareness

- Present to teachers the need for change that is required in teaching practice; and
- Present IBSE as an alternative approach.

Phase 2: Learning

- Take teachers through an IBSE learning experience themselves;
- Teachers reflect on the process; and
- Teachers share ideas and plan.

Phase 3: Growth (Practice-based)

- Teachers implement IBSE in their classes with access to support and opportunity to share ideas with one another through mentoring and collaboration;
- Identify further learning needs to strengthen understanding and skill in IBSE; and
- Teachers continue to implement IBSE in their classes, again with access to support and opportunity to share ideas.

TPL is the crux if change within the domain of school education needs to be effected (Anderson, 2002:1). It is not easy to change from one way of teaching to another as this involves the teacher having to abandon his or her safety of knowing what is familiar and comfortable (Johnson, 2006:151). Ongoing, effective teacher learning is required to ensure a shift towards inquiry-based teaching and learning and for the effective implementation thereof.

## 3.6. Implications for the South African context

South Africa needs to pay serious attention to strategies to improve the quality of education in the country (Reddy *et al.*, 2012; Spaull, 2013; Van der berg, 2015). Changes in pedagogical approaches could, amidst continued inequalities and lack of resources, be an answer to moving closer to achieving educational outcomes. IBE and IBSE have delivered good results in terms of deep learning, understanding, developing critical thinking skills and nurturing lifelong learning (Bell & Linn, 2000; Muianga *et al.*, 2018; Shamsudin *et al.*, 2013). These are all key skills required by citizens in order for a country to become a contender on a global level (Kodrzycki, 2002).

So far only one project in line with IBSE principles has been piloted in SA (Onwu, 2015). Furthermore this project was located only within the primary schools context (Onwu, 2015). In this study I focus IBSE at the secondary school level. Science is a compulsory subject at school up to grade nine, after which learners make subject choices. Statistics have shown that few learners opt to take Mathematics and Science as schools subjects in grades 10-12 (DBE, 2017, 2018). One of the reasons for this is that the sciences are perceived as difficult and subjects in which good results are hard to obtain. I believe that introducing IBSE to learners in the lower secondary school grades, can result not only in the learner enjoying Science as a subject, but can also assist in the development of this particular learning tools and skills. These skills could ensure that learners progress well and could lead to learners being more able and more confident in their abilities (Geier *et al.*, 2008; NASAC, 2015). Introducing IBSE in the FET phase of schooling in SA, could lead to senior Science learners ultimately becoming those critical thinkers and problem-solvers that the country needs.

However, the first point of entry for IBSE to be implemented in the classroom, as have been highlighted above, is the teacher. The teacher would be the catalyst that is required in the classroom to initiate the radical shift away from traditional teaching methods which leave learners passive, disinterested and often disengaged from the learning process, to IBSE which is active, learner-oriented and which more effectively results in developing critical thinking, problem-solving individuals (Anderson, 2002; Bell *et al.*, 2005; Garm & Karlsen, 2004). It is for this reason that I focus my study on the secondary school teacher by developing an IBSE TPL opportunity for Natural and Physical Sciences teachers. Learning opportunities for teachers are key as they assist to "bridge the gap between curriculum intention and classroom implementation" (Onwu & Stoffels, 2005:89).

## 3.7. Conclusion

From the above it is evident that even though concepts of constructivist learning have been propounded almost 100 years ago, most schools are still characterized by the more rigid mode of transfer of knowledge and skills. With policies around the world calling for reform in education through a shift to inquiry, especially in Science teaching and learning, a more concerted effort must be made to implement and sustain IBSE. This can only bring benefits to education worldwide and in South Africa, strengthening deeper learning, developing critical thinkers and conjuring more interest in the Sciences.

The teacher is the key to what happens in the classroom. Shifting to IBSE in the Science classroom will require firstly introducing it to the teacher since it is vastly different to traditional instructional methods. Fundamentally it demands a change in teacher beliefs, roles and practices. Effective and supportive teacher learning in IBE and IBSE to equip the teacher to make the change from existing practice, is essential. Furthermore, provision must be made to guide teachers with ongoing support to guarantee successful implementation of IBSE. In the next chapter I describe the model which I designed and followed to introduce teachers to IBSE. I also explain how I went about exploring their perceptions before and after this process in an attempt to investigate the effect this intervention had.

# Chapter 4: **RESEARCH METHODOLOGY**

## 4.1. Introduction

In this chapter I discuss the philosophical orientations of research namely ontology, epistemology and methodology. These elements give shape and definition to the process of an inquiry and thus stand central in the discussion of the nature of social science research (Tuli, 2011), and of a particular research project.

I firstly define my ontological and epistemological orientations, and then set out to discuss various research paradigms and position my research within the most appropriate paradigm. Having done so I present the methodology of action research by discussing its features, and why it is suitable for the purpose of this study.

I then explain the methodology that I followed and describe the design of my study by identifying my data collection tools and explaining step by step how I went about setting up the study. I also explain how I located the data collection tools within the design to generate evidence, and the data analysis procedure that I used so that I could examine the evidence in order to answer my research questions.

I conclude this chapter by explaining how I ensured that the study was done in an ethical manner, and that my findings are trustworthy. I also highlight the limitations of the study.

## 4.2. Philosophical orientations and research paradigms

### 4.2.1. Philosophical orientations

For every researcher it is advisable to consider one's investigation carefully before embarking on any action. This is due to the complex nature of our world, which is influenced by many factors. The process of considering one's research includes, first and foremost, deep reflection on the philosophical orientations of the research namely ontology, epistemology and methodology. A philosophical origin or theoretical framework provides a route or a map for social and educational research (Le Grange, 2004; Plowright, 2011), and clarifies the assumptions on which the research activity is based. The theoretical framework, which is different from a theory, is also known as the research paradigm and influences the way knowledge is considered and understood (Mackenzie & Knipe, 2006). The responses to ontological, epistemological and methodological questions define the paradigm of the research endeavour (Guba & Lincoln, 1994; Wahyuni, 2012). Ontology relates to the nature of the world and so represents the researcher's stance to how reality is perceived while epistemology relates to the theory of knowledge and how knowledge is acquired. Research choices made and research actions taken by a researcher are informed by both ontology and epistemology (Tuli, 2011).

One way in which to view reality is to regard external reality as stable, for example, that the laws governing the universe are set. This ontological orientation is known as the realist stance (Wahyuni, 2012). The way in which information is gathered in this case is by the researcher being an objective, detached observer who gathers measurable information. This epistemological orientation is known as positivism (Wahyuni, 2012).

An alternative ontological orientation is one of constructivism, where reality is seen as being constructed by the participants, and when the participants' internal and subjective experiences are being considered. Here the researcher is empathetically and also subjectively or inter-subjectively immersed in the research. This is regarded to be an interpretive epistemological orientation, demanding that the researcher constructs his/her own version of the events (Wahyuni, 2012). Over the years a number of research paradigms which are aligned to different philosophical orientations have developed.

### 4.2.2. Research paradigms

The positivist paradigm has been the dominant research paradigm for many years. Positivists use observation and measurement in an attempt to test a theory or describe an experience (Mackenzie & Knipe, 2006). Positivism states that science is based on the accumulation of observable facts (Mouton, 1996). Research conducted in the positivist paradigm is experimental in nature whereby repeated measurements or observations are applied to prove or compare. Positivist research is mostly associated with the collection and analysis of quantitative, i.e. numerical data (Mackenzie & Knipe, 2006). Positivism makes the assumption that the social world can be studied in the same way as the natural world by applying methods that are value free and providing explanations of a causal nature (Mackenzie & Knipe, 2006).

However, the positivist paradigm can be restrictive for the purpose of social or educational research. This led to the development of other paradigms that would be better suited to social and educational research. The various paradigms, alternative to the positivist paradigm, allow for different angles from which to approach the research and are more constructive in nature. One particular paradigm is not necessarily better than the other or a replacement for another (Le Grange, 2004). The paradigm which is most appropriate and fit for the research study and what it wants to achieve should be selected. I now continue to briefly introduce other research paradigms and motivate the choice of paradigm for the purpose of my study.

The post-positivist paradigm is one such new philosophical paradigm which arose from the positivist paradigm after World War II (Mackenzie & Knipe, 2006). This theory makes the claim that “causes probably determine outcomes” (Creswell, 2009:7). While still closely related to the positivist paradigm in its activities, post-positivism recognises that when we study human behaviour and action, our claims about knowledge cannot be positivist (Connole, 1993; Creswell, 2009). Post-positivists assume that research is affected by a variety of theories, and so post-positivism is intuitive and holistic, inductive and exploratory, resulting in evidence that is qualitative in nature. (Mackenzie & Knipe, 2006). That means that knowledge is constructed through interpretation and is not just there waiting to be discovered. Consequently, the post-positivist paradigm leans towards the constructivist or interpretive paradigm (Mackenzie & Knipe, 2006; Wahyuni, 2012). However, where post-positivists propose objectivism and a single truth, interpretivists reject this. The interpretivist researcher holds the opinion that reality is constructed by people and their perceptions of it (Wahyuni, 2012), and that the background of the research participants has an impact on the research. Therefore, interpretive researchers usually do not start off with a theory, but they rather "generate or inductively develop a theory or pattern of meanings" (Mackenzie & Knipe, 2006:3).

Another common research paradigm is the transformative or critical paradigm. Even though it is closely related to the interpretive paradigm, the transformative paradigm includes the dimension of politics to adequately address issues pertaining to social justice and marginalised groups of people (Mackenzie & Knipe, 2006). This paradigm allows for freedom from limiting social forces so that knowledge obtained through the research can lead to social action (Connole, 1993). It contains an action agenda for reform "that may change the lives of the participants, the institutions in which individuals work or lives, and the researcher's life" (Creswell, 2009:9). Therefore, one can say that the transformative or critical paradigm is emancipatory in nature. The strength of critical research is that it aims to bring about reform and change. It also does so without further marginalising participants by allowing the participants to have a voice.

The post-modern worldview is another paradigm which is often used. This paradigm is described by Creswell (2009) as a participatory worldview or paradigm since the research participants can be asked to assist in designing the research. Here the aim of the research is to empower the participants so that they can speak for themselves without the researcher imposing his or her interest on those of the participants (Connole, 1993).

The paradigms I referred to above each has its own guidelines and sets of prescriptions, which can be limiting to research (Le Grange, 2004). A paradigm alternative to the ones traditionally adhered to, is pragmatism. What distinguishes pragmatism from other paradigms is the fact that it is based on an integrated perspective. This perspective supports the research process rather than linking a specific methodology to a specific philosophy (Plowright, 2011). Knowledge is viewed as relative. The pragmatic researcher also acknowledges that there is a possibility of knowledge being incorrect. Therefore, it holds a further view that one cannot, at any point, reach a final indisputable understanding of the world but rather that "beliefs are work in progress and subject to change" (Plowright, 2011). Table 4.1 provides a summary of the various features and forms of research in the paradigms discussed above.

**Table 4.1: Features and forms of various research paradigms**

| Positivist/<br>Post positivist | Interpretivist/<br>Constructivist | Transformative/<br>Postmodern | Pragmatic |
|---|---|---|---|
| Experimental<br>Quasi-experimental<br>Correlational<br>Reductionism<br>Theory verification<br>Causal comparative<br>Determination<br>Normative | Naturalistic<br>Phenomenological<br>Hermeneutic<br>Interpretivist<br>Ethnographic<br>Multiple participant meanings<br>Social and historical construction<br>Theory generation<br>Symbolic interaction | Critical theory<br>Neo-Marxist<br>Feminist<br>Critical Race Theory<br>Freirean<br>Participatory<br>Emancipatory<br>Advocacy<br>Grand narrative<br>Empowerment issue oriented<br>Change oriented<br>Interventionist<br>Queer theory<br>Race specific<br>Political | Consequences of action<br>Problem-centred<br>Pluralistic<br>Real-world practice oriented<br>Mixed models |

**(Source: Mackenzie & Knipe, 2006)**

When doing social science research, and in my case research in education, one has to bear in mind that society is made up of people with social interrelationships, opinions, customs, habits, lifestyle, conditions of life, communities and many other features which can be the focus of study (Walliman, 2006). Therefore, it is important to carefully consider the above-mentioned paradigms when embarking on a study as the choice of paradigm establishes the intent, motivation and expectations for the research (Mackenzie & Knipe, 2006).

### 4.2.3. Theoretical framework for this study

The purpose of my research is to investigate whether teachers' introduction to IBE, a method of teaching Science other than the traditional transmission mode, will change their perceptions of Science and the teaching thereof. This fits well into the transformative or critical paradigm. I have chosen this paradigm because of its emancipatory nature which can lead to reform and social action

(Scotland, 2012). The transformative action element of this paradigm is in line with my expectation that my study will lead to a change in teachers' perceptions and practices of Science teaching. The critical aspect will come into play when reflecting on the current practices of the research participating teachers (RPTs) and using this information to plan the process to be followed to introduce them to IBSE and to design the training. By considering the information gathered from the RPTs, the critical paradigm will therefore provide room for the voices of the RPTs. Other features of this paradigm, which align well with my study, are that it is participatory, empowering, issue- and change-orientated, as well as interventionist. One has to keep in mind though that the change hoped for may only occur to a minimal extent or not occur at all. However, while the particular action research may not lead to observable change, the participants would have been made aware of an issue, situation, or problem and alternative options. Table 4.2 below shows how my study aligns with the features I highlighted.

**Table 4.2: Alignment of the research study to the transformative/critical paradigm**

| Features of the transformative/critical paradigm | How it aligns with this study |
|---|---|
| **Participatory** | Teachers will actively participate in the research process by undergoing training, by having a voice and their input will be used to inform further planning. |
| **Emancipatory** | The study aims to liberate teachers from set teaching ways i.e. teacher-centred classroom approaches, and to open their minds to consider innovation in teaching. |
| **Empowerment** | By introducing teachers to IBE they will be empowered with new pedagogical skills. |
| **Issue- and Change-orientated** | The study deals with a specific issue, which I aim to change (teacher perception and practice of Science teaching). |
| **Interventionist** | The research process includes a number of interventions with the objective of changing teachers' perceptions and practices in teaching Science. |

**(Own table)**

Research in the transformative critical paradigm, which I have chosen to work within, calls for qualitative data. Qualitative data is gathered in a social setting and is complex. It relies on personal contact and a partnership between the researcher and participants. A qualitative study can be an empowering process for the participants and one in which they can freely express their views. Qualitative methodologies are usually inductive, which means they are oriented toward discovery and process, and are concerned with deeper understanding of the research problem in its unique context (Tuli, 2011). For the purpose of this study which is positioned in the transformative, critical paradigm, and gathered qualitative data, I decided to use an action research methodology due to the flexible and cyclical nature thereof. In the next section I discuss action research as a research methodology and argue the suitability of action research as a methodology for this study.

## 4.3. Action research

### 4.3.1. Action research as a methodology

Research methodology and research methods are two distinct concepts. A few definitions help to clarify the distinction. According to Wahyuni, (2012:72) "a methodology refers to a model to conduct research within the context of a particular paradigm". Mertens (2010:14) states that: "Methodological assumptions constitute the philosophical basis for making decisions about appropriate methods of systematic inquiry". A research method, on the other hand, consists of a set of specific procedures, tools and techniques to gather and analyse data. Mackenzie and Knipe (2006:5) distinguish between the two by simply stating that "methodology is the overall approach to research linked to the paradigm or theoretical framework while the method refers to systematic modes, procedures or tools used for collection and analysis of data". In other words, the research methods are the practical ways in which research is conducted (data is collected and analysed), while the methodology is the broad approach to the research project (Wahyuni, 2012). I continue in this section to discuss action research as a methodology whereas the research methods that I used are discussed in Section 4.4.

According to Noffke and Somekh (2009), action research is an applied research methodology. Importantly, action research can be described as a research strategy designed to find the most effective way to bring about a desired social change or to solve a practical problem, usually in collaboration with those being researched (Wicks, Reason & Bradbury, 2018).

Kurt Lewin, a social psychologist, is believed to have introduced this research approach and coined the term action research in the 1940's. Lewin did so "to address social system change through action that is at once a means of effecting change and generating knowledge about the change" (Cole, Purao, Rossi & Sein, 2005:4). He departed from the decontextualized nature of research by moving away from surveys and statistical approaches and instead involving participants in a cyclical process of fact finding, planning, exploratory action and evaluation (Somekh & Zeichner, 2009). This cyclical nature of action research allows for reflection and an opportunity to use findings to change or set a new course for the research process and, in so doing, bring about change (Ebersohn *et al.*, 2007). This must not be confused with design-based research, which is closely related to action research. Design-based research often has elements of action research for instance, having a cyclical nature, however, it differs from action research in the sense that it does not have a political nature, and focuses on artificial and not natural phenomena (Cole *et al.*, 2005). Artificial phenomena mainly refer to technological and information systems.

As implied by its name, action research has two components, one of which is research, a higher order academic activity with the quest to generate knowledge. The other is taking action with the aim of effecting change. This means doing something concrete to address a practical problem (Somekh & Zeichner, 2009).

### 4.3.2. Features of action research methodology

Action research is a practice-based research methodology as it is normally conducted by practitioners who also see themselves as researchers (McNiff & Whitehead, 2010). Traditionally research is regarded as an 'outsider' activity since the researcher adopts a position from outside the context which is being studied. In action research the researcher, who is also the practitioner, finds him- or herself an insider, being positioned within the situation and having, to some extent, influence over what is happening in the context of the study (McNiff & Whitehead, 2010).

Noffke (1997) highlights three foci of action research namely the political, professional and personal dimensions. These three foci result in three different motivations for action research. The political strives to bring about action, which in turn leads to change that could hopefully result in greater equity and democracy. The professional seeks the production of knowledge that could benefit other educators, while the personal aims for a better understanding of one's practice within the contexts in which one operates (Noffke, 1997; Somekh & Zeichner, 2009).

The nature of my project touches on each of the above foci. On the political front I would want to see that by using this approach a shift occurs by which some of the barriers which prevent educational equity in a still divided South Africa are overcome. On the professional level I foresee that this investigation could contribute to the production of knowledge which could be useful to educators to ensure more effective implementation of the Science curriculum in order to reach the goals and aims for Science education as set out in the CAPS document. Thirdly, I use this opportunity to give teachers the opportunity to receive training and guidance (Du Plessis, 2015), and to reflect on their practice, providing them with tools which could enable them to create more effective and rewarding teaching experiences, and in so doing, bringing about change. The required change is the improved interest amongst learners in the subject of Science and an improved learner performance in Science. Personally, I anticipated that I would come to a better understanding, and gain more knowledge and insight into how I could guide and support teachers during future TPL activities, in making the shift from a more traditional teacher-centred approach to a learner-centred approach in the teaching of

Science. This would allow me to inform thinking and practices within the SUNCEP TPL component too.

Action research has a cyclical nature. This allows for reflection by the researcher on what has been done and to make decisions on how to take the process further. The process consists of a number of stages which link with one another in a way which makes the research both layered and cyclical in nature (Ebersohn *et al.*, 2007). The various stages include research, planning, taking action and reflection. These stages can be applied in one or more cycles.

Action research can have different contextual conditions. It can either be done as an individual project or a collaborative group project (Somekh & Zeichner, 2009). Action research is also increasingly being used within pre-service and in-service teacher training programmes as well as school reform projects due to its nature of facilitating action and ultimately change (Noffke, 1997). For the purpose of this project I, as an individual researcher, investigated the role of TPL within educational reform for the purpose of improving the practice of both teachers and my own practice as TPL practitioner. McNiff, Lomax and Whitehead (2003) speak about "putting the 'I' at the centre of the research" as one of the main features of action research. This allows the researcher to be the object of the research, to own the claims and to take responsibility for actions recognising that her/his ideas could be wrong and having the freedom to change (Mc Niff, Lomax, & Whitehead, 2003).

The many forms and variations of action research open up the possibility for it to be contextualised within the community it is utilised in, taking the culture of that community into consideration. In this case the community was a district of the Western Cape Education Department (WCED) in South Africa. Due to the history of South Africa schools in any particular area can vary significantly on the basis of socio-economic standing. This standing affects all components of the school: the financial strength of the school, which determines the resources available to teachers and learners, the teachers, learners and parent bodies. This is a direct result of the fact that various population groups in South Africa are still largely located within their historical group areas. So even though schools from the same district were chosen for this research project, one could expect significant differences in how they operate and what they are capable of in terms of implementation.

There are different types of action research which include cooperative inquiry, participatory action research, emancipatory research, and insider action research (Noffke & Somekh, 2009). My specific design leans towards emancipatory research whereby my intention is that the research will empower those who participate in the research (Rahman, 2008). This was done through introducing teachers to and training them in the IBSE approach to the teaching of science.

The aim of this project was to initiate a change not only in teacher practices but also in teacher perceptions. The identified challenges encountered in Science education demand a change in how Science educators go about their business in the classroom. Due to the nature of action research, this methodology allowed for the RPTs to experience a possible change by actively participating in a process of learning themselves, evaluating if change is needed and how it can make a difference.

### 4.3.3. Suitability of action research methodology for this study

The educational problem that I identified and wanted to address in this research project, is the current situation where learners avoid taking Science as a subject or where those who do take Science seem to struggle to perform well in this subject. As a Science teacher myself I have always aimed to allow learners to experience Science and in so doing contextualised the subject for the learners. Whilst working as a Physical Sciences facilitator for SUNCEP I have had an opportunity to further experiment with pedagogies which allow for more learner-centred teaching approaches. In the SciMathUS programme we followed a hybrid problem-based learning approach and as a TPL facilitator with SUNCEP I was introduced to the IBSE approach. I planned, therefore, to introduce teachers to this new approach to teaching Science and at the same time to establish whether this process will influence the teachers' perceptions of Science and its teaching. I therefore set out doing this research with the aim of shifting Science teachers' perceptions and practices of Science teaching. This ties in with the transformative impact of the action research methodology. I hoped to achieve this by offering teachers guidance and support in effective Science teaching strategies.

South Africa as a country has undergone major changes in recent years and is still undergoing much needed change. Learners from groups who have previously been separated are starting to interact and function together. Action research is described as having a boundary-crossing nature making it a particularly well-suited methodology for educational transformation in rapidly changing communities (Somekh & Zeichner, 2009). Since educational transformation is ongoing in South Africa action research is a good fit for this context.

On a more local level action research is a methodology which is closely embedded in the values and culture of its participant-researchers. This is possible because of its flexibility, and in this way the methodology allows for the research to be highly applicable to its local context (Somekh & Zeichner, 2009). This is very important when working with teachers, especially since participating in the research would be demanding of their already limited time. Thus, it is important for teachers to see the relevance and value of participating in the research and acknowledge that it is not a waste of time. Action research makes it possible to take participant needs and contexts into consideration as it strives to improve current practice.

This model provides the ideal setting within which to perform this study with which I hope to use the results to not only inform my own practices within SUNCEP's teacher professional learning (TPL) programmes but also to impact and inform the school Science education community, starting with my research participants. My intention is that by doing this it could help to raise the profile of Science in schools to a position where more learners will take an interest in Science as well as demonstrate good performance in this subject. As invading the spaces of learners and teachers may not be well received, the opportunity given by action research of being able to involve the participants could result in participants more readily giving their cooperation. This also ties in with my aim to affect teachers in a way that will cause them to reconsider their practices and make some changes. This would require reflection, which is included in the action research process. I now proceed to discuss the various research methods I have selected for this action research project.

## 4.4. Research methods

I now introduce the research methods which I have chosen to use for my data collection. In Section 4.3.1. the difference between research methodology and research methods was discussed and research methods were described as the various ways used to gather information for the purpose of doing research.

Since the study is focussed on introducing teachers to an alternative approach to teaching and learning Science, and thus considers teachers' perceptions and teaching practice, I opted to gather qualitative data. For this purpose I decided to use observations, individual interviews and focus group discussions, which are the data gathering methods most widely used for qualitative research (Tuli, 2011). Furthermore, these research methods are all suitable to the transformative or critical research paradigm which normally demands a variety of research methods. (Mackenzie & Knipe, 2006; Scotland, 2012).

### 4.4.1. Observations

In action research observation is an important method of gathering information as it requires the researcher to be present in the environment that is being studied. The researcher him- or herself makes use of sensory tools to gather data (Jones & Somekh, 2005). Due to the complexity of human nature and behaviour, gathering data in this manner is both subjective and challenging as it is not always possible to record every detail observed (Jones & Somekh, 2005). With the wide array of technological devices that are currently available, one could also capture observations using these devices for later reference.

There are different types of observations two of which are structured observations, and unstructured observations. The structured observation makes use of a schedule drawn up by the researcher with predetermined categories and in accordance with the expectations of the study (Jones & Somekh, 2005). This can be helpful as it can guide the researcher to focus on specific aspects relating to the study, and should more than one sample of the same population be observed, it will assist in observing similar aspects making comparisons possible. Unstructured observations requires the researcher to take notes as events unfold. In this case the researcher is guided by prior knowledge as well as the research objectives (Jones & Somekh, 2005).

In this study the first type of evidence was gathered by using structured observations to observe RPTs while teaching a lesson. Observations were done using an observation schedule before the introduction of IBSE as well as at the end of the process. The purpose of the lesson observation prior to the learning session was to get a first-hand experience of the teachers' original approaches to the learners and their teaching practices. Post the introduction of IBSE to the RPTs lesson observations were used to see whether the teacher's practices indicated any changes and if so, to what extent. The same observation schedule (Appendix 6) was used for the pre- and post-observations.

### 4.4.2. Interviewing

Interviews are used to get information and determine perceptions about the problem or situation being studied from the participants (McNiff & Whitehead, 2010). It is important to communicate the purpose and the aim of the interview clearly to the participants. Participants should then be asked if they are willing to participate and indicate this by means of signing a consent form. They must also have the assurance of their anonymity (Wahyuni, 2012). Care should be taken not to influence the participants' responses and the researcher should refrain from coercing participants to think and respond in a particular way when questioning them (McNiff & Whitehead, 2010).

Interview schedules (Appendices 5 and 8) had been drawn up beforehand in line with the research objectives and interviews were held with individual RPTs at key stages of the project. I set up appointments with each participant individually and recorded the interviews using my smart phone and transcribed the interviews thereafter. The interviews served a number of purposes. Firstly, I used them to get to know the teachers: who they are, their qualifications, experience and general insight into their current experience as a teacher. The interviews prior to my introduction of IBSE training were also used to get an initial insight into the teachers' perceptions of Science as a subject and the teaching of Science, for example, how they generally prepared and conducted lessons. Interviews were also held with teachers at the end of the process, focussing once again on the teachers' perceptions and general approach to teaching. These were compared to ascertain whether the introduction to IBSE had brought about any change in the teachers' perceptions and practices, as well as the RPTs' general views about using IBSE.

### 4.4.3. Focus group discussion

Focus group discussions have a number of advantages over individual interviews, such as providing insight into group norms and opportunities for formation or changing of viewpoints, which is more difficult to do in individual sessions (Schostak & Barbour, 2005). The researcher should keep in mind that focus group discussions are a reflection of a group interaction and not of the individual participants' opinion (Schostak & Barbour, 2005). Generally a focus group would be a sample of a larger group compiled through purposive sampling to give a good representation of the larger group (Schostak & Barbour, 2005).

In the case of this study the focus group discussion included all the participants since the group was small and manageable enough to do so. I made use of a semi-structured interview schedule to guide the discussion. (See Appendix 7). I once again used my smart phone to make a recording of the discussion and then transcribed thereafter.

Focus group discussion transcripts should be considered as texts and not be taken at face value, thus they should be submitted to the same rigour of analysis as other texts when doing research (Schostak & Barbour, 2005). I also requested the RPTs to give written responses to the semi-structured interview schedule. Written responses to an interview schedule are not neutral and can be misleading. One must bear in mind that answers to questions in a questionnaire are neither correct nor incorrect. Two types of questions can be used, namely closed-ended and open-ended questions. Closed-ended questions restrict responses and limit the answer to the boundaries specified by the question, while open-ended questions give the opportunity for a wide range of responses. Even though the responses to open-ended questions are often rich in information, they can be tough and time consuming to analyse (McNiff & Whitehead, 2010). I predominantly made use of open-ended questions (Appendix 7), but not exclusively.

The combination of the various research methods chosen for this research study will not only allow me to make comparisons prior to and after the TPL intervention to answer my research question but also allow for the confirmation within the findings and ensures a measure of trustworthiness to the final conclusion.

## 4.5. Setting up the action research project

### 4.5.1. Context of the action research project

The first step was to ask permission from WCED to work within their schools and with teachers employed by the WCED. I then had to recruit participants for my study. My original plan was to embed this process within a broader Science TPL opportunity offered by SUNCEP. This would have given me the opportunity to work with a group of teachers who have already committed to be part of a teacher learning programme and from which I could invite research participants. However, after my proposal and ethical clearance had been approved, and I was ready to start the project, SUNCEP informed us that no Science learning sessions for teachers had been requested. This was a consequence of education departments, in 2016, deciding to focus their professional learning opportunities for teachers on the areas of Mathematics, English as First additional language and Grade-R, but not Science.

I then requested permission from the SUNCEP director to recruit a group of teachers for the sole purpose of conducting my study and to allow me to run the project. It was important that the participants would be close to the Stellenbosch area to make visits for observations and interviews feasible, as well as for the purposes of networking, support and mentoring amongst the RPTs. I started my recruitment process by contacting subject advisors from the Cape Winelands and Metropole East districts of the WCED.

### 4.5.2. Sampling

I first sent invitations to schools in the Stellenbosch area. From there I did not get anyone who indicated that they were interested. I then shifted my focus to neighbouring areas of Stellenbosch. I invited teachers to an opportunity to receive an introduction to IBSE free of charge. I hoped that a number of teachers would take an interest so that more people could benefit from the introductory learning opportunity about IBSE and then I could recruit my five RPTs from these respondents. I give a more detailed account of my efforts to invite teachers in Chapter 5 Section 5.2. My intention was to consider the profile of all the teachers who responded and do non-probability sampling. This meant that I would not choose participants randomly, but select a group by using specific criteria to meet the aim of my study (Plowright, 2011). For this purpose, I decided to use purposive and convenience sampling. In terms of purposive sampling the main criterion was that the participants must be Science teachers as the aim of my study was to explore the perceptions and practices of Science teachers. Convenience sampling would come into play for practical reasons such as meeting with participants and doing observations; hence, selecting participants based on the geographic area where they work would be a further criterion to be considered.

In order to get a well-rounded picture of the effect of introducing teachers to IBSE, I was required to work with a diverse group. Therefore, further criteria which I considered when choosing the RPTs included age, qualifications, institution from which the qualification was obtained, number of years teaching experience, quintile of school where RPTs are employed, race and gender. I provided a profile of the RPTs to give a description of each RPT and point out the diversity among them in Section 5.2 of Chapter 5.

Once the teachers had been selected and they had agreed, via email, to participate, I set out to start the process. I first approached the principal from each school to inform him or her of my intended study and asked permission for the teacher from the school to participate. I did this by making contact through email explaining what the project would about (See Appendix 3 for email letter). I also made sure that I communicated the purpose and aim of the study to the RPTs, and explained my expectations from them, as RPTs, in person. I communicated that all information would be handled in a sensitive and confidential manner and that all participants would remain anonymous. Each RPT was then asked to sign a consent form (Appendix 4). Since the group consisted of only five RPTs, I planned to apply all the research methods and data collection instruments to each participant.

### 4.5.3. Cycles and stages in an action research project

In order to answer my research questions, I gathered information from RPTs prior to, during and after the introductory learning sessions in order to make comparisons. The cyclical nature of action research, which allows for reflection and reorganising, was ideal for this (Ebersohn *et al.*, 2007) as it allowed me to gather data which I could use to plan the action stages with.

This action research project had three cycles. Cycle 1 was for observation and learning, Cycle 2 focussed on mentoring and further learning, and Cycle 3 concentrated on further implementation and conclusion. Each cycle consisted of the following stages or combinations thereof:

- Gathering information and research, and reflection;
- Action planning; and
- Taking action.

Figure 4.1 below illustrates the 3 cycles and the stages within each cycle.

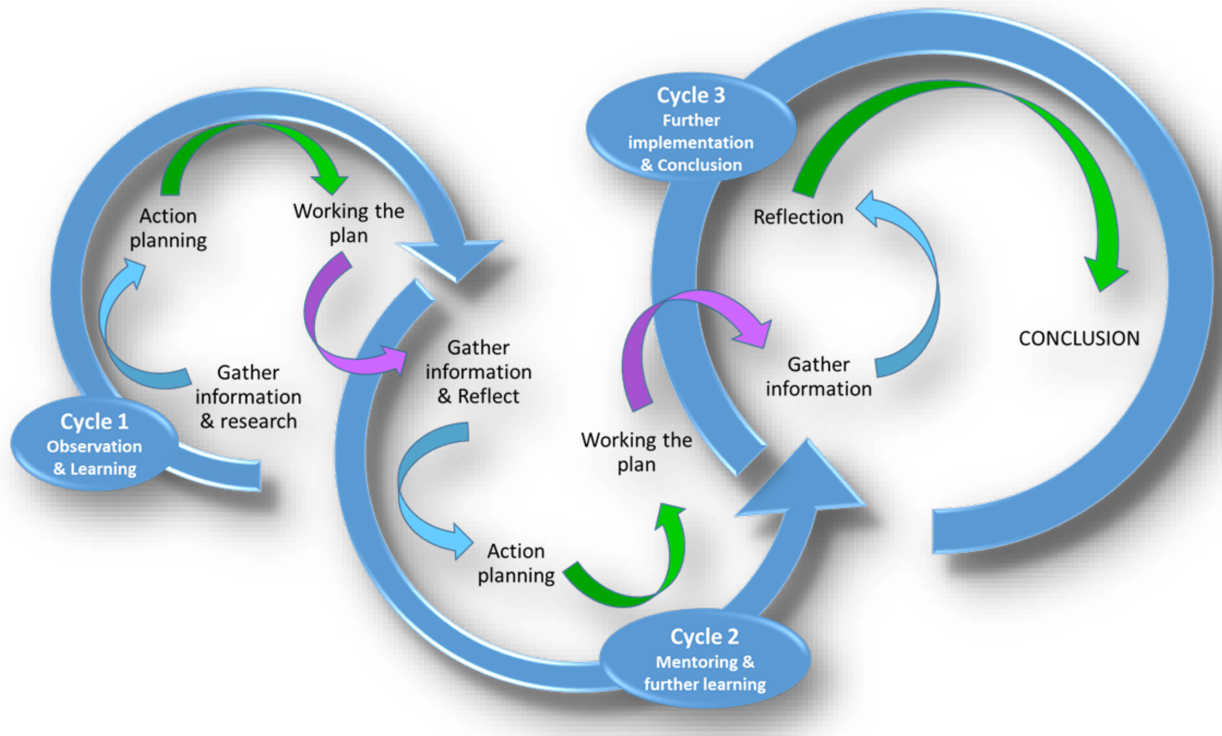



**Figure 4.1: Action research cycles**
**(Own diagram)**

In Cycle 1 RPTs were firstly observed and interviewed to get a view about their initial perceptions and practices of Science and Science teaching. This information informed the initial learning session and assisted in finalising the plan of action for the learning session which was held in the form of a workshop.

In Cycle 2, after the initial learning session, teachers were given some time to implement and experiment with the IBSE teaching approach. After a period of implementation, a feedback session consisting of a focus group discussion and a semi-structured interview was held mainly for the purpose of support, collaboration and mentoring, but also to again gather information to plan the next action. Responses from this focus group feedback discussion session were used to assess the degree by which the RPTs implemented IBSE and the RPTs' understanding of IBE at this point in time. These responses were then used to determine whether RPTs needed further learning sessions and to guide further learning sessions.

Cycle 3 concentrated on gathering data after RPTs have now received a fair amount of learning and support and have been given time to implement IBSE. Another round of interviews and observations were used for this purpose and all data was then considered for analysis to draw final conclusions Table 4.3 below gives a concise picture of the stages and the activities that made up each stage for each cycle of this action research project and also indicates where the chosen research methods fits in. A full description of each cycle will be given in Section 4.6 hereafter.

**Table 4.3: Content of the cycles and stages[14] in an action research process**

| CYCLE | STAGES per CYCLE | ACTIVITIES TO EXECUTE STAGES |
|---|---|---|
| **CYCLE 1**<br>**Observation & learning** | Research & gathering information | Learn about IBSE from literature. Develop introduction sessions for teachers on IBSE. **Interviews** & **class observations** with teachers prior to IBSE intervention. |
| | Action Planning | Further development of material for an introduction learning session in IBSE. Plan a contact learning session for teachers |
| | Taking action | Run the introduction on IBSE session with RPTs. Provide RPTs with e-learning resource, and give RPTs an assignment to implement IBSE in their lessons |
| **CYCLE 2**<br>**Mentoring & further learning** | Gather information and reflect | Have a feedback session in the form of a joint **focus group** discussion with all RPTs. Use a semi-structured interview schedule. RPTs to also complete it in writing. |
| | Action planning | Use responses from the feedback session to plan a follow-up TPL workshop session. |
| | Taking action | Run the follow-up TPL workshop and give RPTs an assignment to further implement IBSE in their lessons. |
| **CYCLE 3**<br>**Further implementation & conclusion** | Gather information | **Interview** and do **class observations** with RPTs post the introductory learning sessions, and implementation of IBSE by RPTs |
| | Reflection | Analyse RPTs responses |
| | Conclude | Draw conclusions |

**(Source: Own table)**

## 4.6. Describing the action research cycles of this study

I now describe and provide detail of each action research cycle and the stages within each cycle.

### 4.6.1. Cycle 1 – Observation and learning

***a) Stage one – Research into IBSE and gather information about RPTs***

Prior to any contact with research participants, I set out to read widely about IBE and IBSE and developed an introductory learning session for teachers on IBSE. The next step was to set up the initial appointments for the interviews and the observations prior to the introductory learning session to IBSE. I have to emphasise that for this initial class observation I visited each RPT only once. I

[14] The colours in the table match the colours in Figure 4.1.

acknowledge that this only gives a tiny glimpse into how the teacher plans and approaches her lessons. Therefore, I did not intend to make a definite call on the RPTs' methods or abilities from the observations that I had made. It was mainly to get an initial insight into each RPT's teaching methodologies, and to see if the RPT included any form of IBSE related activity in the lesson. An observation schedule (which is included as Appendix 6) was used. RPTs did not see the observation schedule beforehand. The schedule focussed on these areas in particular:

1. Lesson structure;
2. Methods (pedagogical) used;
3. Teacher-learner interaction;
4. Subject content; and
5. Learner participation/activity.

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**Lesson observation schedule**

Name of teacher: ______________________ Subject: ____________

Grade of learners: [ ] No. of learners in class: [ ] No. of learners present in class at time of lesson: [ ]

Purpose of observation: ______________________________

| **Lesson Structure** |
|---|
| Reviews previous lesson |
| Introduces current lesson by means of overview |
| Summarises main content points covered |
| Directs learners' preparation for next class |
| Maintains good pace during lesson |
| **Methods Used** |
| Asks open ended questions |
| Asks closed ended questions |
| Provides well-designed materials |
| Employs non-lecture learning activities (i.e. small group discussion, student-led activities) |
| Organises the classroom/seating plan well |
| Invites class discussion |
| Employs other tools/instructional aids (i.e. technology, computer, video, overheads) |
| Delivers a lecture |
| Is inclusive to all learners and their specific needs |

| **Teacher-learner Interaction** |
|---|
| Actively encourages learner participation |
| Monitors learner understanding |
| Involves a variety of learners |
| Listens to learners and responds appropriately |
| Demonstrates awareness of individual learner educational needs |
| Ensures an environment that is conducive to learning |
| **Subject Content** |
| Has good content knowledge of the subject |
| Appears well organized |
| Explains concepts clearly |
| Relates concepts to learners' experience |
| **Learner Participation/activity** |
| Learners are given an opportunity to: |
| gather their own resources |
| do their own research |
| synthesise their own information |
| present their findings |
| reflect on their own learning |

**Figure 4.2: Category breakdown of the lesson observation schedule**

Figure 4.2 gives an overview of what was specifically looked for within these categories. For example, in the section 'Lesson Structure' I aimed to observe whether the RPTs naturally linked the start of the lesson to what had been done previously, whether they maintained a good flow and pace and if they summarised what was done and linked it to what will be done next.

The lesson observations were followed by individual interviews with the RPTs. During every interview I attempted to get a comprehensive picture of the RPT's career as a teacher as well as her thoughts on Science and teaching. There were three main foci, namely:

1. Background as a Science teacher;
2. Approach to planning and delivering lessons prior to being introduced to IBSE; and
3. Perceptions of the subject Science and the teaching of Science prior to being introduced to IBSE.

The interview sheet consisted of the following questions:

1. Can you please give me some background information to your career as a Science teacher?
2. Please describe your approach to planning and delivering Science lessons and mention what you find easy and what you find challenging.
3. What are your perceptions of Science as a subject and the teaching of Science?
4. Select words/phrases which you will choose to describe how you feel about teaching Science? Circle **ALL** the ones you feel apply to you now.
   The full interview schedule is available as Appendix 5.

#### *b) Stage two – Action planning: Reflection and finalising introductory learning session*

Since action research uses the information gathered to inform the action to be taken (Ebersohn *et al.*, 2007), I used the information gained from the interviews and observations to tailor make and finalise the learning sessions I had developed to introduce the teachers to IBSE. I scrutinised the interview responses and observations to identify specific needs of the teachers and attempted to align the learning sessions accordingly.

#### *c) Stage three – Taking action: Introduction to IBSE learning session*

My initial approach to introduce teachers to IBSE included a face-to-face learning session together with e-learning sessions to provide the necessary learning opportunity to practically introduce teachers to IBSE as discussed in Sections 3.5.5. Once the initial interviews and observations were completed, the responses considered and the learning session was finalised, a Saturday morning was scheduled to do the face-to-face learning session. This took place at the Faculty of Education at Stellenbosch University. An invitation was again extended to all the Science teachers of the participating schools to attend the learning session, yet only the five RPTs attended the session. Figure 4.3 shows the title slide of the first TPL session on IBSE into which I incorporated a variety of aspects. The session covered:

- insight into the purpose of the session;
- theoretical background to IBSE;
- a practical, first-hand experience of an inquiry activity;
- a debriefing session of the inquiry activity;

- an opportunity for the RPTs to plan a lesson which they could implement when back at their schools; and
- some considerations to bear in mind when implementing IBSE activities.

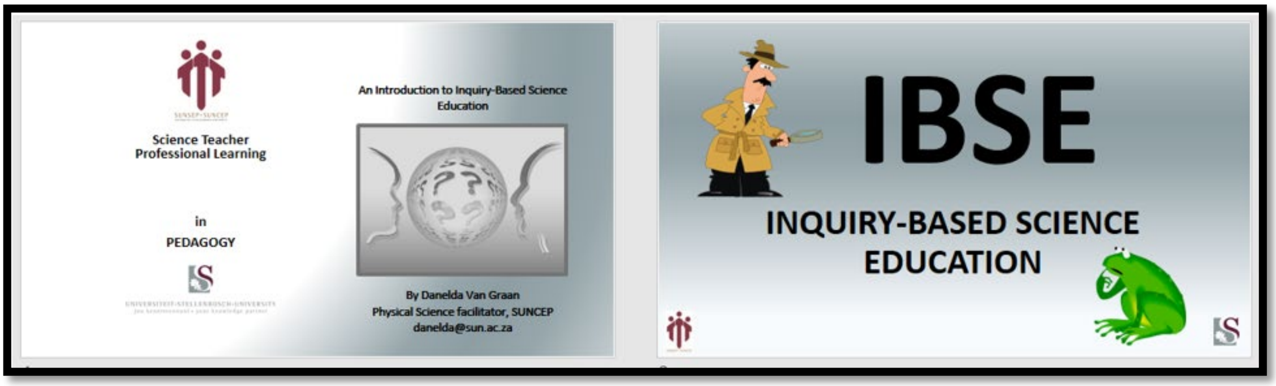


**Figure 4.3: Title slide for first face-to-face introduction to IBSE workshop**

Time was given for group discussions after each activity to allow teachers an opportunity to share their thoughts and ask questions. Teachers were encouraged to implement IBSE gradually and to identify opportunities that lend itself to an IBSE activity. The programme for the morning is given in Figure 4.4 as well as Appendix 9 that also shows the PowerPoint slides used at the session.

**Sciences contact session planning**

**Discipline: Pedagogy** **Concept: IBSE method of teaching** **Duration: 3h30min**

| Activity | Description | Resources/equipment required | Start time | Duration |
|---|---|---|---|---|
| Welcome & Intro | | | | 10 min |
| Background<br>- Ppt lecture | Go over theoretical basis for using IBE to teach science;<br>what IBSE entails;<br>Video: What is IBSE? (7 min) | Data projector and laptop<br>Slides 1 – 7 | | 20min |
| Group discussion & feedback | Let teachers discuss what they think about IBSE method of teaching. Some Questions: Do participants think there are benefits? What are the difficulties? | | | 20 min |
| Lesson experience | Heat packs, how do they work? Hand out heat packs – let teachers explore and experience. They need to write down What they know, What questions they have.<br>Show Hot ice videos – does it answer some questions? Do they have more questions<br>Hand out Text resources – One reads – others take notes – discuss. Use textbooks to further answer questions.<br>Draw a poster to display what they have learnt (New knowledge) | Heat packs<br>Poster paper<br>Felt tips<br>Resource books<br>Internet<br>Slide 9 | | 60min |
| Debriefing - Group discussion & feedback | What was this experiences like? Do they think that it can be used in their lessons? What would the challenges be, especially relating to their context? | | | 20 min |
| Video | Investigating solar panels. E.g. of IBSE activity in action | Slide 12 | | 15min |
| Planning for implementation | Teachers look at a lesson topic they will be doing in the near future and plan to include elements of IBE in the lesson.<br>Teachers draft a plan that they will implement in their classes | Slides 13-16 as intro<br>CAPS document,<br>Lesson plans<br>Textbooks<br>Internet | | 45 min |
| Considerations of implementations and end. | Practical ideas of implementation in teachers own context Teachers share what could make implementation difficult in their context. Further considerations for implementation of IBSE activities. | Slides 17 – 21 | | 15min |
| e-Learning Task | Brief teachers to the e-Learning task prepared for them. | | 5 min | |

**Figure 4.4: Programme for Introductory IBSE contact sessions with RPTs**

In Section 3.5.3 I discussed the learner-centred orientation to IBSE. The face-to-face learning session was purposefully designed to give teachers the opportunity to be learners in a learner-centred environment and to give them first-hand experience of what learners would typically do, feel and gain during an IBSE lesson. One has to bear in mind that requiring teachers to follow an inquiry approach is very different to how they may know and understand teaching to be, and it demands a major mind shift which challenges their beliefs and values (Anderson, 2002; Johnson, 2006). Taking the RPTs through an inquiry experience themselves assisted in them making this required shift as they were not only introduced to IBSE theory, but had first-hand experience of how effective it could be as a learning activity. The inquiry activity that was given to the RPTs was a guided inquiry (Bell *et al.*, 2005) which took them through a number of the stages that were planned beforehand (Bell *et al.*, 2005).

During this process the RPTs were not lectured on the topic but given an opportunity to construct their own knowledge (Fosnot & Perry, 2005). The activity was about investigating and researching the chemistry of heat packs. This was done through allowing the RPTs to observe what happens in a heat pack, and subsequently allowing them to ask questions. They were then provided with text resources and shown videos to assist them with finding the answers to their questions. Afterwards they had to draw a poster of their observations, main questions and answers and present it to one another. This was included to give RPTs the opportunity to collaborate, learn through social interaction and communication (Artigue *et al.*, 2012; Minner *et al.*, 2010), and so demonstrate the power of learners interacting and sharing ideas with their peers.

Teachers then had a debriefing session on this very short IBSE experience. They were asked to share their thoughts on:

1. How this process made them feel;
2. What the benefits of teaching is this manner would be;
3. Whether it could work in their contexts; and
4. What the challenges would be teaching in this manner in their own classes.

This was to start a process of reflection by the individual RPTs so that they could start thinking about how they could use similar activities in their own teaching contexts. Reflection is a necessary and crucial part of the process to contribute to bringing about change and the nature of action research makes space for this (Ebersohn *et al.*, 2007).

This debriefing session was followed by a short presentation highlighting the theory and process of IBSE, as well as the possible practical challenges and considerations when implementing IBSE. The RPTs were then tasked to identify topics and parts of lessons within the content they had to teach in the upcoming weeks of the term where they could implement IBSE. They were given an opportunity to plan at least one such lesson so that they could leave the training session with an already prepared or partially prepared activity. This would encourage the RPTs to implement IBSE as the huge demands on teachers' time often prevent teachers from attempting something new.

RPTs were also asked for permission to set up a WhatsApp group[15] that would be used for ease of communication as well as a platform on which they could engage and possibly collaborate with each other.

Before the close of this first TPL workshop on IBSE, the RPTs were provided with an electronic lesson (e-lesson) on a compact disk (CD). I developed this resource for the purpose of giving the RPTs an opportunity to further learn about and get a deeper understanding of IBSE. As an in-depth background study into IBSE required more time than the face-to-face session allowed for, this tool would allow RPTs to work through the e-lesson at a time that best suited them. Furthermore, the e-lesson[16] would also provide them with a tool in hand which they would be able to use as a reference.

A short video named 'INQUIRY-BASED EDUCATION' was developed by Scott Crombie and created by the Inspiring Science Education Project in Ireland. Crombie was approached to seek permission for the use of his video resource, which he granted (See Appendix 12). The article 'Implementing Inquiry-Based learning in Science education,' by Wynne Harlen (Harlen, 2010) was used as a text reference. These two resources provided a concise yet informative background and introduction to IBSE. I also used both resources to design e-learning interactive quizzes. This e-lesson was set as assignments for the RPTs to complete to assist the RPTs with engaging with the information, and, in so doing gaining a better understanding about IBSE, its features and processes.

The CD contained two content resources namely a video and an article, together with interactive e-learning activities for conceptualisation of IBE and IBSE. I used the Articulate Storyline software programme to design and produce the interactive e-learning resource. A set of instructions of how to use the CD was also provided. The e-lesson thus provided the RPTs with theoretical background

[15] WhatsApp is a communication service owned by Facebook. It can be run from a cellular mobile device and can also be accessed from a desktop app on a computer providing the mobile device and the computer remains connected to the internet. In order to register as a user one has to provide a standard cellular mobile number. The platform allows communication through text messaging, voice messages, make voice and video calls, and share images, documents, user locations, and other media. The platform allows users to set up various groups of the contacts they have on their mobile device which makes group chats and information to be sent within a closed group possible.

[16] The e-lesson is available on request.

about IBSE and an opportunity to strengthen their understanding of the principles of IBSE as they worked through the e-learning activities. Figure 4.5 shows the title slide of the e-lesson. Figures 4.6 and 4.7 show the title slides with instructions to the two interactive e-learning activities. More detail of the content of the e-lesson is given in Appendix 10.

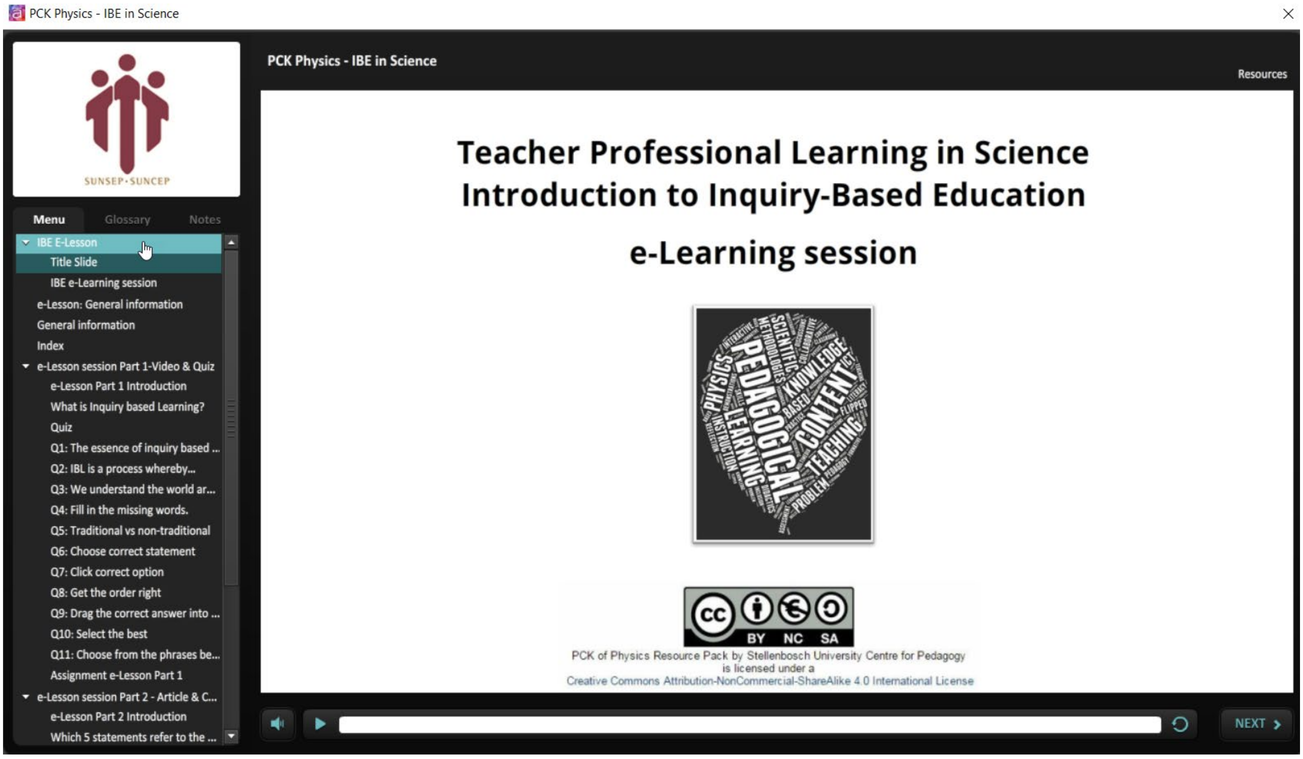


**Figure 4.5: Title slide to e-Lesson**

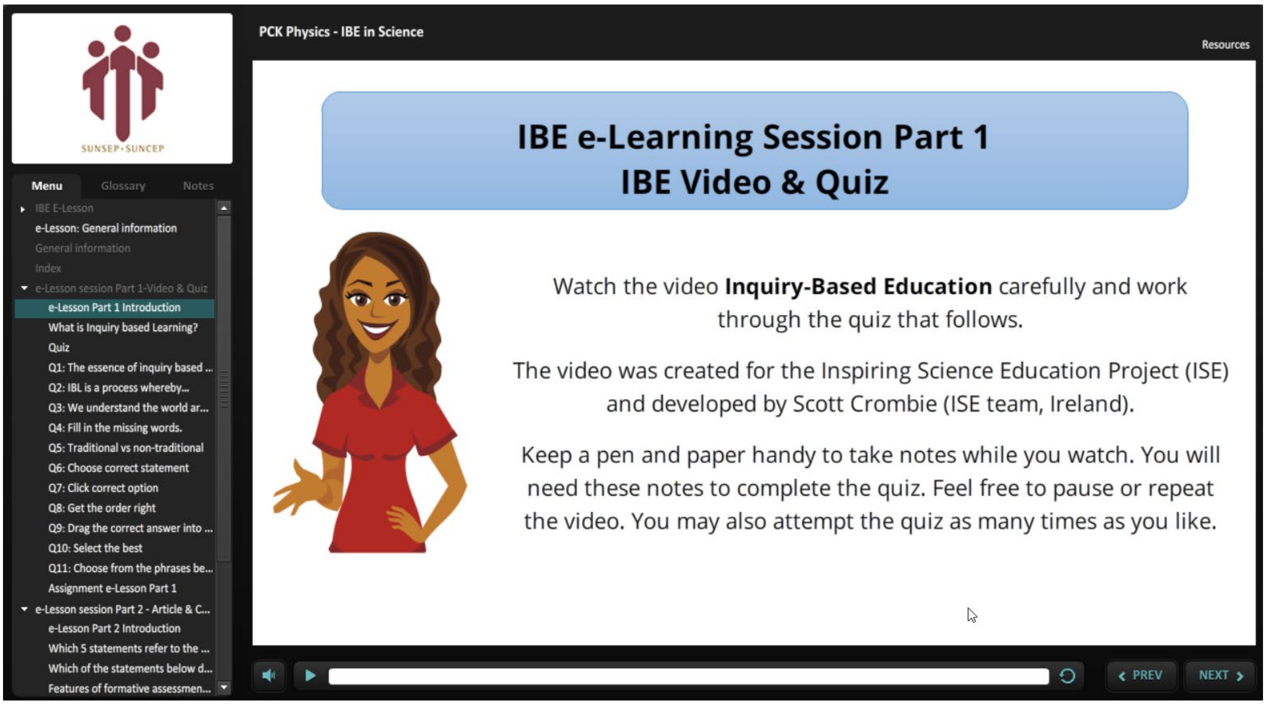


**Figure 4.6: Title and instruction slide for part 1 of the e-Lesson**

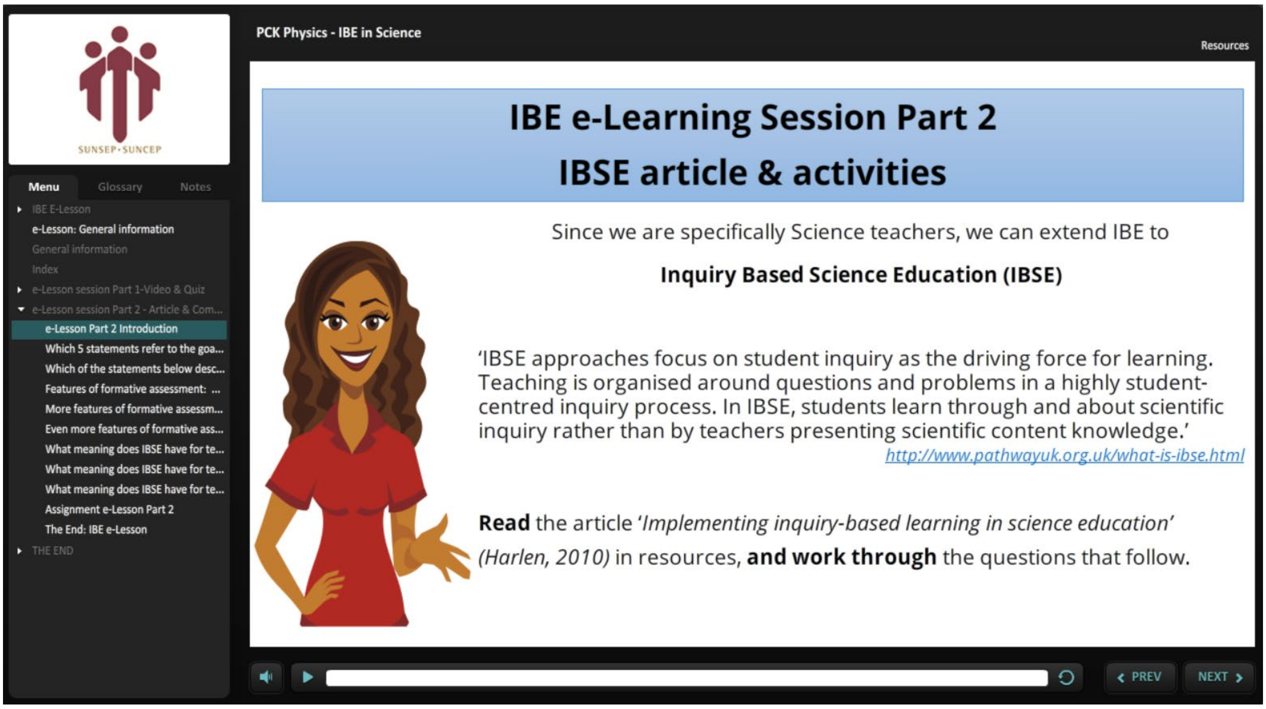


**Figure 4.7: Title and instruction slide for part 2 of the e-Lesson**

Providing the material to the teachers in this format afforded the RPTs an opportunity to actively engage with information on IBSE, and also allowing them to work through the material in their own space and time. This would hopefully provide support to the RPTs when attempting to implement the IBSE principles as they would have access to the e-lesson at all times to go back to the material. Teachers were expected to apply what they had learnt from the face-to-face session and the e-lesson, to the topics they had chosen.

## 4.6.2. Cycle 2 – Mentoring and further learning

This cycle was the main part of the mentoring phase in the project in which an attempt was made to address RPTs' specific challenges and questions regarding IBSE. In Section 3.5.5 the importance of continued support for teachers in the process of adopting IBSE was mentioned.

### *a) Stage one – Gathering information post implementation and reflection*

After a period of time during, which teachers had the opportunity to implement elements of IBSE, I undertook to set up individual follow-up and feedback sessions. It was important to first give the RPTs a chance to implement IBSE on their own so that they would be able to identify what they found difficult and what they needed help with. During the follow-up sessions I would meet with each RPT and interview them individually about their experiences with implementing IBSE. The purpose would be to support the RPTs with the challenges that they had encountered in their own context when implementing IBSE. Setting up appointments with the RPTs individually presented with a number of difficulties due to last-minute changes happening at schools and the start of the exam period. Since time was running out, I then decided to arrange a joint feedback session at the most central school in the form of a focus group session. At the focus group session a semi-structured interview schedule was used to guide the discussion. I first gave teachers the opportunity to share their experiences verbally and thereafter I asked them to individually answer the questions on the schedule in writing. The questions were focussed on the RPTs' experience of the e-lesson and of implementing IBSE in class. The semi-structured interview can be found as Appendix 7.

### *b) Stage two – Action planning: Planning a follow-up learning session*

At the focus group session I specifically asked RPTs to indicate what they had found challenging about IBSE and would like to have more guidance with. The data I gathered through the discussion and questionnaire was used to determine whether the RPTs understood the concept of IBSE, the extent to which they understood IBSE principles and whether what RPTs reported they were doing in their lessons were in fact in line with IBSE principles. I used this information to plan and set up a follow-up face-to-face learning session on IBSE.

### *c) Stage three – Taking action: Presenting a follow-up face-to-face IBSE learning session*

Another Saturday focus group face-to-face session was held to explore the principles of IBSE in more depth and provide further mentoring and support. The programme, as shown in Figure 4.8, once again included guidance by the instructor as well as opportunity for the RPTs to share their thoughts and ask questions.

**Sciences contact session Part 2** — **Discipline: Pedagogy**
**Concept: IBSE method of teaching** — **Duration: 3h30min**

| Time | Programme | Things to do |
|---|---|---|
| 9:00 | Welcome & coffee | |
| 9:15 | Ask teachers to brainstorm their topic and work out a basic lesson plan. | Request that teachers bring their topics, any prior planning and resources to the session |
| 9:45 | Teachers give feedback highlighting any IBSE they have included. | |
| 10:00 | Ask teachers to give their understanding of IBSE. Teachers write it down and then share. | |
| 10:15 | What is IBSE? Go over principles | Do ppt presentation |
| | • Point out from the texts given what IBSE is. | |
| | • Look at examples form LAMAP | Provide materials |
| 10:45 | Ask teachers to continue to work on their topic and incorporate elements of IBSE further. | |
| 12:00 | Feedback & suggestions | Group discussion |
| 12:30 | Lunch | |

**Figure 4.8: Programme for face-to-face session part 2**

There may not have been solutions to all questions, but the RPTs were at least given an opportunity to share their challenges, discuss possible solutions, share ideas, be encouraged and ultimately learn more. One of the main issues addressed was that IBSE does not simply mean that learners do activities but that the aim is to get learners to engage with subject content in various forms as well as with their peers and then to get them to think and deliberate. Figure 4.9 shows the main focus of the content covered at the face-to-face follow up IBSE learning session. The session also addressed misconceptions about IBSE and IBSE processes. The full learning programme, and PowerPoint slides for the follow-up learning session are included in Appendix 11.

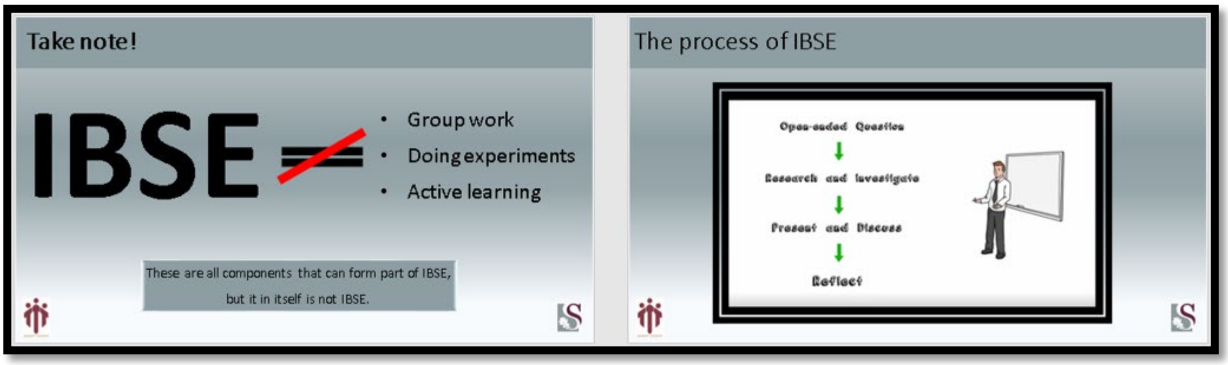


**Figure 4.9: Content focus of face-to-face follow-up IBSE learning session**

The RPTs were also tasked with identifying topics and lessons they needed to teach in the weeks to follow and in which they could attempt to implement IBSE. They were encouraged to continue to work through the e-lesson to further solidify their understanding of IBSE.

### 4.6.3. Cycle 3 – Further implementation & conclusion

After teachers had another period of time to implement and practice using IBSE, I set up individual observation and interview sessions. These would constitute the observations and interviews post the learning sessions.

#### *a) Stage one – Gather final views*

Where possible I observed the RPTs using the same observation schedule (Appendix 2) to see if there had been any changes in their approach and class practice now that they have been given a comprehensive introduction to IBSE. The observation lesson was again followed by an interview with the RPT. An interview schedule which is presented as Appendix 6, was used to gather the RPTs' perspectives on the process. The questions for the post introduction interview had a slightly different slant to the ones in the first interview round prior to introducing RPTs to IBSE, and this time read as follows:

1. What are your impressions of the IBSE approach to teaching Science?
2. Please describe how IBSE has affected your approach to planning and delivering Science lessons, if at all, and mention what you find easy and what you find challenging about implementing IBSE in teaching Science.
3. How has IBSE affected your perceptions of Science as a subject and the teaching of Science, if at all?
4. Which of the following words/phrases will you choose to describe how you feel about teaching Science?

The list of words and phrases in Question four was kept identical in both interview sheets for purposes of comparison and to pick up if a shift had occurred in the RPTs' views.

***b) Stage two – Reflection***

By now, I had gathered a considerable amount of information, which could be considered and compared in an attempt to answer the research questions. I analysed the last set of data and started a process of organising, coding and determining themes for my data. I used the data from both rounds of interviews and observations to gauge if there had been any change in the perceptions and practices of the RPTs. I analysed the data and compared it with the data set gathered and analysed before the introductory TLP session. I explain the data analysis methods in more detail in Chapter 5.

***c) Stage three – Conclusion***

During this final stage I considered the entire process, including the literature review, action research process and data gathered and analysed to compare results and draw conclusions. Here I hope to find answers about the RPTs perceptions and practice of teaching Science, specifically, whether the introduction to IBSE had an effect on their perception of and practice in the Science classroom. I would also like to evaluate the value and effectiveness of the guided TPL in IBSE to get an indication of the impact the learning session and mentoring process had.

### 4.6.4. The timeline of the project

Ideally, the project phase of my study should take 32 weeks. Table 4.4 gives the proposed or planned time frame over which the project was set to proceed. It starts at the point where I have secured the RPTs and have set up the initial meetings with each RPT.

**Table 4.4: Proposed time frame of introductory IBSE learning session for teachers**

| Proposed timeline | Activity |
|---|---|
| Weeks 1 & 2 | Meet each RPT individually at their schools. I used this time to:<br>• introduce myself;<br>• explain the aim and purpose of the project;<br>• explain that all information would be handled in a confidential manner and that RPTs will remain anonymous;<br>• give them a consent form and ask them to go through it and for a final time consider if they want to be part of the project; and<br>• set up the first observation and interview session.<br>I also introduced myself to the principal to ask for his or her permission. |
| Week 3 | Pre-observation & pre-interview – 1 teacher |
| Week 4 | Pre-observation & pre-interview – 2 & 3 teacher |
| Week 5 | Pre-observation & pre-interview – 4 & 5 teacher |
| Week 7 (Saturday morning) | Face-to-face introductory session A |
| Week 8 – Week 17 | RPTs are given an opportunity to implement IBSE in their classes. A WhatsApp group has been set up to create a community of practice where RPTs could ask questions and share ideas. |
| Week 18 | Set up appointments for a feedback session |
| Week 21 | Face-to-face follow-up and introductory session B |
| Week 22 – Week 30 | RPTs are given a further opportunity to implement IBSE in their classes. |
| Weeks 31 – Week 32 | Set up final individual appointments for the post-observation and post-interview. |

During the first two weeks of the project I set up individual appointments with each RPT to kick start the process. This was my initial meeting where I introduced myself and the project and worked through the consent forms with the teachers. At this meeting I also set up appointments for my first round of collecting data.

Over the next three weeks, I collected the first round of data using the observation schedule (Appendix 2) while observing a lesson of each teacher as well as gathering information about each RTP during an interview, which was held immediately after the lesson observation and by using an interview schedule (Appendix 5).

In weeks 6 and 7 I used the information from the observations and interviews to finalise the programme content for the first introductory IBSE learning session which was held at the end of week seven. The RPTs would get approximately two months (weeks 8 – 17) to use opportunities in their Science lessons to implement IBSE or elements of IBSE. In week 18, I set up visits with the RPTs again to get feedback from them regarding the learning session and materials and the implementation phase. This constituted the next data collection period.

I used the information gathered at the feedback session to set up and plan a follow-up face-to-face learning session. This took place around week 21. Now, hopefully with a better insight and understanding, the RPTs got a period during which they could implement the IBSE approach again. During this period, the RPTs could use the WhatsApp group as a community of practice to share information and ideas with each other.

The last and final data collection period took place in weeks 31 and 32. I once again set up appointments to observe teachers in class while teaching a Science lesson using the observation schedule (Appendix 2). Each lesson observation was followed by an interview with each RPT using an interview schedule (Appendix 6), just as I have done prior to the learning sessions.

## 4.7. Data Analysis

For some, data analysis could mean manipulating data through processes like coding, indexing sorting and retrieving, and this is primarily referred to as data handling. Others would say that data analysis is primarily a process of imaginative interpretation and the actions of manipulating data through processes as named above is merely ordering and sorting data (Coffey & Atkinson, 1996). From this I would come to the conclusion that ordering and sorting the data for interpretation is what is required for data analysis.

In this study my aim was to gain an understanding about the experiences of the participants. In the case of gathering qualitative data for the purpose of understanding the experience of the participants, thematic analysis is well suited (Harding & Whitehead, 2013). I therefore set out to use coding and organise my data according to themes. Themes identify important notions in line with the research focus and can then provide patterns of meaning within the data (Braun & Clarke, 2006).

One can distinguish between an inductive thematic approach and a theoretical thematic approach. With the inductive thematic approach, the development of themes evolve as the analysis process continues. When one codes towards a specific research question, the type of thematic analysis followed is theoretical (Braun & Clarke, 2006). So theoretical thematic analysis is more specific and works within the confines of predetermined themes that is in line with the research question (Braun & Clarke, 2006; Harding & Whitehead, 2013). I decided to opt for the theoretical thematic analysis as I wanted to have specific research questions answered. I therefore predetermined the themes, applied selective colour-coding, and presented the evidence as a narrative according to the themes (Harding & Whitehead, 2013). Figure 4.10 below shows a simple illustration of a thematic analysis process.

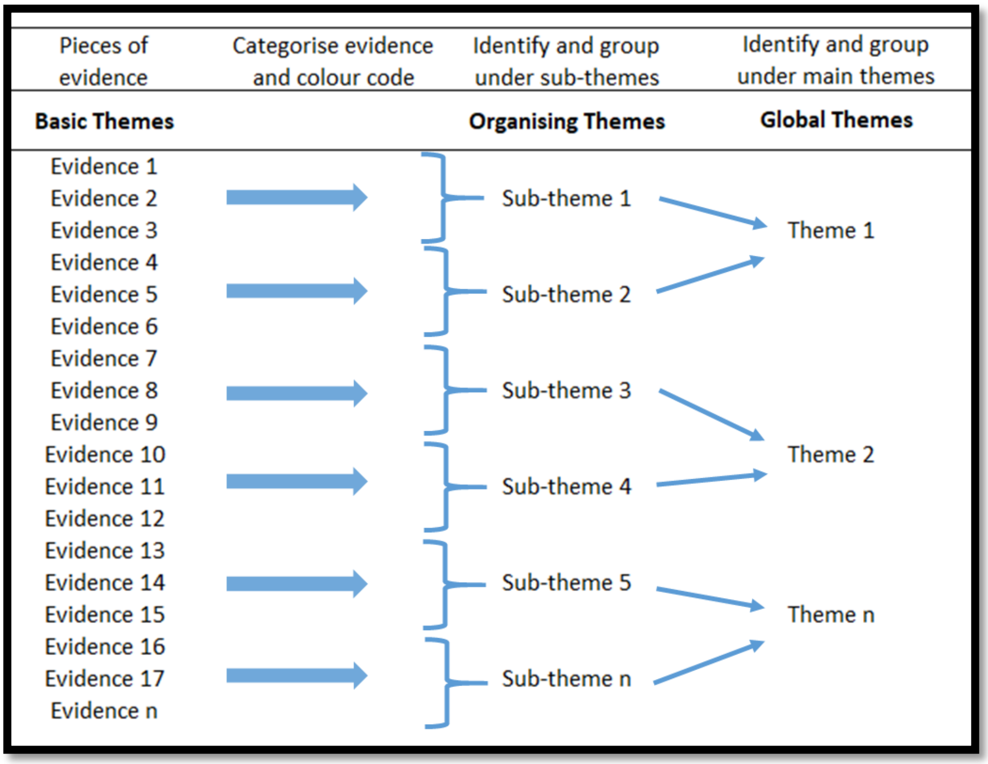


**Figure 4.10: Illustrating resulting components of a thematic analysis process (Own diagram)**

The purpose of my study was firstly to establish the general perceptions that the RPTs have about Science as a subject and the teaching of Science. The second purpose of my study was to introduce the RPTs to the approach known as Inquiry-based Science Education (IBSE) through a practice based TPL opportunity consisting of a series of learning sessions, and then establish if it had an effect on the perceptions and practice of the RPTs. Therefore, the themes I predetermined were closely related to my research questions to help me establish the answers to these questions. The themes were:

- RPTs' views of Science as a subject;
- RPTs' views of learners in Science lessons;
- RPTs' views of teaching; and
- RPTs' views of teaching Science (including IBSE post TPL sessions).

Figure 4.11 below shows my research questions and how the main themes link to these questions.

During my action research process qualitative data were gathered by means of a variety of research methods as explained in Section 4.3. I started analysing my data as soon as I started collecting it. The responses from the observation schedules were combined onto one sheet, which enabled me to look for common trends per observation category. I also wrote up the informal notes of the observations I had made during the observation periods. The individual interviews as well as the semi-structured interview from the focus group session were audio recorded and then transcribed. I then proceeded with the coding process.

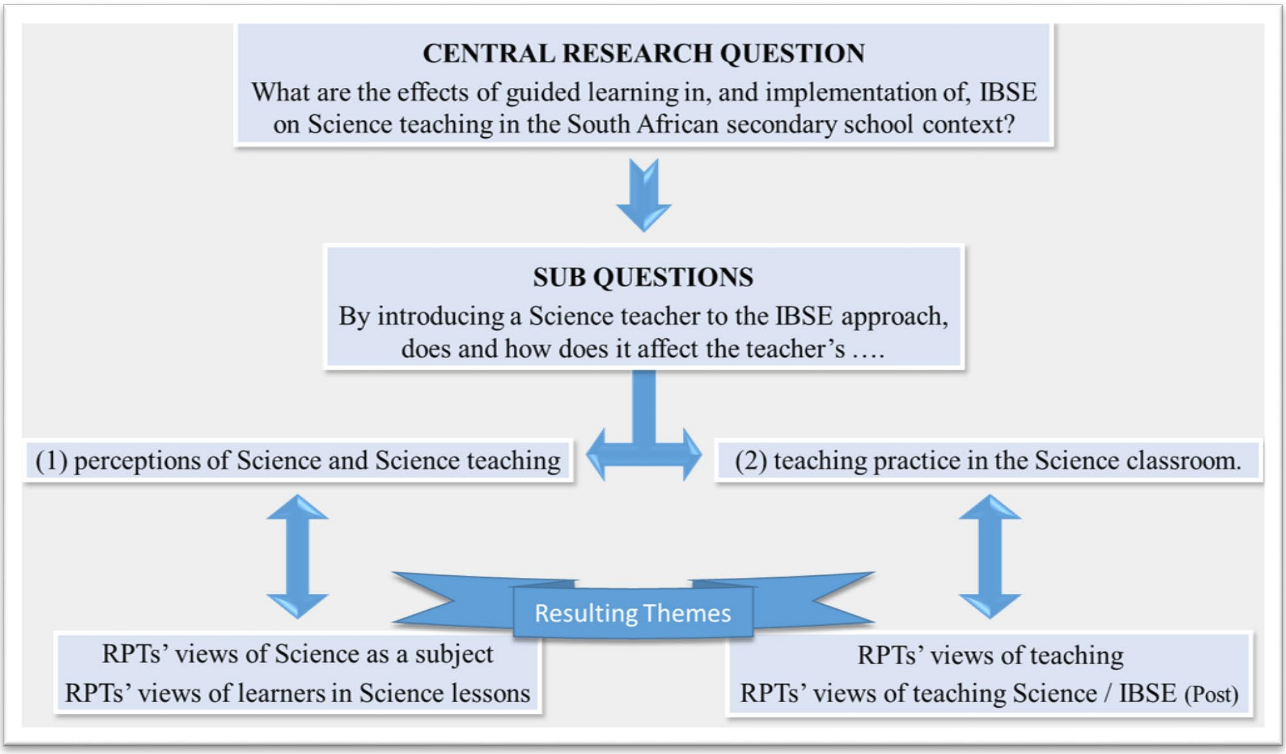


**Figure 4.11: Analysis of themes as they relate to research questions**

The first step of the coding process was to collate the pieces of evidence in the cells of an Excel document. I then identified keywords and key phrases from the data that was collected. The information containing cells were then colour-coded the according to these keywords and phrases. The next step was to group keywords and key phrases according to the organising themes. Lastly, I grouped the organising themes according to the main themes. Figure 4.12 is a diagrammatic depiction of the coding process. It displays the main themes, examples of the colour-coded sentences containing data, as well as how the data is grouped into organising themes and how the organising themes are linked to main themes. Note that only examples where used to illustrate the analysis process which I followed and the diagram does not contain all the organising themes.

## 4.8. Trustworthiness

It is important to ensure that one's research can be relied upon and trusted. Having a good rationale that justifies the chosen methodology and research methods is one way to make sure that one's research is credible and authentic (Tuli, 2011). With positivist research, which primarily uses quantitative data which is measurable, this can easily be achieved as one would be able to repeat data measurements under similar conditions (Lincoln & Guba, 2007; Tuli, 2011). In this way one is able to determine the reliability and validity of data and findings in a positivist inquiry.

In the case of this study, which mainly relies on qualitative, naturalistic data, reliability and validity are not easily achieved. Terms like validity and reliability, which are primarily used in a positivist

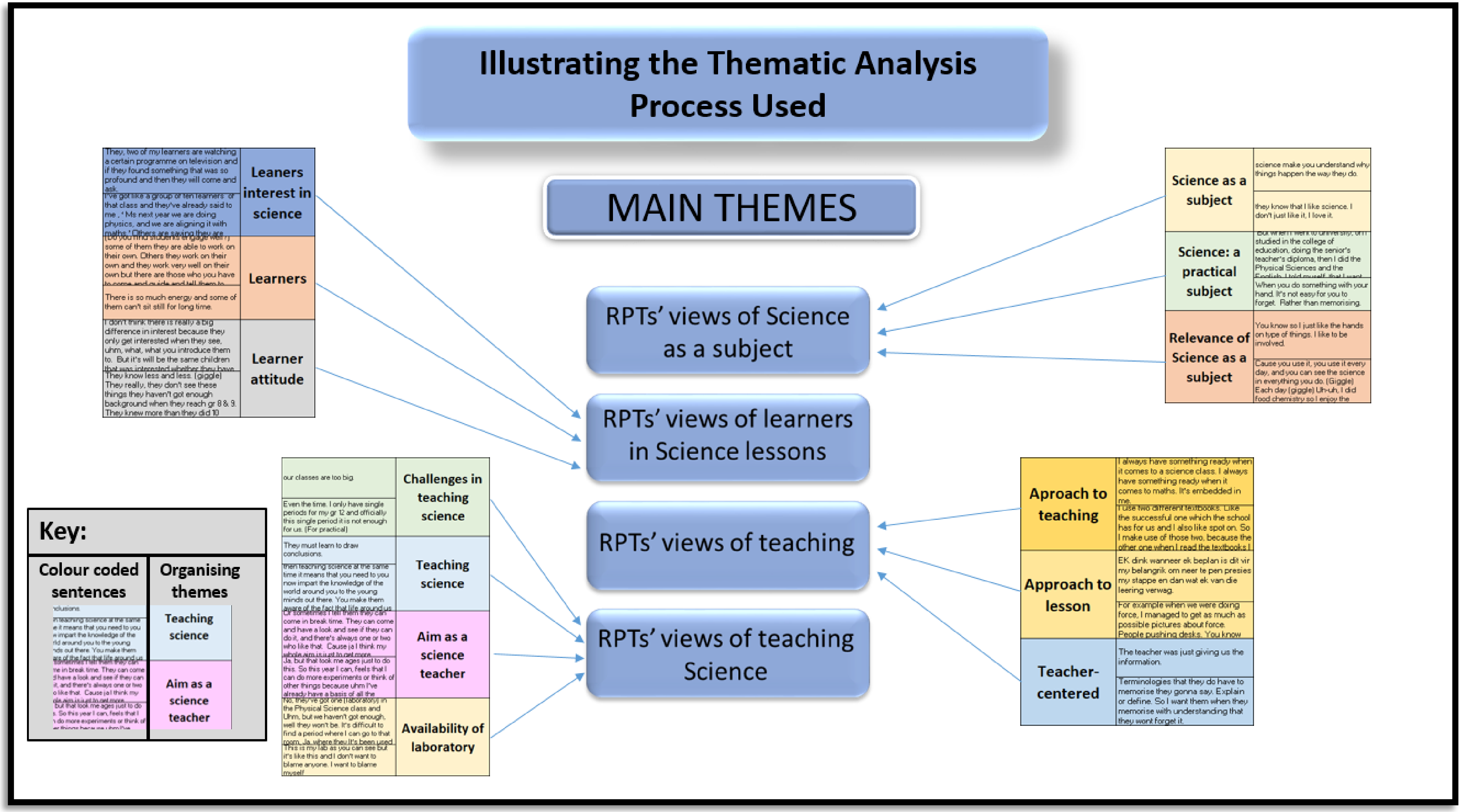


Figure 4.12: Illustration of the main themes and coding process for this study

paradigm, are inappropriate in this context (Tuli, 2011). This is because qualitative data reflect perceptions, ideas, opinions and reflections of individuals, which cannot be verified through rigorous repetition. Alternative ways must be employed to ensure that the study is verified. More recently, terms like 'goodness' and 'trustworthiness' have been used to refer to the fact that the evidence of a qualitative study can be relied upon (Arminio & Hultgren, 2002; Creswell & Miller, 2000; Lincoln & Guba, 2007; Tuli, 2011).

For qualitative research to be authentic it must adhere to the criterion of goodness (Arminio & Hultgren, 2002). Goodness allows the interpretive researcher to make a shift away from empirical expectations (Arminio & Hultgren, 2002; Tobin & Begley, 2004). Goodness requires a study in which ontological and epistemological orientations link well with the chosen methodology, which has a clear method of data collection and analysis and which offers an understanding of the phenomenon which will lead to recommended actions (Arminio & Hultgren, 2002).

The multiple data collection instruments I used contributed to ensuring trustworthiness of the findings of this study. The data collected with the observation schedule was strengthened and verified by the interviews I had with each RPT and vice versa. The repetition of data collection versus only collecting one set of data also contributed to the trustworthiness and goodness of the study.

Initially triangulation was used as a way to combine rationalistic and naturalistic paradigms (Tobin & Begley, 2004). This could mean that quantitative data was used to back-up qualitative data and vice versa, within a particular study. In naturalistic inquiries triangulation was used as a means to demonstrate confirmation and completeness (Tobin & Begley, 2004). Triangulation can be seen as a way of cross checking data by using different methods, sources of data or even investigators (Lincoln & Guba, 2007), in other words, the process where multiple data sets of a particular kind and within a particular context are used. For example, in this study I wanted to gather information of the teachers' practices and approaches to teaching Science. Therefore, I set out to do class observations by using an observation schedule as well as doing interviews with each teacher using a structured interview schedule. After analysing the two data sets I could compare the two and look for areas of overlap. Another example is the case of the focus group discussion where I made use of a semi-structured interview schedule. During the session I first had a discussion with the group and then I asked the RPTs to complete the interview schedule in writing as well. After transcribing the focus group discussion I could compare what had been said with what the RPTs wrote down on paper. Figure 4.13 illustrates that observations and interviews prior to the introductory session were compared with one another as well as with those post the session.

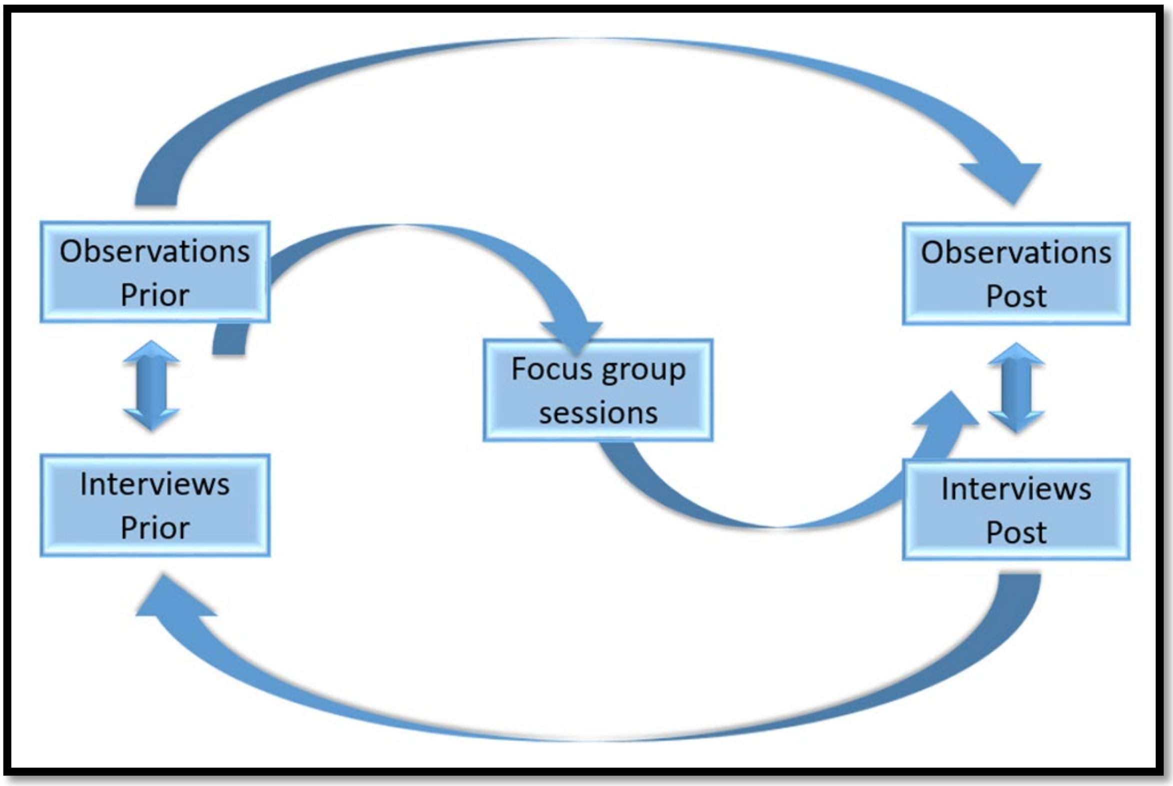


**Figure 4.13: Links between data from the different instruments used (Own diagram)**

Data prior and post the introductory session was also compared with each other. Focus group data looked back to data prior to the introductory session and forward to data post the introductory session.

The benefits of triangulation include increasing confidence in research data. This method of collecting data from multiple sources, termed data triangulation, assists the researcher not only to collect more comprehensive relevant information but also to cross-check their consistency in order to enhance the robustness of findings (Patton, 2002). Triangulation and goodness are ways to ensure the quality of naturalistic inquiries (Tobin & Begley, 2004).

## 4.9. Ethical considerations

This study lent itself to certain ethical concerns, thus requiring various procedures to be put in place to ensure that all participants were treated fairly and with respect. I did not proceed with any action until I had received ethical clearance (See Appendix 2) for my study as well as permission from the relevant educational structures. Since the perceptions and personal opinions as well as progress information of individual participants were gathered, the purposes and method of the study were clearly communicated to all participating in the research at the start of the project and at key intervals during the course of the project.

Participants, namely the five teachers, were requested to give informed consent (See Appendix 4) to the researcher to use information about themselves, their ideas and comments they shared. Since the research was done in public schools, permission was sought from the WCED (Appendix 1 contains the permission letter received from the WCED), and school management authorities (Appendix 3 contains the letter which I sent to and discussed with the respective school principals). The instruments used to gather the data (Appendices 5, 6, 7 and 8) were presented to the WCED when permission was sought.

No candidate was forced to participate in the study, and if a participant wanted to withdraw at any stage, he or she was free to do so. They also received the assurance that their anonymity would be protected at all times.

## 4.10. Limitations and challenges

The study was limited to only five teachers as they were the only ones who responded positively. Ideally the IBSE introductory learning session would have been embedded into a SUNCEP TPL programme for Science. This would have given more teachers the opportunity to be introduced to IBSE, and I would have had a larger pool of participants to work with. However, due to a lack of funding for Science programmes specifically, SUNCEP have had no requests in the Cape Metropole for Science TPL programmes. Starting with only five teachers also meant that when two teachers had to withdraw due to personal reasons the group became considerably smaller.

Time constraints due to the heavy demands made on teachers, was the primary reason for limiting the cycles to only three. Working conditions of teachers are quite challenging with large numbers of learners per class, resulting in much time spent to mark big volumes of assessments as stipulated by the curriculum. High learner teacher ratios also mean that teachers have very few free periods to attend to administrative tasks. Social challenges at many of the schools also take up much of teachers' individual and also teaching time.

Many delays were encountered in the actual data gathering process. This process demanded individual interview and observation sessions, as well as times when all five teachers were available for joint learning, follow-up and debriefing sessions. Under normal circumstances it is often complicated to find a time which suits all participants but this was hampered even further with schools not adhering to set programmes and timetables. Even individual visits would sometimes be difficult as programmes at schools could change on a daily basis. Although schools have a set timetable it so happened that meetings, tests, exams and visits to schools by officials from the education department, which have not been announced well in advance, all impacted on the availability of teachers. This resulted in me often having to postpone and change appointments to accommodate the teachers.

## 4.11. Conclusion

The motivation for this study came from a desire to enhance the teaching of Science at school level. This would require introducing teachers to new ways of thinking and doing. In this chapter I explained the philosophical underpinnings to my study. I discussed various paradigms and provided a motivation for choosing a constructivist and interpretivist orientation. With a focus on change, the paradigm best suited for the study was the transformative and critical paradigm in which qualitative data would be gathered. The features of the transformative and critical paradigm seemed to make it the most suitable for this purpose allowing RPTs to participate, be challenged, and to possibly attain an end result of being empowered. I decided on the methodology of action research since action research allows for participation and reflection. A number of methods were used to gather qualitative data. In the chapter that follows I present the data that resulted from action research project, do an analysis thereof and present my findings.

# Chapter 5: RESEARCH DATA AND FINDINGS

## 5.1. Introduction

In this chapter, I present the data gathered from my research together with the findings from this data as revealed by my analysis. I firstly give a description of each of the research participant teachers (RPTs) according to their age, race, qualification, teaching experience and working environment. I secondly present my research findings per cycle. The focus of Cycle 1 is the RPTs' views and practice of Science education prior to introducing them to Inquiry-based Science Education (IBSE), as well as their initial responses to the introductory teacher professional learning (TPL) sessions. The focus of Cycle 2 is the RPTs' impressions of the introductory TPL session and their attempts to implement IBSE, as well as how this shaped the follow-up TPL session. Lastly, Cycle 3 focuses on the RPTs' views and practice of Science education after introduction to and implementation of IBSE. The observation schedule findings are given per category as indicated on the schedule, while the findings from the interviews are presented according to the themes predetermined for theoretical thematic analysis as described in Chapter 4. I conclude this chapter with the findings from a brief analysis of the RPTs' perspectives on Science and Science teaching before and after the introduction to IBSE. This was determined by asking the RPTs to select words describing Science teaching before and after IBSE, and these are presented as two comparative word clouds.

## 5.2. Research participant teachers' profiles

In planning my research project, my aim regarding the recruitment of participants for my study was to do non-probability purposive and convenience sampling in order to work with and learn from a specific, yet diverse group of participants. Recruiting a group of teachers was not an easy task. I sent emails to all Physical and Natural Science teachers at secondary schools from in and around Stellenbosch directly, and even to principals of some of the schools. None of the teachers from the Stellenbosch area, which is in the Cape Winelands District, came forward. The next area that I targeted was the Helderberg area which falls in the Metro East District. This area is close to where I live and would also make school visits feasible. I initially targeted six schools in the Somerset West and Strand area and sent emails with the same invitation and made a follow up phone call to the various schools, but still none produced a positive response. Eventually, with the help of the Physical Sciences subject advisor in the Metro East District, invitations were sent to all Physical and Natural Sciences teachers throughout the district. This led to ten teachers showing an interest in the study, of whom only five teachers eventually committed to be part of the study. Some of the reasons teachers gave for not being able to participate was that they were already involved in other projects or that they did not have the time.

Most of the teachers who volunteered to participate in the study taught Natural Science and one taught Physical Science. This met my main criterion of working with Science teachers. The other important criterion was that they would be from a school in relatively close proximity to Stellenbosch University or my home to make visits to the teachers at school feasible. All the RPTs taught at schools within the Metro East District of the Western Cape Education Department (WCED). Figure 5.1 indicates the WCED districts of which Metro East is one, and the locations of the areas, Khayelitsha, Macassar and Strand, where the RPTs' schools are in relation to Stellenbosch University. The schools were varied in terms of quintile (cf. Chapter 2 Section: 2.3.3). The school in the Macassar area is a quintile 5 school, whereas the two schools in Khayelitsha, a township between Macassar and Cape Town, are both quintile 3 schools. The school in Strand is also a quintile 5 school, even though contextually very different to the school in Macassar.

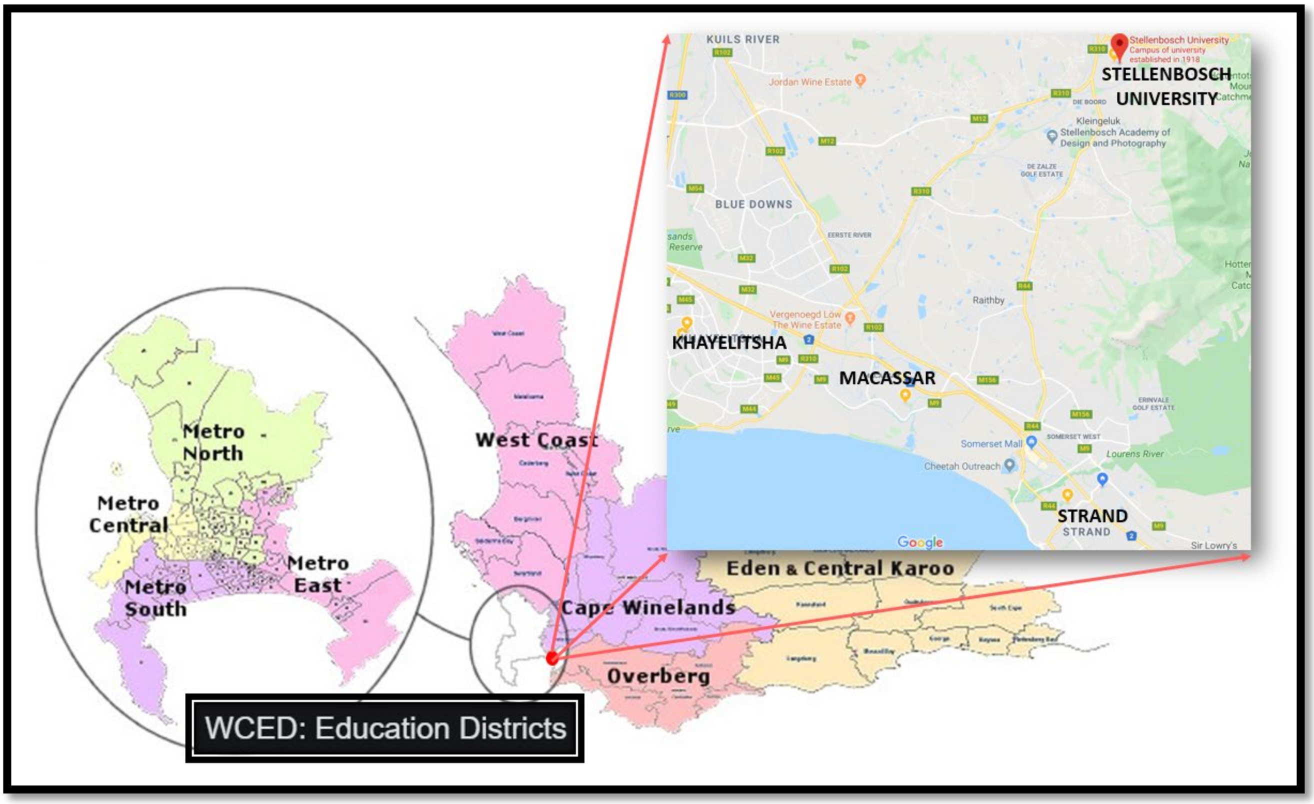


**Figure 5.1: WCED Districts and the locations of the areas of RPTs' schools (Source: WCED)**

Even though my choices were limited due to the low response rate to my invitations, and I had to work with the five teachers who voluntarily had agreed to participate in the project, I still had a varied group of teachers to work with. This was in line with my plan to ensure dissimilarity. The only category in which the group was homogenous was gender as all five participants were female. Apart from this there was variation in age, race, language, qualifications, teaching experience and work environment.

The age range of the RPTs was between 25 and 60. Three races were represented, namely black, coloured and white. In terms of language, three of the teachers have Afrikaans as first language and that is also the language in which they teach. The other two teachers have isiXhosa as their first language. The learners they teach also speak isiXhosa, but are taught in English as the learners must be prepared to write Mathematics and Sciences exams in English. In terms of teachers' experience and teaching profiles one participant was still a student teacher when we started the process. Two teachers had been teaching for more than ten years and the last two for more than three but less than five years. Table 5.1 displays an overview of the demographic and educational variation within the group of the RPTs.

In the subsections that follow I describe the profile of each RPT in more detail. I make use of pseudonyms to ensure anonymity and to protect the identity of the participants, as I agreed with the RPTs that I would not divulge their identities; this was also a requirement of my ethics approval.

**Table 5.1: RPT profile comparison**

| | Joe | Rose | Lisa | Pat | Sally |
|---|---|---|---|---|---|
| Age | 28 | 51 | 43 | 42 | 58 |
| Gender | Female | Female | Female | Female | Female |
| Ethnic group | Coloured | Coloured | Black | Black | White |
| Home language | Afrikaans | Afrikaans | isiXhosa | isiXhosa | Afrikaans |
| Language of instruction | Afrikaans | Afrikaans | English/isiXhosa | English/isiXhosa | Afrikaans |
| Suburb | Macassar | Macassar | Khayelitsha | Khayelitsha | Strand |
| School quintile | 5 | 5 | 3 | 3 | 5 |
| Highest qualification | B.Ed | B.Sc Honours | Teaching Diploma | B.Ed | B.Sc HDE |

### 5.2.1. Demographic characteristics

In this section I report on the race and age of the RPTs. Three South African race groups were represented. It was necessary to take cognisance of the race of the RPTs because of the effect apartheid had had on the background and education of the RPTs. Also, as highlighted in Section 2.3.3, the effects of race discrimination are still evident in the schools where the RPTs are currently working. This results in different teaching experiences and would affect the opportunities for the RPTs to adjust their approach.

The group of RPTs included a good spread in age, with the youngest a newly qualified teacher and the oldest teacher close to retirement age. Lisa and Pat are both black isiXhosa ladies in their early forties who both teach in Khayelitsha, but at different schools. Khayelitsha is a large black township in the Cape Town Metropole. Joe, a young, newly qualified teacher and Rose, a lady in her early fifties are both coloured and teach at the same school in Macassar, a former and still predominantly coloured community. The fifth teacher, Sally, a white lady in her late fifties, teaches at a high school in a previously white area in Strand.

Figure 5.2 displays the age range of the RPTs. It is necessary to consider the age of teachers as the periods in which they themselves were learners and students play a role in how they have been shaped academically. This was discussed in Section 3.5.5. Older teachers come from an era when classrooms were very structured and disciplined, with younger teachers having been more exposed to activities like group work and collaboration. Furthermore, age differences amongst teachers in SA mean different experiences of growing up and schooling due to apartheid. Joe, the youngest of the RPTs, grew up in a post-apartheid SA, while Rose (coloured) and Sally (white) grew up during the height of apartheid resulting in them having totally different experiences, even though they are more or less the same age. Lisa and Pat, on the other hand, grew up and completed their schooling and training during the period in which SA underwent the transition from apartheid to democracy.

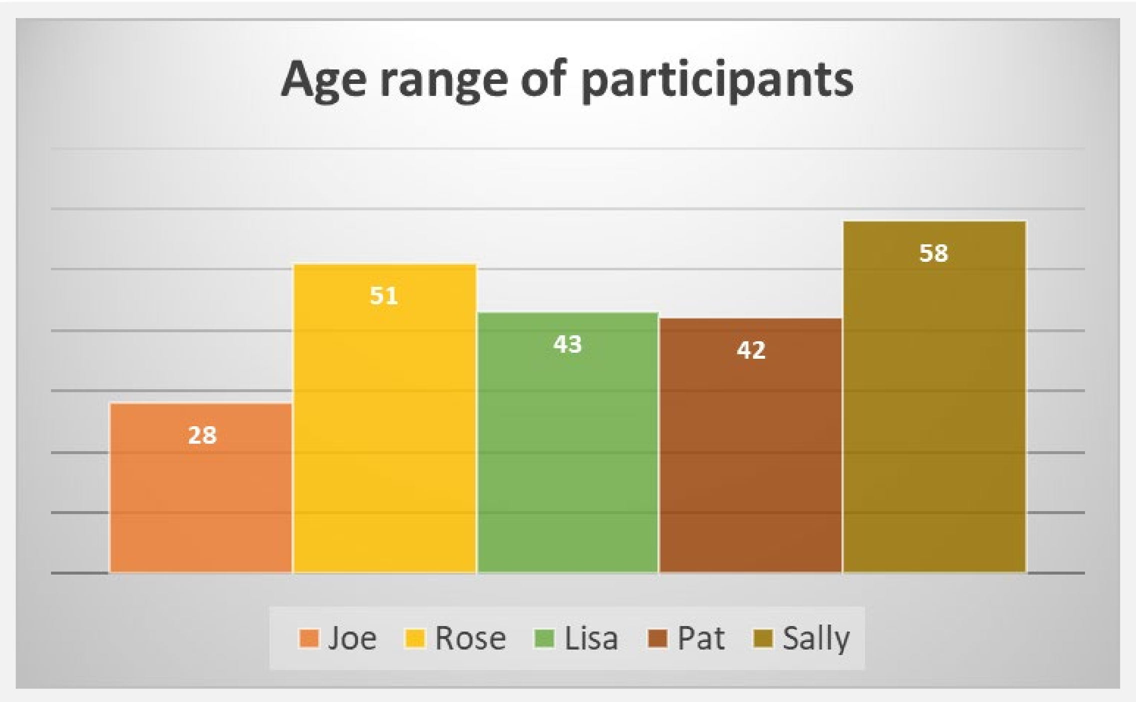


**Figure 5.2: Age range of the RPTs**

### 5.2.2. Places of study and qualifications

Variation was also found in the RPTs' levels of qualification. When one considers the effect of education the highest educational qualification (HEQ) is used most often, as opposed to the number of years spent in education (Easterbrook, Kuppens & Manstead, 2016). The development and implementation of the South African National Qualification Frameworks (NQF) was started in 1998 and overseen by the South African Qualifications Authority (Keevy, 2006). Table 5.2 below gives the structure of the NQF levels in SA, and includes NQF levels for teacher qualifications specifically. It shows that in SA, in order for a teacher to be deemed as a qualified teacher the person must have a qualification in education on at least NQF level 6 (DHET, 2015).

**Table 5.2: Current architecture of the South African NQF**

| NQF level | Band | Qualification types with emphasis on Teacher Education Qualifications | | |
|---|---|---|---|---|
| | | Degrees | Diplomas | Certificates |
| 10 | Higher Education and Training (FET) | Doctoral<br>Professional doctoral | | |
| 9 | | Masters Education Degree<br>Professional Masters Education Degree | | |
| 8 | | B.Ed. Honours Degrees | Postgraduate Diploma in Education | |
| 7 | | B.Ed. Degree | Postgraduate Diploma in Education<br>Advanced Diploma | |
| 6 | | Degrees, Diplomas and Certificates | Diploma in Gr R Teaching | Advanced Certificate |
| 5 | | Diplomas and Certificates | | |
| 4 | Further Education and Training (FET) | Certificates | | |
| 3 | | Certificates | | |
| 2 | | Certificates | | |
| 1 | General Education and Training (GET) | Certificates | | |

**(Source: DHET, 2014; Keevy, 2006)**

Places of study for the RPTs included universities, universities of technology and a college of education. Rose is the only RPT who has an honours degree, which was the highest qualification in the group. Sally held a B.Sc. degree and postgraduate diploma in education, while Joe and Pat both held B.Ed. degrees. Lisa holds a teaching diploma and did an Advanced Certificate in Education. By matching the HEQ of the RPTs with the levels in Table 5.2, I was able to display the variation of qualification level for RPTs in Figure 5.3 below.

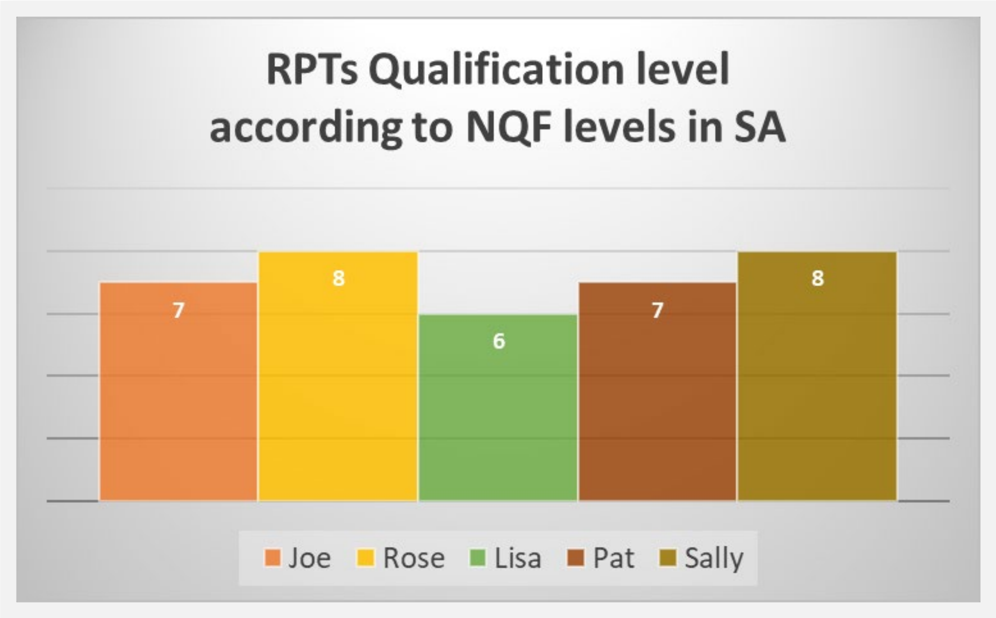


**Figure 5.3: Qualification levels of RPTs**

From Figure 5.3 one can see that even though the qualification level varies within the RPT group, all the RPT's have a good qualification level for teaching. However, for the purposes of this study it is important for this study to note that while all the RPTs were qualified teachers, the majority of them were not qualified to teach Science. Pat and Rose are qualified to teach Mathematics, while Sally is a qualified Home Economics teacher, who has done a Chemistry course as part of her studies. Joe and Lisa are the only two RPTs who are qualified Life and Physical Sciences teachers respectively and who teach these subjects as well. Pat, Rose and Sally all teach Natural Sciences. Table 5.3 summarises what RPTs are qualified for and what they are currently teaching.

**Table 5.3: What teachers qualified for and what they are teaching**

| QUALIFIED | Joe | Rose | Lisa | Pat | Sally | | TEACHING | Joe | Rose | Lisa | Pat | Sally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Physical Science | | | x | | | | Physical Science | | | x | | |
| Natural Science | | | | | | | Natural Science | x | x | | x | x |
| Life Science | x | | | | | | Life Science | x | | | | |
| Mathematics | | x | | x | | | Mathematics | | x | | x | |
| English | | | x | x | | | English | | | x | | |
| Home Economics | | | | | x | | Home Economics | | | | | |
| Afrikaans | x | | | | | | Afrikaans | | | | | |
| Consumer studies | | | | | | | Consumer studies | | | | | x |
| Life orientation | | | | | | | Life orientation | | x | x | | |

From this table one can see that even with just these five RPTs, a strong pattern of teachers' teaching subjects not being aligned with their qualifications. This was discussed in section 2.5.3. In the case of the RPTs, this situation arose as the RPTs' respective principals requested that they teach science subjects due to the need at the schools and the lack of qualified Sciences teachers. Pat's situation is a clear example hereof.

> "I majored with Maths and I majored with English at university. However when I arrived here at the school the science teacher, the grade nine science teacher she was off sick. The principal said to me he will rather place me in her position. Just to close that gap. So I started off as a person who was caretaking that department, but now you know when he made me permanent, he made me permanent as a natural science teacher. It's about two years now. This year is my second year teaching."

This is a common occurrence in South African schools and was referred to in Section 2.6.3. Importantly for this study, and specifically in view of a shift towards IBSE, the possible implications resulting from such a situation had to be considered.

### 5.2.3. Teaching experience

Figure 5.4 shows the RPTs' years of teachings experience as well as the years of teaching experience in the subject of Science specifically.

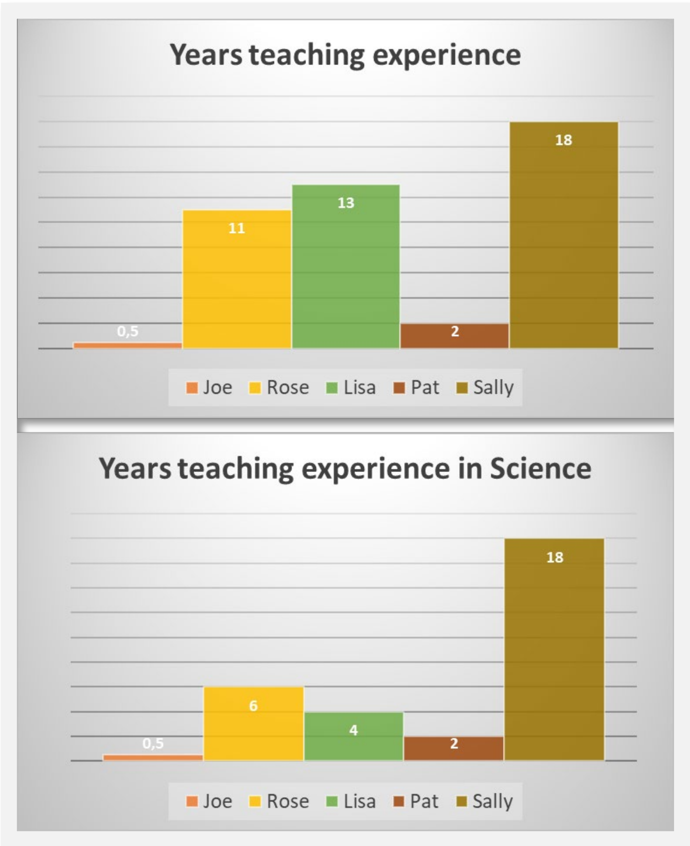


**Figure 5.4: RPTs' years teaching experience vs years teaching experience in Sciences**

Three of the RPTs have more than ten years' teaching experience. One has only two years of experience and another RPT is a newly qualified teacher in her first year of teaching. Even though three of the teachers, Rose, Lisa and Sally, have each been teaching for more than ten years, Rose and Lisa have been teaching a Science subject for only six and four years respectively. Rose teaches Natural Sciences to Grade 9 learners, while Lisa teaches Physical Sciences up to Grade 12 level. Pat and Joe have both had their qualifications for less than three years. Pat qualified two years ago while Joe only qualified in the year when the project began. Both Pat and Joe have been teaching Natural Sciences to Grade 9 learners since they started their teaching careers. Joe also teaches Life Sciences to Grade 10 learners. Sally is the RPT with the most teaching experience generally, as well as Natural Sciences teaching experience. Figure 5.4 indicates and compares the years of teaching and teaching of Science. Sally has been teaching for 18 years, and has been teaching Natural Sciences to Grade 9 learners since she started her teaching career.

### 5.2.4. Working space / School environment

Even though the RPTs all worked in state schools in the same educational district, namely Metro East in the Western Cape Province, the suburbs and schools they live and work in are very dissimilar milieus. In Figure 5.5, I display the variation in suburb and school quintile.

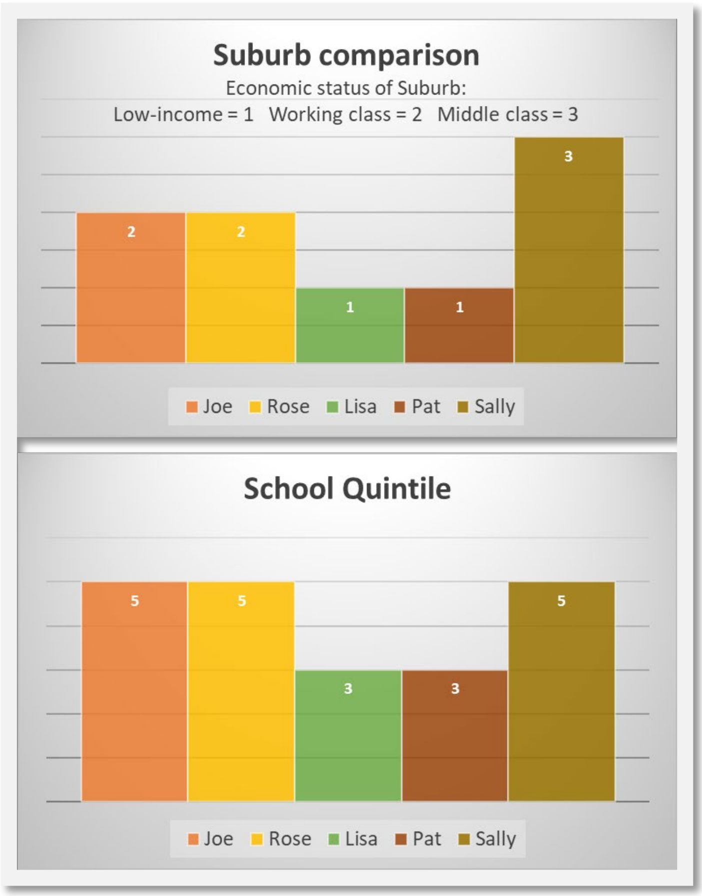


**Figure 5.5: Variation of suburbs and quintiles of RPTs schools**

Each area has its unique social and cultural background, which affects the learners they teach and the communities in which they work. In turn, this affects the resources the RPTs have access to. The two schools in Khayelitsha are both quintile three schools, which means that the learners do not pay fees.

As mentioned in Section 2.3.3 of Chapter 2, the government subsidises no-fee schools. The subsidy covers basic requirements, which include provision of school infrastructure, staff salaries, textbooks and some stationery, and is often not adequate to provide sufficient resources to schools, teachers and learners. School management teams are still responsible for maintenance of the infrastructure, and day-to-day expenses of water and electricity, just to mention a few. In Chapter 2 results from studies were highlighted showing that in most instances learners from quintiles 1-3 schools do not have access to resources like libraries in their community or books and other reading matter at home. Furthermore, these communities are characterised by homes without flushing toilets and running water. An aspect which has a big effect on learners' progress is that most of the learners from quintile three schools are not taught and assessed in their home language. This holds huge implications for teachers who have to factor in time they need to spend making provision to help learners overcome this language barrier.

The school in Strand as well as the one in Macassar are quintile five schools where parents have to pay fees and where the government subsidy is even lower. However, the resources and infrastructure of these two schools are quite different. The school in Strand is a previously white school in a previously white area, while the school in Macassar is a previously coloured school in a previously coloured area. Due to the apartheid history of SA, the Strand school has much better infrastructure than the school in Macassar. Even though the Strand school community is currently more diverse, it includes a parent body that is financially able to pay fees. This allows the Strand school to appoint more teachers than only those allocated by the government, which allows the school to have smaller learner numbers per class. Another point to keep in mind is that learners from the Strand school would generally come from a background where there is easy access to resources, and homes which have the basic amenities and even more.

The school in Macassar has, similar to the school in Strand, been categorised as a quintile five school. It is regarded as a quintile five school because its buildings are of bricks and it has flushing toilets for its school community. The home environment of the learners also plays a role in categorising schools. Macassar secondary school learners have access to amenities like flushing toilets and running water in their homes. This classification has, however, been done more than 20 years ago when the community where economically better off. The Macassar school is visibly different from the one in Strand and also operates on a much lower level. Firstly, the Macassar school building is smaller and much more basic, but it has to accommodate a higher number of learners. It is characterised by classrooms with open verandas, compared to indoor corridors at the school in Strand. Secondly, it has poorly developed sports facilities. In fact, at the Macassar school there is just an open space where sports could take place compared to lush green fields at Strand High school. Thirdly, even though housing in the community is better off than in many other communities in South Africa, homes in Macassar are generally small and basic and often have to accommodate large families. This impacts on the learners' chances to effectively do homework or study at home. Furthermore, the school governing body and broader parent body in Macassar are not in an economic position to make a significant contribution in school fees, resulting in a position where upgrading or maintenance of physical infrastructure and appointment of additional teaching staff, like is the case with Strand, is not possible. This results in the class sizes being bigger than those of the school in Strand. Furthermore, in Macassar, only a few members of the community have completed tertiary education, this has an impact on the guidance, and motivation learners receive from their home environment. All these factors, which differ amongst the schools represented in this study, impact on the teachers' experiences in the classroom and the ease with which they can perform their duties, which in turn affect teachers' inclination and ability to adjust their approach to teaching and learning.

As discussed in Section 1.3, the problem statement of this study, my aim with this study was to explore Inquiry-Based Education in a professional learning programme for science teachers. I specifically gathered data to investigate whether introducing a Science teacher to the IBSE approach would affect the teacher's:

(i) perceptions of Science and Science teaching, and
(ii) teaching practice in the Science classroom.

Having clearly explicated the context of the RPTs, in the next part of the chapter I report on the data collected during the course of the professional learning programme that introduced science teachers to IBSE. The instruments used were lesson observations and interviews with RPTs before and after introducing IBSE as well as a focus group discussion during the programme process. I also made some informal observations during the learning programme sessions. I report the data according to the steps I followed in the action research (AR) process that is fully outlined in Section 4. 6. The AR process consisted of three cycles.

## 5.3. CYCLE 1: Observations and learning

The aim of this cycle was to gather information and to take action. I did a class observation followed by an interview with each RTP individually at their respective schools. I used some of the information gathered in this way to finalise the introductory learning session on IBSE. I also finalised the date for the learning session to take place.

### 5.3.1. Class observations prior to the introduction to IBSE TPL sessions

During the class observations, which I made prior to introducing the teachers to IBSE, I could pick up a number of common teaching practices followed by the RPTs. The observation schedule (see Appendix 6) guided the observation process that focused specifically on the following:

- Lesson structure;
- Methods used;
- Teacher-learner interaction;
- Subject content; and
- Learner participation.

The findings of the first round of observation sessions are presented below in Table 5.4. This round of observation was done prior to the RPTs being introduced to IBSE or being interviewed. I provide a descriptive account, which is inclusive of further notes that I have taken, under the above headings by referring to Table 5.4. These notes are given in Appendix 13. Table 5.4 is a summary of the completed observation schedules of the lessons I observed of the RTPs at the start of the learning programme, prior to their introduction to IBSE.

#### *a. Lesson structure*

All, apart from Pat, started their lessons by reviewing or referring to the previous lesson. Most of the RPTs kept to the same format of introducing the lesson topic, presenting the facts and doing a follow-up exercise. All the teachers proceeded to lecture, maybe ask a question here and there, and gave learners instructions for follow-up exercises. In most cases teachers carried on talking with the learners left to just listen and follow. None of the RPTs drew the lesson together at the end by means of a summary. The RPTs, except for Joe, did not have time nor did they attempt to highlight how the next lesson would tie into the current lesson. Two teachers also seemed to run out of time as their respective lessons were still hanging in the air by the time the bell rang. In these instances, the time constraints were often due to the school day suddenly having shortened lesson periods due to unplanned meetings that occurred.

**Table 5.4: Completed pre-TPL session observation schedule**

| KEY: ✓ = Implementation observed **Blank** = Implementation not observed * Features of IBE or IBSE lessons | | | | | |
|---|---|---|---|---|---|
| **Lesson Structure** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** |
| Reviews previous lesson | ✓ | ✓ | ✓ | | ✓ |
| Introduces current lesson by means of overview | | | | | |
| Summarises main content points covered | | | | | |
| Directs learners' preparation for next class | ✓ | | | | |
| Maintains good pace during lesson | | ✓ | | ✓ | ✓ |
| **Methods Used** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** |
| Asks open ended questions | | | | | |
| Asks closed ended questions | ✓ | ✓ | ✓ | ✓ | ✓ |
| Provides well-designed materials* | | | | | ✓ |
| Employs non-lecture learning activities* (i.e. small group discussion, student-led activities) | | | | ✓ | |
| Organises the classroom/seating plan well | ✓ | ✓ | ✓ | ✓ | ✓ |
| Invites class discussion | ✓ | ✓ | ✓ | ✓ | |
| Employs other tools/instructional aids* (i.e. technology, computer, video, overheads) | ✓ | | | ✓ | |
| Delivers a lecture | ✓ | ✓ | ✓ | ✓ | ✓ |
| Is inclusive to all learners and their specific needs* | | | | | |
| **Teacher-learner Interaction** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** |
| Actively encourages learner participation | | ✓ | ✓ | ✓ | |
| Monitors learner understanding | | ✓ | | | ✓ |
| Involves a variety of learners | | ✓ | ✓ | | ✓ |
| Listens to learners and responds appropriately | ✓ | ✓ | | ✓ | ✓ |
| Demonstrates awareness of individual learner educational needs | | | | | |
| Ensures an environment that is conducive to learning | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Subject Content** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** |
| Has good content knowledge of the subject | ✓ | ✓ | ✓ | ✓ | ✓ |
| Appears well organized | ✓ | ✓ | ✓ | ✓ | ✓ |
| Explains concepts clearly | ✓ | ✓ | ✓ | ✓ | ✓ |
| Relates concepts to learners' experience | ✓ | ✓ | | | ✓ |
| **Learner Participation/activity** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** |
| Learners are given an opportunity to gather their own resources* | | | | | |
| Learners are given an opportunity to do their own research* | | | | | |
| Learners are given an opportunity to synthesise their own information* | | | | | |
| Learners are given an opportunity to present their findings* | | | | | |
| Learners are given an opportunity to reflect on their own learning* | | | | | |

### *b. Methods used*

Lecturing was the main lesson delivery method. Only Joe and Pat made use of a PowerPoint presentation to aid their teaching and in this way, they expanded the learning experience beyond listening and reading skills. Most of the RPTs spent a large portion of the lesson time on giving facts and explaining on the chalkboard. Lessons were mainly focused on transferring facts and sometimes doing a follow-up worksheet to test if learners could supply answers to problems given or apply the facts. Questions were mostly of the closed-ended type. None of the teachers used open-ended questions that would allow for other than a right or wrong answer and lead learners to think more out of the box. None of the RPTs made use of any feature of the IBSE approach. The IBSE approach gives learners the opportunity to pose questions, and gather resources and information themselves. Furthermore, this approach requires that the learners be guided to synthesise their own knowledge, and share and reflect on that knowledge. At this point none of the teachers implemented any of these teaching and learning elements which form part of the IBSE approach. This is indicated on Table 5.4 above.

### *c. Teacher-learner interaction*

Teacher-learner interaction started with instructions given to learners to take their seats and to behave in an orderly and quiet manner. During the course of the lesson questions were posed to learners in an attempt to engage them in the lesson. In all cases the RPTs had good command of the classroom in terms of discipline and structure. The RPTs also seemed to have a gentle approach with the learners and did not have to exert their authority in a forceful way, which gave an indication of the RPTs ability to effectively command respect with the learners. This was the case with all the RPTs despite the big differences in school environments, as pointed out in Section 5.2.4. This is important for effective implementation of IBSE as with the IBSE approach learners will have to take responsibility for their own learning through active participation in lessons, yet under the guidance of the teacher who must ensure a classroom environment conducive to learning (Von Glasersfeld, 2005; Levy *et al.*, 2011; Minner *et al.*, 2010). If teachers do not have a good command of their classes it can result in chaos with little or no learning taking place.

### *d. Subject content*

All the RPTs displayed a sound knowledge of the topic taught which showed their commitment to ensuring that they, as teachers, firstly knew the topic well before entering the classroom. This was despite the fact that some of them did not hold a Science teaching qualification. Only on two occasions did teachers refer to the previous lesson. Also, none of the teachers ensured that there was a form of differentiation for learners who could be more able or others who could be struggling. This is in conflict with IBSE principles which place a strong emphasis on *how* learners learn (Škoda *et al.*, 2013).

### *e. Learner participation*

The most common form of learner participation was by the teacher posing questions and calling on learners to give answers. In most cases teachers ensured that a variety of learners were called upon to give answers. However, as previously mentioned, these questions were largely of the close-ended type which check if learners know facts of the topic being taught.

Lesson observations done prior to introducing the RPTs to IBSE show that not one of the RPTs' lessons included any of the elements of IBSE. This is evident from the completed observation schedules for each of the RPTs that are all blank for this category. These include having a problem to solve, searching for answers or solutions, discussing findings and presenting facts (Anderson, 2002; Artigue *et al.*, 2012; Bell *et al.*, 2005; Levy *et al.*, 2011). Therefore, these observations highlight a strong leaning towards a teacher-centred approach as opposed to a learner-centred approach. A teacher-centred approach see learners as empty vessels which need to be filled with information and result in teachers engaging in transmission teaching (Carney, 2008; Dewey, 1933; Lourenço, 2012; Pardjono, 2002) (Section 3.2). Learner-centred teaching enables learners to think for themselves, and so gives them the opportunity to motivate themselves to learn, and to take responsibility for their learning. (Minner *et al.*, 2010) (Section 3.5.1).

## 5.3.2. Interviews prior to the introduction to IBSE TPL sessions

I planned my visits with the RPTs in such a way that after each class observation there would be time for me to do an interview with the RPT who had just been observed. This means that these interviews were also done before the RPTs were introduced to IBSE. I made use of an interview schedule, which is provided as Appendix 5, to guide my interview process. My findings from these interviews are presented according to the following themes which inform my research questions. I used the same categories to report my findings from the interviews held after the introduction and implementation of IBSE:

- RPTs' view of Science as a subject;
- RPTs' views of learners in Science lessons;
- RPTs' views of teaching; and
- RPTs' views of teaching Science.

### *a. RPTs' views of Science as a subject*

Teachers all had a positive attitude towards Science as a subject and indicated that they liked the subject and saw Science as an integral part of their daily lives. It was for this reason that they deemed it necessary for learners to take the subject since people encounter Science on a daily basis. This was strongly emphasised by Pat as she said,

> "I loved physical science even in those years when I was still a student at school. I used to be part of the science expos at University ....everything is Science, I mean we are living Science."

Sally shared the same sentiments,

> "Science is necessary 'cause you use it, you use it every day, and you can see the science in everything you do. Each day!"

Besides confirming what the other RPTs said, Lisa also highlighted the fact that Science is an important school subject as this will ensure that our nation has a regular stream of trained scientists.

> "They *(the learners)* know that I like science. I don't just like it, I love it. This is our living. Then, we live science ……. This is why I like it. Science is a need. Without learners doing science we won't have the doctors, scientists." [17]

Teachers also saw Science as a subject that is practical and emphasised that learners should be involved and should do activities. Many referred to the fact that they would love to do more practical work in the classroom. Pat indicated that she liked to be involved, to do things, experiment and explore and these were the aspects of Science that attracted her to the subject and what she believed the subject to be all about. To have the learner actively engaged in the learning process is one of the main features of IBSE and has it foundation in the constructivist learning theory (Hein, 1991; Minner *et al.*, 2010). The experimental component of Science provides good opportunities for learner active engagement, and the fact that the RPTs leaned towards it was a positive sign. Pat went further to say,

> "You know, so I just like the hands-on type of things. As a subject, Physical Science is a subject of experimenting."

This was echoed by Lisa,

> "I believe that Science is a practical subject."

Sally went further by mentioning that there is much benefit of doing something hands-on or practical as one would remember it better.

> "When you do something with your hand it's not easy for you to forget."

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[17] I made use of verbatim quotations from the interviews, but I edited out filler sounds like "uhm" and "laughter" for ease of reading.

### *b. RPTs' views of learners in Science lessons*

The general feeling of the RPTs towards learners in Science lessons were leaning more towards the negative side. Firstly, the RPTs experienced that learners' background in Science was not up to standard. Rose believed that,

> "Because the learners are not on the level they are supposed to be, it makes it difficult for me to teach."

Sally experienced the following,

> "They *(learners)* know less and less. They really, they don't see these things. They haven't got enough background when they reach grade eight and nine. They knew more ten years ago, or even when I started, ja *(yes)*, then I think they knew more."

There was also a perception among the RPTs that since information is so readily available through the internet and in the form of videos, learners do not readily pay attention or make an effort to fully get to know and understand various topics. This is what Sally said,

> "I don't think there is really a big difference in interest because they only get interested when they see, what you introduce them to. I think it is more ignorance than knowing more. Ja *(Yes)* I don't think they know more because they have the internet. Because this is not always what they use the internet for. …One or two will tell you they've seen this and that on the internet and then we can talk about it. But it will be the same children that were interested whether they have the internet or not."

This led some RPTs to conclude that there was a need to spend some time on going back to foundational principles when teaching content. This, however, holds a threat to implementing IBSE. The learner's prior knowledge is the basis for teachers to work from when following the IBSE approach (Barrow, 2006; Cakir, 2008; Driver, Asoko, Leach, Mortimer & Scott, 1994; von Glasersfeld, 2005). In Section 3.3.6, it was pointed out that Dewey, Piaget, Ausubel and Vygotsky all recognised the role of prior knowledge in the process of learning and making new constructs. The RPTs often felt the need to provide learners with subject knowledge as they have the impression that learners' prior knowledge is lacking. This led to the RPTs feeling reluctant to hand the learning process over to the learners themselves. Furthermore, it results in the IBSE approach not being fully implemented. Prior knowledge or lack thereof should not be seen as a hindrance, but rather as a point of connection from which the learner can be guided to continue to discover more. Irrespective what the level of prior knowledge is, this is the place from where the learner should be taken to further develop understanding (Driver *et al.*, 1994).

Secondly, the RPTs found the learners to be very energetic and as a result they often had to call on the learners to be quiet and to focus. This too was seen by the teachers as disruptive to the process of teaching and learning. Pat's experience was,

> "There is so much energy and some of them can't sit still for long time."

Whereas the RPTs saw energetic students in a negative light, the IBSE approach is one that could channel this energy positively. Dewey emphasised the importance of creating opportunities for learners to achieve their own learning objectives as guided by their own experience, interest and concerns (Hyslop-Margison & Strobel, 2007). As stated in Table 3.2 in Section 3.3.7, conceptual understanding increases when learners are actively engaged and discussion with others develops scientific thinking (Artigue *et al.*, 2012; Levy *et al.*, 2011; Minner *et al.*, 2010; Shamsudin *et al.*, 2013). The active engagement of learners and discussion with peers are two main features of the IBSE approach.

Thirdly some of the RPTs also commented that learners are lazy. Lisa, for example, said,

> "Learners don't do well as our learners are very lazy."

On the other hand, this can point to the need to change teaching practices, as learners may be apathetic and not necessarily lazy. The transmission approach to teaching often results in passive and thus disinterested learners (Carney, 2008; Dewey, 1933; Lourenço, 2012; Scheurman, 1998).

On a more positive note, the RPTs' responses show a desire to involve learners and getting them to participate more actively during lessons, as that would improve the quality of learning. Some of the statements which indicated this are cited below:

> "When you do something with your hand it's not easy for you to forget. Rather than memorising. Also take them to a place where they can…like ESKOM, to see Science in action" *Sally*

> "Because I said to you it is a practical subject. And the more you give them something to solve, they can. It's gonna make them to feel that, 'Ah I can do science,' and it's gonna excite them. This is what I want. I want them to like, love science. *Lisa*

Some of the RPTs suggested that some learners showed a keen interest, could work on their own and had indicated that they would like to continue with Science as a subject.

> "They, two of my learners, are watching a certain programme on television and if they found something that was so profound and then they will come and ask. Some of them they are able to work on their own. Others work on their own and they work very well on their own but there are those who you have to come and guide and tell them to *shh*. I've got like a group of ten learners of that class and they've already said to me, 'Ms next year we are doing physics, and we are aligning it with maths.' Others are saying they are doing Physics and they are combining it with Life science." *Pat*

This is a good sign for the implementation of IBSE which requires that teachers allow learners to be actively involved and take responsibility for their own learning (Artigue *et al.*, 2012; Minner *et al.*, 2010; Shamsudin *et al.*, 2013).

### *c. RPTs' views on teaching*

There was a strong sense among the RPTs that in order for the learners to think for themselves they should be interested in the subject. In order to get them to be interested the RPTs believed that they needed to introduce learners to novel concepts.

> "You must try and keep those children interested and to think for themselves. So you must try to keep them interested, show them that there's always something new. Cause I think my whole aim is just to get more children to be interested in the subject. " *Sally*

Teachers spoke about the importance of learners understanding the work and thinking for themselves. However, they believed that the way to do that in Science teaching was by 'showing' the learner, i.e. doing practical work in class, and due to a lack of adequate time and equipment for practical work teachers felt that they were not able to do this effectively. Sally said,

> "I thought I was going to show them all these lovely things and then you can't do that. Because there's no time and you are working with 30, 35, 40 children in your class. So you just have to give them the information and try to get them to remember everything. I like to show them the real thing."

Joe added that,

> "As soon as I get to content that is abstract I prefer to do things more visually. / *Sodra ek by die abstrakte inhoud kom sal ek verkies om dinge meer visueel te doen."* [18]

These comments tie in well with IBSE as they indicate that the RPTs did want to kindle learner interest, but the IBSE approach is one where learners' interest is developed through a learner-centred process of self-discovery. This process must be guided by the teacher and not be one where the teacher simply presents interesting facts or science demonstrations (Kang *et al.*, 2016; Levy *et al.*, 2011; Minner *et al.*, 2010).

The interview responses also showed that the RPTs still regarded transferring of information and sharing of facts with learners as one of their key responsibilities. Phrases or terms like 'giving notes', 'teaching what they need to know', 'transferring knowledge', 'giving information' and 'providing the simplest form of a definition to make it easy to memorise', are evident hereof.

Pat was clear about the need to 'give notes' to the learners and that teaching Science meant that the teacher has to 'impart knowledge'.

> "I first like to show them the PowerPoint slides and then give them the notes afterwards."

[18] Some of the RPTs' responses were in Afrikaans. In these cases I include the English translation followed by the original Afrikaans response.

Pat also said,

> "Then teaching science at the same time it means that you need to now 'impart the knowledge' of the world around you to the young minds out there."

Rose echoed Pat and confidently stated that she believed she had the 'skill' to do this.

> "I teach them what they need to know."

Rose also said,

> "I believe I have that skill to transfer (knowledge)."

Sally too endorsed these sentiments and took them further by pointing out that once teachers had shared information with learners they needed to also find ways to get learners to remember all the information. This strongly points to memorisation and rote-learning.

> "So you just have to give them the information and try to get them to remember everything."

Lisa explained the extent to which she tried to find the simplest format of facts to share with learners to aid memorisation.

> "I used to take more information from the different textbooks. Then I need to have a lesson plan. I do have my book whereby I'm planning my lesson. Then I'll go to different textbooks. Even if it is a definition for example, I will take this textbook and see how they define this because at the end of the day I do want to give my learners the simplest one so that they can memorise it."

Joe, the newly qualified teacher, was the only RPT who referred to the fact that learners have different learning styles. However, she limited this to only listening and seeing, and indicated that in order to cater for those who are visual leaners she would from time to time move away from explaining to including a diagram or playing a video. However, Joe also shared the belief that the teacher should provide the learner with information in various ways and formats.

> "We all have different ways of learning, and when it comes to planning I try and incorporate as many of these elements in my lesson. For example, not all of us are aural. Many of us are visual……..I will have to make use of diagrams or play a video….That kind of thing. */ Ons almal leer anders en as dit kom by beplanning, probeer ek so veel as van daai elemente in my lessie hê, soos ons almal hoor, is nie ouditaal nie. Baie van ons is visueel……. ek moet die sketsie gaan teken of die videotjie speel… daai tipe ding."*

These ideas of transferring information to the learners and of memorisation by the learners were common to all the RPTs. This is demonstrated by the examples shared above. The fact that the RPTs were a relatively diverse group of teachers who were teaching in different environments did not seem to make a difference. This pointed to the strong emphasis that the RPTs, and one would want to say, teachers in general, still place emphasis on transferring of facts and memorisation as the key learning processes. This is in contrast to the IBSE approach which is a process whereby learners construct their own knowledge and make meaning of it through reflection and discussions with others (Artigue *et al.*, 2012; Minner *et al.*, 2010; Ramnarain, 2016).

### *d. RPTs' views about teaching Science*

The RPTs stressed the importance of knowing one's subject well when teaching Science. They alluded to the fact that they often found themselves in a position where they did not feel comfortable with a specific topic and that this hampered how they approached teaching the topic. The RPTs' preferences and lack of confidence could also influence the learners' preferences and confidence about the Sciences, causing the learners not to embracing Science fully. Pat said,

> "You know I would prefer the first term's work, which is life science part, to be taken by somebody who teaches life science. You know that to be taken away (from me). To somebody who teaches life science, because I believe if somebody knows the subject then they can be able to teach it in a very diplomatic and more dynamic way, than a wannabe like myself who's trusted here."

Similar sentiments were voiced by Lisa,

> "I don't like Physics… I am comfortable when it comes to Chemistry. This is my third year now. Then after that (no) I'm also giving my learners this attitude. That they can see that Miss doesn't like the Physics as a subcategory of Science. This year let me not show them my problem. I must be excited on both sides."

Some of the RPTs believed that often teachers who were not sufficiently qualified were given the task to teach a Science subject and that this compromised the quality of Science education. Joe indicated that this was particularly the case in lower grades where a general Science syllabus is offered to learners. She said the following,

> "I think that often Natural Sciences are being neglected. Let us just get a teacher quickly to teach this (Natural Sciences), but then we forget that there are basic principles that the learners must learn to build the foundation for Life Sciences. I think that in most cases the Life Sciences teacher must also specialise in Natural Sciences. */ Ek dink, baie keer word Natuurwetenskap onder die mat gevee. (Daar word gesê,) 'Kom ons kry gou 'n onderwyser om dit aan te bied', maar dan vergeet ons die basiese beginsels wat daai kinders daar moet leer sodat hulle die fondasie kan bou vir Lewenswetenskappe. En ek dink in baie gevalle moet onderwysers wat Lewenswetenskappe aanbied, spesialiseer in Natuurwetenskappe ook."*

IBSE entails that teachers facilitate a discovery learning process for learners. This requires that teachers know their subject well and have a high degree of confidence in their field, and so the above could be unfavourable to the RPTs using the IBSE approach.

Careful planning and organisation is required in order to place the responsibility of learning in the hands of the learner and to facilitate such a process as demanded by the IBSE approach. (Levy *et al.*, 2011; Minner *et al.*, 2010). The RPTs made planning for lessons a priority, but they also pointed out the challenges they encountered with preparing and planning for Science lessons. Pat indicated that preparation for Science lessons was time consuming and sometimes complex as it consists of various facets.

> "You know preparing most of the time is what is challenging. You know Natural Sciences is comprising of life science first term and then it's equations and reactions second term. Third term is force and then fourth term is earth and beyond. So it's a combination of different subjects."

Joe spoke about the fact that one can spend much time on planning and then in reality things did not go according to plan.

> "Look you can spend all the time to plan as good and thoroughly as possible, but what really happens could be something completely different. I think I do try my utmost to execute what I have planned. / *Kyk jy kan hoe lank, en hoe goed, hoe deeglik beplan, maar wat hier gebeur is iets heeltemal anders. En ek dink ek probeer baie hard om dit wat ek beplan uit te voer."*

Sally pointed out that preparation would take much time, but once the basics were in place one could build on it.

> "Ja (*Yes*), but that took me ages just to do this. So this year I can, feel that I can do more experiments or think of other things because I already have a basis of all the things I can show them on the screen."

These comments brought home to me that TPL sessions would have to be used optimally to assist with and give guidance for effective planning.

The RTPs were aware that Science is a subject that can, to a large extent, be presented in a practical way. Teachers could allow the learners to experience the Sciences first-hand by allowing learners to experiment and doing practical work. RPTs indicated the importance of doing Science practically, but shared their challenges in this regard too. Lisa shared her experience as follows,

> "Another thing, the challenges firstly we don't do the practical. You know even today if you can see my lesson. When I was supposed to show them the galvanic cell. Now we are supposed to do all this practical, so that they can see what is happening. How does this oxidation happen, but unfortunately we don't have it. I said to you I believe in practical when it comes to Science. If I can every time when I do something, it's either I demonstrate or I just give them practical. Now it's only textbook. It's only textbook and me writing on the whiteboard. I'm not happy. I need more. More things that I can show them so that they won't forget. I mean when it comes to chemicals where I say this is soluble, they can see. The colour changes they can see. Not giving them from the textbooks."

Both Lisa and Rose highlighted the lack of adequate facilities, namely appropriate Science teaching spaces to do practical work, being a hindrance to teach Science effectively.

> "But unfortunately for us we don't use our equipment because we don't have a science lab. This is my lab as you can see but it's like this. Our government doesn't give us enough. Because you see our school is still new, but if you can look at our labs and the classes are few. To me, I think they were supposed to give us big, big rooms only for chemistry or only for science. Whereby the learners only come here for practical, but that's the problem we don't

> have the space. Then we have to take every learner to this classes, you know and sometimes they even vandalise the equipment." *Lisa*
>
> "No, our school got one (laboratory) in the Physical Science class, but we haven't got enough, well there won't be practical. It's difficult to find a period where I can go to that room (laboratory). It's being used for a class. It's not an empty room that's there for your use." *Rose*

Sally's school has a laboratory, but she indicated that this was very seldom available for her lessons as it was mainly used for more senior learner groups. This alerted me to the fact that TPL sessions must include demonstrating alternate ways to doing practical work when one does not have access to a laboratory.

The RPTs did recognise the use of technology as an alternative to be used in the case of absence of a laboratory or lack of time for practical work. This is positive as technological resources can be used very effectively when a laboratory and scientific equipment are not available. When used well technology can also help with time management. Lisa commented that,

> "The demonstrations for us now are going to be easy because we've got the computers now and then the overhead projectors. But not in all the classes. It's going to be easy for us to do the slides whereby you just take the lesson and then you do the presentation to them. That is a demonstration".

The RPTs highlighted that more time was needed to teach Science and that the length of the period should at least be adequate to make Science lessons more effective. Lisa complained that,

> "Even the time. I only have single periods for my grade 12 and officially (for practical work) this single period is not enough for us".

The number of learners in the classes also made the teaching of Science to be challenging especially when the lesson includes a practical component. This was mentioned by both Sally and Lisa.

> "Our classes are too big." *Sally*
>
> "Sometimes we have overcrowded classes." *Lisa*

Overcrowding in classes has direct implications should one want to follow the IBSE approach where group work and facilitating learners' own learning is the order of the day. Bigger class sizes could make this process difficult to follow and implement. Teachers would find it difficult to reach all the learners if the classes are too big and bigger groups can easily become out of control and disordered.

The above highlighted a number of frustrations that the RPTs had with teaching Science. The positive side was their desire to teach Science effectively, and I decided to use this to good advantage when introducing IBSE to the RPTs.

### 5.3.3. Informal observations during the first face-to-face IBSE TPL session

The first face-to-face IBSE TPL session started with a brief lecture giving some background on IBSE. Following this, a practical session was presented in which the RPTs had to investigate a phenomenon. They were presented with a heat pack which was used as an object to excite their curiosity. They were given the instruction to click the button and observe what happened. This made teachers to become enthralled with the object resulting in a number of questions. They wanted to know what caused the reaction they saw taking place in the heat pack, what caused the heat and how the metal 'button' operated.

The RPTs responded well to the instruction to write down their observations as well as any questions that arose as they made the observations. The RPTs also had a very keen response when they were presented with some reading material that they could use to search for answers to their questions. Since they were intrigued by the observations, they eagerly scanned through the short article resources for answers. The RPTs presented their thoughts and findings quite effectively by producing a poster and making a short presentation.

In general, RPTs all responded very well to the session. They all were keen to participate even though I could see that the method used was new to them and therefore made them feel somewhat apprehensive at first.

The following section covers the implementation and mentoring phase of the action research project. I use the focus group discussion data to present more of the RPTs responses to this learning session.

## 5.4. CYCLE 2: Implementation of IBSE by RPTs and mentoring

The focus of the second cycle of the action research project was for the RPTs to implement the newly discussed IBSE approach and provide them with some form of mentoring.  The RPTs were instructed to start to introduce elements of IBSE into their lessons. They were cautioned not to attempt making a complete change to IBSE. It was suggested that they could use IBSE principles in parts of lessons, to introduce lessons or to investigate something. This was to prevent the RPTs becoming overwhelmed, as neither teachers nor learners were familiar with IBSE. Also, IBSE requires careful planning since learners need clear guidelines and instruction.
After granting a period of four months for the RPTs to implement IBSE in their lessons, a focus group session was arranged. The initial plan was to have individual feedback and mentoring sessions, but when that could not be secured the focus group feedback session was arranged. The feedback session gave much insight into the RPTs' understanding of IBSE.

### 5.4.1. Focus group session: RPTs' responses to IBSE as a teaching approach after initial implementation attempts

The session started with a discussion of the RPTs' perspectives on the introductory learning session on IBSE as well as their experiences with implementing IBSE in their lessons. The RPTs were also asked to complete a semi-structured interview schedule in writing. I start by reporting on the perspectives shared during the focus group discussion and follow on with the feedback they provided on the semi-structured interview schedule. Lisa was unable to attend the focus group discussion. I had an individual feedback and mentoring session with her during which she completed the semi-structured interview schedule as well. I also include her responses in this report back together with the responses of the other RPTs.

#### *a. Feedback about the initial training session*

My first question to the RPTs at the focus group discussion was what the introductory session meant to them. The feedback was overwhelmingly positive with adjectives like "profound", "exciting", "inspirational", "stimulating" and "informative" used to describe how they encountered the introductory session. Rose indicated that the way the activity was presented made them "want to do it" and that this was important for learners in order for them to learn: "they must want to do it". Pat referred to the fact that people, and thus learners, are generally inquisitive beings leading to them asking questions. This, she said, could be a way of stimulating learning amongst learners. Sally said that it presented her with new ideas and made her think about her teaching. Joe liked the fact that the session was broken up into sections. She felt that each section was easy to follow and understand, and that it gave them a good foundation in IBSE. The RPTs also indicated that they received sufficient information to start to implement IBSE, especially since they had been given a CD with further background information about IBSE.

#### *b. Examples of IBSE implementation by RPTs*

The RPTs also gave examples of how they had implemented IBSE in their classes. Pat used a cue card activity for which she placed cards in various parts of the classroom, which leaners needed to find, gather information about the item mentioned on the card and then match the cards. Sally suggested a cut-and-paste activity to get learners engaged, as well as getting learners to recite facts in pairs to each other.

During this period Joe, who was completing her B.Ed. degree, had to do a lesson for assessment purposes. She decided that she would use IBSE principles. She mentioned that this called for considerable planning, and even though the learners did not quite succeed in fully understanding what she required of them, she could then fall back on traditional practices. The lesson resulted in her getting a distinction for the assessment, which was a huge motivation for her.

Rose mainly teaches Mathematics and described how she implemented IBE in a Mathematics lesson:

> "Scale. I would teach them the theory of scale, definitions, give examples, let them copy off the board and then let them work out questions. This time I gave them a task whereby they had to measure objects in class, draw up their own scale and redraw the object on a sheet according to their own scale".

### *c. Challenges to implementing IBSE as identified by RPTs*

The RPTs' feedback also highlighted the challenges they experienced with implementing IBSE. Sally became discouraged by learners' lack of interest when she wanted to attempt something new. She also found that by and large the learners in her class did not show good behaviour when she attempted group activities which is a prominent feature of IBSE. She said the following:

> "I had a group activity for my grade nine class, but I decided not to do it with the others. I don't know if it is just me who is overwhelmed when people do not work well together".

Rose responded to Sally's statement by suggesting that they as teachers are too 'old-fashioned' and therefore find it difficult to cope with group work. She encouraged the group further by describing the 'buzz' she experienced in her classroom when implementing an activity other than the normal as a 'healthy buzz'. She emphasised that one has to plan carefully and have structures in place to maintain order within this type of learning environment.

> "When I did an activity with my grade ten class there was a buzz. We think there is something wrong if the class is not completely quiet. I almost want to say that we are old-fashioned. It was a healthy buzz. My class is generally organized in a way that if I say groups, they already know who to work with. I used to struggle a lot with discipline and I learnt from my peers. One thing I learnt is that when they are in groups they must identify a leader".

What Rose found difficult was to find ideas for her Natural Sciences class as she says she is 'more mathematically inclined'. She said it was easier for her to think of ideas for her Mathematics class. This points to the importance of teachers having a solid foundation and good knowledge of the subject when using the IBSE approach.

Sally pointed out that the textbook resources provide ideas of what to do but that these are not always practical to follow. She would then refer to the internet for ideas, which would suit her context better. What made even these ideas difficult to implement was the limited Science equipment.

> "The textbook does tell us what we must do, but we can't always do what the textbook tells us to do. That is why I sometimes go to the internet then I get other experiments, maybe from the primary school that I can still do with the grade eight and nine learners, but again

> I do not have enough equipment. Also in my classroom I do not have flat tables on which I can do experiments. The school only has one laboratory and other classes are using it all the time so we don't get a turn and over and above that my classes are so big in number it is difficult to do something with all the learners".

### 5.4.2. Suggestions made to RPTs regarding implementation of IBSE

#### *a. Suggestions made to RPTs by the researcher*

I, the researcher, made the following suggestions during the focus group discussion to further guide and mentor the RPTs in implementing IBSE.

1. With reference to Rose's difficulty of not always knowing what to do, I encouraged the teachers to make use of the group chat to share examples of effective implementation or to ask questions. The purpose is to learn from, encourage one another, and so develop a community of practice.
2. As researcher/practitioner, I further encouraged the teachers to implement IBSE principles incrementally since this teaching approach is also new for the learners and they needed time to get used to a new way of learning. I advised the teachers to start slowly and only do certain sections of the lesson in this manner. For example, only use this method to introduce the lesson.
3. I also further guided the teachers by highlighting the importance of good planning and anticipating the different ways in which learners could respond, questions they could ask and behavior they could display.
4. I pointed out that breaking away from traditional conceptions of teaching and learning was required. The quiet, disciplined classroom is not the only environment in which learning can take place. Even though it may feel chaotic learning could take place in the group work sessions.
5. I reminded the teachers that these days learners are exposed to many different sources of information. This could give the false impression that they know it all.
6. I suggested that teachers allowed learners to make posters, as this worked well for consolidation at the end of a lesson.

#### *b. Suggestions made by the RPTs themselves.*

It was encouraging to find that the RPTs engaged with one another when their fellow participants asked for advice and made sound suggestions to improve the process. Below are the contributions they made.

1. Generally, the RPTs found it hard to decide what they could do in a lesson in order to follow the IBSE approach and a suggestion was made that a guide indicating topics with suggestions of IBSE activities could be helpful.
2. Joe suggested that they as RPTs should each keep a journal of what they tried doing the IBSE way and then they could meet up on occasions and share what they had done.
3. Sally encouraged the RPTs to share sources or resources with one another to make lessons interesting. She shared her idea of buying inexpensive fibre optic commodities and using those as an example of total internal reflection. This was a good way of making science relevant to the learners so that they can see how science fits into everyday life.

4. Rose pointed out the existence of multiple intelligences. As an example she used learners who are strong kinetic learners and would learn better when they can move around. Teachers sometimes don't understand why certain learners struggle to sit still in a desk with a pen. By being aware of different styles of learning one could plan for more learner-centred lessons.

### 5.4.3. Responses from the semi-structured interview schedule

The semi-structured interview schedule used for the RPT feedback is available as Appendix 7. I present the responses given by the RPTs in Tables 5.5 to 5.8. Tables 5.5 and 5.6 give responses to the question about the face-to-face TPL session in general and about the e-Lesson. Tables 5.7 and 5.8 give the responses to the questions relating to the implementation of IBSE by the RPTs. The questions are given in the grey blocks with the responses of each RPT colour coded with colours corresponding to a specific RPT.

#### *a. Views on the face-to-face learning session*

In Table 5.5, the first column contains responses on the face-to-face session while columns two and three contain responses about the e-lesson. In Table 5.6 responses to the e-lesson continues in the first and second columns of the table with the last column referring to responses about the learning session overall, whether face-to-face or e-lesson. The responses as given in the tables indicate that all the RPTs received the introduction to IBSE well. Joe indicated that the training was beneficial as she could, drawing on what she had learnt, implement it in her lessons. Lisa mentioned that it gave her new ideas, and a different way to approach her teaching, catering better for all learners. Sally said that she was encouraged to try something new. Words like "unique", "stimulating", "a teaching and learning environment conducive to all in the class" and "learner-centred" were used to describe their views about IBSE. Participating in the TPL programme challenged the RPTs to rethink their practice.

#### *b. Feedback regarding the e-learning session*

Only two of the RPTs, Rose and Sally, could complete the e-learning component. The others only partially worked through the e-learning sessions. Workload, tight schedules, limited access to technological devices and personal circumstances were some of the reasons given for not completing it.

Positive responses to what the RPTs could complete included reference to the fact that it was broken down into manageable sections from which they could learn. Rose found it positive that the content in the e-lesson not only confirmed already known information, but it also provided her with new knowledge. Sally indicated that it gave her a new model to implement. Lisa, who also could not finish the full e-lesson, indicated that even though she was aware of new methods she never considered implementing it in her lessons. She said:

"Some other things I was aware of, I've never took them serious up until I attended the e-learning session."

**Table 5.5: Semi-structured interview responses regarding TPL sessions - A**

| | Was the contact training beneficial and why? | Could you complete the e-learning session? If no, why not? | Please give comments about the e-learning session? POSITIVE |
|---|---|---|---|
| **Joe** | **YES,**<br>I am slowly but surely implementing the IBE-approach into my science and Afrikaans lessons. | **NO,**<br>I'm having some personal difficulties pertaining to technology. My workload has prevented me from completing the e-learning session. I am swamped with five assignments and a portfolio all due on the same date. Also at school, two Grade 9 Natural Sciences classes were allocated to me and I am involved in extra mural activities. | It was extremely informative as it was broken down into easily understandable chunks of information that served as the foundation for us teachers to build on. This is lifelong learning at its best. |
| **Rose** | **YES,**<br>we learned about another educational approach | **YES,** | Confirmation of old knowledge and learning of new knowledge and approach |
| **Lisa** | **YES,**<br>Since I attended this training I've gained new methods of teaching Physical Sciences.<br>I have learned different ways that can make the teaching and learning environment conducive for everybody in the class.<br>My lesson is always learner centred. | **NO,**<br>My schedules were very tight sometimes I had Saturdays and afternoon classes during the week. And I had a family problem in the last section. | I am a new teacher now, with new methods of teaching. Some other things I was aware of, I've never took them serious up until I attended the e-learning section. Science is a practical subject, we need to try every time to give the learners chance to explore and investigate and come with suggestions. In class I must teach them to be able to apply and implement the information that they gained in their everyday life. |
| **Pat** | **YES,**<br>It was very beneficial because I could be introduced to a very unique style of teaching which is stimulating to the learners. | **NO,**<br>There has been so many things happening to me such as my sick mother-in-law and I lost my cousin over the last two weeks. Also, this week at school is full of disruptions, i.e. COSAS coming to school and sending learners home. | None |
| **Sally** | **YES,**<br>It showed me that I was on the right track and also supported me and encouraged me to try new things. | **YES** | Inspiring and gave me a model to work from |

**Table 5.6: Semi-structured interview responses regarding TPL sessions – B**

| | Please give comments about the e-learning session? NEGATIVE | Please give comments about the e-learning session? SUGGESTIONS | General comments about the TPL programme |
|---|---|---|---|
| **Joe** | None | None | None |
| **Rose** | Time constraints. Shortage of equipment and material. Chemicals are old, space is limited. | We need more resources because there is a shortage of equipment and material, even if the learners work in groups, because we mainly have 1 or 2 instruments. | The head of the Natural Sciences, Joe, and I will have a discussion (soon) on which lessons we will use to implement IBE in Natural Sciences. |
| **Lisa** | Time frame of the training. Little time for the training. | We need more time for the sessions. All the science teachers must attend if possible. We need equipped labs in our schools. The number of learners per teacher must be considered. | I want to thank you for giving me this opportunity to learn more about teaching science. To encourage me to be positive especially in our world of work. I just wish the university could create more time for us to learn more. |
| **Pat** | None | None | IBE makes teaching and learning to be fun and learners enjoy it as well. It takes much time of course to prepare but the end result is great. |
| **Sally** | Overwhelming - puts a lot of pressure on me to try to do it right, but at the same time it is time-consuming and difficult to do in a classroom with 30+ learners. | Make children use to different ideas and methods of teaching. | IBE is time-consuming, but I like the idea of children exploring. It is difficult to find images, videos or articles for them to explore. Just easier to use basic knowledge of a topic. IBE brings a lot of excitement in class. Groups tend to get out of hand (especially gr 9). Textbooks are not really compatible with this idea. Summaries at the end of each chapter make learners lazy and does not teach them to synthesize. |

Lisa said further that it helped her realise that she must teach her learners to apply and use knowledge gained. This is an indication of a shift in her thinking to not only present the learners with facts that must be studied in a rote-learning fashion, but that they need to use new knowledge, and in so doing getting learners to think more deeply about knowledge they gain. Doing so will develop conceptual learning as referred to in Section 3.5.1 (McNeill *et al.*, 2013; Minner *et al.*, 2010; Muianga *et al.*, 2018).

It became evident that the RPTs misinterpreted some questions about the e-lesson and thought that it was about IBSE learning in the classroom. This highlighted for me the importance of being very clear when phrasing text questions where one is not present to correct participants if they misinterpret questions.

However, the general feeling amongst the RPTs on learning about IBSE, whether face-to-face or via the e-lesson, was that it brought back fun and excitement in class. Rose and Joe were even planning to introduce IBSE to the other Science educators at their schools. Lisa indicated that it rejuvenated her attitude to her work and that she appreciated the opportunity to learn and would not mind more opportunities like this. Pat and Sally mentioned that it did demand much effort, but was worthwhile.

#### *c. Response on implementing IBSE*

All the RPTs indicated that they had made efforts to implement IBSE. From their descriptions, as indicated in column one of Table 5.7, it became clear that what they did was to use elements to engage learners actively. Even though the RPTs were not at a point of implementing IBSE as a whole, as described in Section 3.5.3, and following through with different stages (Bell *et al.*, 2005), moving away from only presenting learners with facts was a good start. For me, this was an indication that the RPTs still lacked understanding of what IBSE entails and that further learning had to be provided.

Some of the RPTs indicated that learners struggled at first with responding to the new approach. Others experienced that it brought an excitement and buzz into the classroom. Whilst Sally was positive about how the new approach led to learners having good discussions about subject topics, she was still apprehensive about the new approach. She indicated that she struggled to control the class. In my initial lesson observation Sally had good control of her learners and now it seemed that she was not comfortable giving up that control. She also mentioned that only learners, who in her opinion already had good knowledge of the topic, i.e. good prior knowledge, could participate meaningfully. Here I picked up her hesitation to relinquish the teacher-centred approach for the learner-centred approach. It is also worth noting that Sally was the oldest amongst the RPTs, and hence, possibly more set in her ways than the younger RPTs.

**Table 5.7: Semi-structured interview responses regarding implementation of IBSE - A**

| Have you used some aspects of IBE in some of your lessons? If YES: | | | |
|---|---|---|---|
| | **Give a brief description of what you have done.** | **How was it received by the learners?** | **Did the activity lead to effective learning? Why?** |
| **JOE** | I used the IBE approach at the beginning of this term's new chapter (Population Ecology). We first needed to work through some "new" terminology. I used the IBE approach to get a sense of what they already knew and how well they could observe what's in the picture I provided. First they had to work in groups to provide examples of each term, followed by their group's definition. Then they got the lesson content to reflect on what they knew and what they didn't. | Initially I could tell just how unfamiliar they were with this approach. Thus I decided to give them 3 extra minutes pertaining to the activities. This approach needs to be practised in order for learners to fully benefit from it. | Yes, it resulted in learners examining their own knowledge and figuring out what they knew and what they did not - without the teacher acting as sole possessor of information and knowledge. At the end of the lesson they knew that each of them had something to bring to the table and that their contributions were valued. |
| **ROSE** | I applied IBE in math lit, Grade 10 class. They had to draw a plan of the classroom, posters, cupboards using scale decided /calculated by each group. | There was a positive buzz in the class as the different groups discussed their problem | All the learners participated. Some groups got their answers sooner than others. This also gave me the opportunity to spend more time with those who struggled. |
| **LISA** | In one of my lessons I downloaded a video from YouTube (Acids and bases) we watched it. | After the lesson the learners discussed everything they watched. I never saw them so active like that before. | Yes it did. I gave them classwork from the past question papers as I used to do. But this time I did not talk a lot. It was just to emphasise a few things. |
| **PAT** | I have pasted cue-cards of the different systems of the planet earth as well as pictures of each of these systems. Whoever found the cue-cards pasted them on the boards, and those who found the pictures pasted them in the appropriate spaces next to their relevant systems. | At first they were lost. They did not know where to find the pictures. They started saying I was joking until they moved away from their chairs and looked under the desks and found the information pasted there. | They did not know anything about this topic when it was started. When I introduced the lesson to them that it was about earth and beyond they said I must present lessons in this manner more. |
| **SALLY** | I gave learners a picture in groups and they had to discuss reasons why plant or mouse had died or survived. | Good discussions, but not always so easy to control. Children, who understood photosynthesis in primary school, could remember and interpret. | They could at least remember the importance of plants to provide $O_2$. There are still pupils who confuse $O_2$ and $CO_2$! |

The RPTs felt that teaching in this way was an effective way to learn. Some of the RPTs experienced that the changes they made as teachers led to increased participation by their learners. Joe indicated that greater participation by her learners resulted in most learners being able to make a contribution and feeling that their contributions were valued. This was a positive shift in the direction of putting the focus of learning on the learner with the teacher acting as the facilitator (Levy *et al.*, 2011) (Section 3.5.2). With learners being actively engaged, the RPTs said that it freed them up to attend to learners who needed more assistance. Even though Lisa continued with class activities similar to those she used before, she made a shift by stepping back and not just providing answers, but giving learners the opportunity to work through the problems themselves. Here she also saw the value of stepping back as it gave her a chance to engage with those who really needed her assistance. This was not entirely implementing IBSE as IBSE requires giving the learners a problem to solve, allowing the learners to find solutions through research and experimenting and then organising and discussing findings (Anderson, 2002; Bell *et al.*, 2005; Čeretková *et al.*, 2013; Ramnarain, 2016; Shamsudin *et al.*, 2013) (Section 3.4.1). However, there was a shift in the RPTs' conception of the role of the teacher from one who teaches to one who facilitates learning (Levy *et al.*, 2011; Muianga *et al.*, 2018; Ültanır, 2012) (Section 3.5.2). It was gratifying that some learner groups requested that lessons be done in this way, more regularly.

Table 5.8 contains the responses about whether the RPTs would continue to implement IBSE. The RPTs recognised that engaging learners could develop thinking and this would be their motivation to continue teaching in this way. Some of the RPTs indicated that they needed more learning and guidance in IBSE. This in itself was a good sign. If teachers did not find IBSE worthwhile, they would not request more learning about it. Also, the fact that they were willing to learn more was encouraging.

The focus group session worked well. Sharing their experiences and highlighting successes and challenges resulted in the focus group session being a more valuable exercise than the original plan to meet with the RPTs individually. Through participating in a joint focus group session the RPTs could learn from and encourage one another by sharing their thoughts and experiences. They could also hear first-hand about ideas used by others in the classroom. If I had stuck to my original plan to do individual follow-up sessions the benefits of this collaborative element would have been lost.

**Table 5.8: Semi-structured interview responses regarding implementation of IBSE - B**

| *Have you used some aspects of IBE in some of your lessons? If YES:* | | | |
|---|---|---|---|
| | **Will you do more such activities in the future?** | **Give reasons for not implementing IBE.** | **Do you need further support in implementing IBE? Specify.** |
| **JOE** | Absolutely yes! We need to develop innovative thinkers to be able to lead this country. Not scribes and secretaries. | I haven't implemented it in many lessons simply because as student-teacher I find methods such as group work is difficult as I don't know the academic and social strengths and weaknesses of all the classes I teach. | None |
| **ROSE** | The learners enjoyed the activity. Some learners experienced the 'lightbulb' experience. | None | None |
| **LISA** | Yes, but I need support.<br>I need support of:<br>• how to present my lesson practically all the time.<br>• Always make my lesson to be learner centred.<br>• Produce good results. | Exam time | Yes, I will really appreciate that.<br>I need support of how to present my lesson practically all the time.<br>Always make my lesson to be learner centred<br>Produce good results. |
| **PAT** | It's possible to do more lessons even if it is in maths next time. However, currently I am finding it difficult to incorporate IBE in Maths | None | None |
| **SALLY** | Yes | None | None |

The aim of the focus group session together with the semi-structured interviews was to ascertain how the RPTs experienced the input about IBSE through the two learning opportunities, as well as the implementation of IBSE. It had the added benefit of providing an opportunity for mentoring to take place with me giving input, but, more importantly, the RPTs themselves giving valuable input. The responses of this session also provided important insights to me as the researcher into further needs the RPTs might have with their understanding and practice of IBSE, in order to effectively plan and present the follow-up TPL session.

### 5.4.4. Follow-up face-to-face TPL session on IBSE

Another key component of cycle two was the follow-up face-to-face TPL session. This was planned based on observations and suggestions made in the focus group session, and from the feedback given in the semi-structured interview. During the focus group discussion I picked up a number of misconceptions held by the RPTs regarding IBSE. When asked to give examples of IBSE strategies they used in class they mentioned the following:

- Cut out and recite;
- Cue cards;
- Experiments;
- Use of videos; and
- Group work.

All of these are activities, which engage the learner and can certainly form part of an IBSE process. However, as stand-alone activities these are forms of active learning. The main aim of the IBSE process is to guide learners to construct their own knowledge and to get learners to think to make meaning (Artigue *et al.*, 2012; Levy *et al.*, 2011; Minner *et al.*, 2010; Ramnarain, 2016; Shamsudin *et al.*, 2013). The RPTs did not demonstrate a deep understanding of this aim.

The responses from the semi-structured interview, which focussed mainly on the e-learning session also, revealed that most RPTs were, for various reasons, not able to complete this session. The purpose of the e-learning session was mainly to give the RPTs theoretical insight into IBSE. Since most of the RPTs indicated that they were unable to complete the full e-learning package, it makes sense that they did not have a good theoretical understanding of IBSE.

I therefore decided to use the follow-up face-to-face learning session to address the fundamental principles of IBSE. I would also focus on what the aim and outcomes of IBSE should be, and I would make sure that we covered different types of IBSE. Lastly, I would allow sufficient time for the RPTs to start planning their next IBSE lesson at the follow-up face-to-face session.

Unfortunately, only two of the RPTs joined this session. During the period between the focus group session and the follow-up face-to-face session, I received an email from Sally to inform me that she would be resigning from her post to move with her husband to Dubai and that she unfortunately had to withdraw from the project. Neither Pat nor Joe could attend due to being ill on the day of the follow-up TPL session.

Rose suggested that an audio recording of the session be made. I decided to edit the recording and subdivide the hour-long session into five 12-minute clips. I anticipated that shorter sound bites of the session would be more appealing to listen to than an hour-long recording. I gave each subdivision a topic title and shared these audio clips together with the PowerPoint slides with all four remaining RPTs who still participated in the project. The topics of the individual audio clips were:

1. Introduction;
2. Structure of IBE;
3. Types & levels of IBE;
4. Practical ideas; and
5. Further ideas for implementation.

This would allow teachers to in their own time, as it suited them, access the material in bite sizes and listen to the discussion while they followed the PowerPoint slides.

## 5.5. CYCLE 3: Further implementation of IBSE and final data collection round

The RPTs were given another four months to implement IBSE after which the post introduction to IBSE lesson observation and interviews were done. At this stage two of the RPTs withdrew. Sally moved to Dubai with her husband and Joe withdrew due to pressures which often accompany one's first year of teaching. As a student teacher she had a limited number of lessons which gave her the necessary space and time to be part of the programme. However, after her full-time appointment she needed time to grow into the full-time teaching post with all the responsibilities that accompany such a post. Joe wanted to focus on finding her feet with the full-time teaching demands and in spite of several attempts to convince her to complete the full course of the research project, she would not allow me to do another observation lesson. In my initial briefing of the RPTs about their participation in the research project and in the consent form I did indicate to RPTs that they would be allowed to leave the group at any time if they so wish, and thus I could not force Joe participate in this very final round. Overall, her verbal feedback regarding the project and what she had learnt remained very positive. I tried to get a written response from her regarding her experience with being introduced to IBSE and how often she had implemented it, but no feedback was received from her.

On arrival at Pat's school for her observation and interview she informed me that learners had written tests earlier in the day and had left school after the test with the result that I could not observe her lessons and she could only participate in the interview.

In the following section, I therefore present the findings of two lesson observations and three interviews that I conducted with the RPTs after the full introductory IBSE TPL programme. This introductory programme on IBSE included all the learning sessions, face-to-face and e-learning sessions, as well as the mentoring and implementation.

### 5.5.1. Class observations post the introduction to IBSE TPL sessions

I used the same observation schedule (see Appendix 6) as the one used for observing the RPTs before they were introduced to IBSE. This was so that I could compare findings of the two sets of observations and establish whether introducing the RPTs to IBSE had caused any shifts in their perceptions and practice as Science teachers. The observation process again focused specifically on the following aspects:

- Lesson structure;
- Methods used;
- Teacher-learner interaction;
- Subject content; and
- Learner participation.

I now proceed to present my findings thereof. Tables 5.9 to 5.14 present a summary of the completed observation schedules of this final round per category. I also added the findings of the first observation sessions of Rose and Lisa to facilitate comparison.

#### *a. Lesson structure*

In the lessons I observed prior to introducing the RPTs to IBSE both Rose and Lisa had a very 'loose' approach to structuring their lessons. The lessons I observed at the end of the process were more structured. Both Rose and Lisa started their lessons with giving an introduction and short overview of what would be done during the lesson time. During the lesson time learners were kept on task and there was a concerted effort, by especially Rose, to ensure that she brought the activities to a close before the end of the lesson. This gave her time to consolidate the learning activities for that period and to give learners homework based on the lesson topic.

**Table 5.9: Final class observations about Lesson Structure**

| **KEY:** ✓ = Implementation observed **Blank** = Implementation not observed | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Post observations** | | | | | | **PRIOR** | |
| **Lesson Structure** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** | **Rose** | **Lisa** |
| Reviews previous lesson | | | | | | ✓ | ✓ |
| Introduces current lesson by means of overview | | ✓ | ✓ | | | | |
| Summarises main content points covered | | | ✓ | | | | |
| Directs learners' preparation for next class | | ✓ | | | | | |
| Maintains good pace during lesson | | ✓ | ✓ | | | ✓ | |

Giving short overviews of the lessons at the start of the lesson led to a more concerted effort by Rose and Lisa to work towards achieving specific outcomes of the lesson. This indicates an attempt being made to plan and streamline lessons better, as well as to place lessons in context for the learners, which is achieved when drawing on prior knowledge. As explained in Section 3.5, both these features, namely focused, structured lessons and using prior knowledge are key to the IBSE approach (Driver, Asoko, Leach, Mortimer & Scott, 1994).

### *b. Methods used*

There was a significant shift in the practical approach to the lesson by Rose and to a smaller degree by Lisa as well. Table 5.10 shows this.

**Table 5.10: Final class observations about Methods Used**

| **KEY:** ✓ = Implementation observed **Blank** = Implementation not observed<br>* Features of IBE or IBSE lessons | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Post observations** | | | | | | PRIOR | |
| **Methods Used** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** | Rose | Lisa |
| Asks open ended questions | | ✓ | | | | | |
| Asks closed ended questions | | ✓ | ✓ | | | ✓ | ✓ |
| *Provides well-designed materials | | ✓ | | | | | |
| *Employs non-lecture learning activities (i.e. small group discussion, student-led activities) | | ✓ | | | | | |
| Organises the classroom/seating plan well | | ✓ | ✓ | | | ✓ | ✓ |
| Invites class discussion | | ✓ | ✓ | | | ✓ | ✓ |
| *Employs other tools/instructional aids (i.e. technology, computer, video, overheads) | | ✓ | ✓ | | | | |
| Delivers a lecture | | ✓ | ✓ | | | ✓ | ✓ |
| *Is inclusive to all learners and their specific needs | | | | | | | |

In Rose's lesson there were elements of lecturing, but only to give background information and instructions for learners to do tasks in groups. Learners actively performing the task, followed this period of lecturing. During the time when learners were 'doing' they were also given an opportunity to give feedback per group. Allowing learners to perform a task and giving them an opportunity to reflect and give feedback, indicates a shift away from lecturing and transferring facts to learners. It also displays a shift away from teacher-centred to learner-centred teaching (Minner *et al.*, 2010; Muianga *et al.*, 2018). The fact that Rose gave the learners instructions on what to do indicates that she followed a form of structured inquiry approach (Bell *et al.*, 2005). By allowing learners to work in groups Rose also created an opportunity for the learners to interact with one another and to work collaboratively (Cakir, 2008; Smyth, 2003).

Lisa also used a brief lecture to introduce the lesson and to summarise what was done so far. She then called learners to the front to do examples of calculations on the board, and asked them to explain to their classmates what they had done. It was obvious that this lesson was an application type lesson and that the subject matter had been covered with the learners in a previous lesson. By letting the learners come to the board to do examples on the board, Lisa did get the learners involved, but not in way where they could discover or synthesise knowledge. The discovering and synthesising of knowledge are key features of the IBSE approach (Anderson, 2002; Bell *et al.*, 2005; Čeretková *et al.*, 2013; Minner *et al.*, 2010; Ramnarain, 2016; Shamsudin *et al.*, 2013).

From my observation of the teaching methods used I concluded that Rose had made some good shifts in her practice of teaching Science, but Lisa's shift had been only very slight.

### *c. Teacher-learner interaction*

Both Rose and Lisa had a good manner and relationship with the learners before they were introduced to IBSE and this remained. It shows that even though the RPTs changed their way of instruction, they maintained a good relationship with the learners. A good rapport between teachers and learners is a valuable and necessary asset for IBSE to be effective in the classroom (Von Glasersfeld, 2005; Levy *et al.*, 2011).

**Table 5.11: Final class observations about Teacher-learner Interaction**

**KEY:** ✓ = Implementation observed **Blank or X** = Implementation not observed
* Features of IBE or IBSE lessons

| **Post observations** | | | | | | **PRIOR** | |
|---|---|---|---|---|---|---|---|
| **Teacher-learner Interaction** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** | **Rose** | **Lisa** |
| Actively encourages learner participation | | ✓ | ✓ | | | ✓ | ✓ |
| Monitors learner understanding | | ✓ | ✓ | | | ✓ | |
| Involves a variety of learners | | ✓ | ✓ | | | ✓ | ✓ |
| Listens to learners and responds appropriately | | ✓ | ✓ | | | ✓ | |
| Demonstrates awareness of individual learner educational needs | | | | | | | |
| Ensures an environment that is conducive to learning | | ✓ | ✓ | | | ✓ | ✓ |

By engaging learners in an activity, Rose found herself free to give focussed attention to learners who were struggling or who had questions. During the feedback session, Rose had more opportunity to give input where learners had maybe misunderstood or formed misconceptions. Lisa could also interject and highlight key concepts as she allowed learners to present solutions to problems they were currently working on.

### *d. Subject content*

During both lessons observed the RPTs displayed a sound knowledge of the topic they presented to the learners and had a clear idea of what they wanted the learners to know as can be seen in Table 5.12.

**Table 5.12: Final class observations about Subject Content**

| KEY: ✓ = Implementation observed **Blank** = Implementation not observed | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Post observations** | | | | | | PRIOR | |
| **Subject Content** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** | Rose | Lisa |
| Has good content knowledge of the subject | | ✓ | ✓ | | | ✓ | ✓ |
| Appears well organized | | ✓ | | | | ✓ | ✓ |
| Explains concepts clearly | | ✓ | ✓ | | | ✓ | ✓ |
| Relates concepts to learners' experience | | | ✓ | | | ✓ | |

They also made an effort to give learners an opportunity to engage with the content themselves instead of presenting the subject content in the form of a lecture and notes. The RPTs were also able to correct learners when learners gave the wrong response or demonstrated a lack of understanding. For teachers to play a facilitating role and guide learners as required by IBSE, it is important that they have a sound and broad subject knowledge (Von Glasersfeld, 2005; Hyslop-Margison & Strobel, 2007; Levy *et al.*, 2011; Minner *et al.*, 2010).

### *e. Learner participation*

This time round the lessons were definitely more active and is evident in Table 5.13.

**Table 5.13: Final class observations about Learner Participation**

| KEY: ✓ = Implementation observed **Blank** = Implementation not observed<br>* Features of IBE or IBSE lessons | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Post observations** | | | | | | PRIOR | |
| **Learner Participation/activity** | **Joe** | **Rose** | **Lisa** | **Pat** | **Sally** | Rose | Lisa |
| Learners are given an opportunity to gather their own resources* | | | | | | | |
| Learners are given an opportunity to do their own research* | | ✓ | | | | | |
| Learners are given an opportunity to synthesise their own information* | | | | | | | |
| Learners are given an opportunity to present their findings* | | ✓ | ✓ | | | | |
| Learners are given an opportunity to reflect on their own learning* | | | | | | | |

Prior to the TPL programme in IBSE I observed that Lisa primarily followed a teacher-centered approach. She basically lectured and asked questions to various learners. Her requesting learners to come to the board and explain to their peers could be regarded as a shift. Rose, too, previously had a chalk and talk approach, but after the learning programme she had an active learning session with learners discovering for themselves what measurement is about. However, the lessons were still far from being full-on IBSE. Since learners were given an opportunity to do something active or practical in class, RPTs felt that IBSE was implemented. Yet, as discussed in Section 3.5.3, IBSE requires a process that involves more than just including active learning components into a lesson (Minner et al., 2010).

### 5.5.2. Interviews post the introduction to IBSE TPL sessions

I managed to have interviews with Rose, Lisa and Pat. I again report my findings from the interviews under the headings of the themes identified with interviews prior to the TPL session. In this report back I include an additional theme related to my findings of how RPTs experienced IBSE.

#### *a. RPTs' views of Science as a subject*

The RPTs' views about Science as a subject remained largely the same. They still deemed it to be an important subject to do at school and one which is exciting, fascinating and interesting. The fact that one should be able to do experiments and practical work was still a high priority for them as teachers, as demonstrated by their inputs below.

> "Science gives me the opportunity to experiment." *Pat*
>
> "I believe that doing Physical Sciences is a practical subject." *Lisa*

Previously the challenges they faced preventing them from doing practical work was a big concern; however, after their introduction to IBSE they discovered that one could engage the learners in ways other than experiments. Rose explained how she did a Mathematics lesson on scale in a more practical way by allowing learners to choose an object in the classroom. This could be a door, a desk, the writing board, a book or anything else. They had to measure the object, determine a scale and draw a diagram of the object in their books according to scale. To me this is not full-on IBSE but it does show that this particular RPT was starting to shift away from doing a standard lesson on scale and then letting the learner do textbook examples. It is an example of getting learners actively involved (Minner *et al.*, 2010). This is in line with the first requirement for a learner centred teaching approach as was discussed in Section 3.5 where it was highlighted that inquiry in IBSE includes involving learners voluntarily in a form of active learning (Anderson, 2002; Bell *et al.*, 2005; Ramnarain, 2016; Shamsudin *et al.*, 2013). Also, at the focus group feedback session Sally shared her idea of buying fibre optic goods at the Crazy Store and using that to demonstrate total internal reflection. This displayed a way of finding solutions to a lack of scientific equipment in schools.

### *b. RPTs' views of learners in Science lessons*

The RPTs' experiences of learners are that they generally are shy and do not feel free to express themselves on aspects of the subject verbally. This is verbalised as follows by Pat,

> "When I look at it the changes were for the betterment of the learners. Especially as far as the presentation side is concerned because our learners tend to be tongue tied when they need to present in front of the classroom, but it actually enhances their confidence in standing in front and presenting and even though, you know, they are still struggling with the language but they are really working very hard to improve on those skills because their other skills underneath that are much more enhanced by the IBE approach."

In this regard I believe the language barrier plays a big role. The home language of leaners of two of the schools represented by RPTs is isiXhosa. This means that isiXhosa speaking learners have to learn and get accustomed to scientific terminology in English and explain scientific phenomena in English. This is the case as learners have to sit the school exit exam, the National Senior Certificate (NSC) exam, in either English or Afrikaans. However, when their teachers implemented IBSE, learner engagement evoked interest which enticed them to ask questions. This had a positive effect in that it helped learners to overcome their reluctance to use scientific language and in so doing improved their ability to communicate in English and to understand the terms in context. One of the benefits of IBSE, discussed in Section 3.3, is that IBSE allows for learners to work in groups giving them opportunities to discuss, question, argue and explain ideas with one another which subsequently leads to the development of team as well as verbal and reasoning skills (Muianga *et al.*, 2018). Pat's comments illustrated this,

> "You know they are much more involved first of all, and they are free to ask and you know, coming to our environment, because they speak isiXhosa but it forces them to understand the language English as far as Mathematics is concerned. It enhances them in terms of grasping all the mathematical terminology. Because now they understand when I am talking about measurements as to what it is that I mean. Without even them thinking twice."

There was a sense among teachers that learners became fascinated by Science and that they wanted to know more about the subject. They indicated that in the past learners would generally approach Science with caution and be apprehensive to the subject; learners now took a keen interest and became bolder when they were engaged and allowed to 'experience Science'. This is not surprising as the IBSE approach caters for a variety of learning styles and needs, it gives learners space to make their own decisions and allows for more learner responsibility (McNeill *et al.*, 2013; Minner *et al.*, 2010; Muianga *et al.*, 2018). This type of freedom and trust given to the learners can lead to positive outcomes. IBSE allows the learners to 'do' and to learn from their experiences (Anderson, 2002; Levy *et al.*, 2011). This was confirmed by Pat and Lisa,

> "But now the IBE takes all of that fear of Science from our learners. It takes it away and it actually makes learners much more fascinated about Science. Because now they are touching things. They are seeing, they're smelling. They are doing things themselves." *Pat*

> "And when it comes also to this method of teaching I have noticed you know our learners, they really want to learn. They really want to learn. Maybe it is because of the methods we are doing I don't know." *Lisa*

The RPTs recognises learners' ability to recall and make use of prior knowledge. Prior knowledge is what the main proponents of constructivism like Dewey, Piaget, Ausubel and Vygotsky ,to mention only some, believe is the starting block for learning (Barrow, L. H., 2006; Cakir, 2008; Von Glasersfeld, 1995). As IBE and IBSE is founded on constructivist principles, using the learners prior knowledge is a key feature in this approach (Driver *et al.*, 1994; Hein, 1991; Minner *et al.*, 2010; Škoda *et al.*, 2013). Pat gave the following example,

> "But now I made those little blocks of right-angled triangles as well as you know isosceles triangles you know different types of triangles and I hand it over to them, and then I asked them to select a right angled triangle. I did not say it in advance. I just gave them the pieces of different shapes of triangles. They could link their prior knowledge to the questions and then from there from that day. My learners know the difference between right-angled triangles, isosceles, equilateral."

The RPTs came to acknowledge that the learners' prior knowledge is that foundation in the teaching-learning process which can be used to grab the learners' attention and they as teachers can build on it. Pat said,

> "It (IBE) is working very well with the learners because this approach enables them to recall the data or the information that they already know and you know in some cases whereby it's the work they covered in the previous years, they are able to retrieve that information. Just you know by posing a question for example. As your introduction to the learners."

The RPTs also recognised that learners could find information for themselves, and that this resulted in better understanding. Lisa said,

> "To me I believe that for research, you need to give them plenty of time so that they can go get more information."

Constructive inquiry does not only improve the learners' understanding of the nature of Science, but it also promotes significant cognitive development (Bell & Linn, 2000; Shamsudin *et al.*, 2013). This was acknowledged by Rose,

> "Yes definitely, they were engaging with the work, which lead to a better understanding."

The RPTs did pick up a level of resistance to a new approach of teaching and learning. The RPTs indicated that to overcome the resistance by learners to the new teaching and learning approach, careful planning to capture learners' interest would be needed. Some of the RPTs also suggested that this new approach to teaching should be introduced within the primary school phase also that learners will be used to it by the time they are in secondary school. Pat commented,

> "They don't want to accept this new approach and others maybe they don't know that this approach is going to be useful to them but because they are not familiar to it they're blocking away from getting it through to them. Although it is going to benefit them at the end of the day. Because it is much more, you know, educational."

### *c. RPTs' views on Teaching*

Through the implementation of parts of IBSE the RPTs discovered new elements and strengths of teaching that they had not previously considered.

Firstly, the RPTs recognised that teaching can take on a more flexible character. Learners do not have to be quiet with teachers being the ones standing in front, talking all the time. Learning can take place even if learners are not sitting in neat rows like in a traditional, industrial model classroom. Both Rose and Pat commented on this.

> "It came across as chaotic, but they were focused on the task and therefore they were learning. *Rose*

> "It makes the teaching and learning in a classroom environment to be much freer you know for you as the educator as well as for the learners". *Pat*

Pat acknowledged that this required careful planning.

> "Now coming to the planning side of it, also I had to think of the mind-set of the learners. I had to think of minimising my talking so that I enable them to do the work to be effectively involved and give them the opportunity to discuss whatever decision that they come up with among themselves and then from thereon present it to the class".

Secondly, the RPTs observed that learners can learn better from one another. This was noticed by Lisa when she allowed her class to do presentations.

> "Then, this is what I like, when they do something they must come and present and they must do the presentation. I believe that when someone does the presentation on this topic, that one can make the other one to understand more than (when) I give them the lesson".

Another benefit one RPT experienced from allowing learners to do presentations was that this helped learners to express themselves verbally, in a more correct manner, which resulted in an improved use of language, specifically scientific language, and ultimately this gave learners more confidence.

Since IBSE was a novel concept to the RPTs they did experience some challenges. This varied from how to apply it to a subject discipline to practical challenges which included lack of resources, time and also large learner groups. However, this, did not discourage the RPTs from attempting to follow the IBSE approach. Pat said,

> "For me from the word go it was challenging because Maths is Maths and Science is Science and I had to think as to how I was going to incorporate the IBE in Maths. But I think the group

> chat that we had and what we still have it actually assisted me because I just threw a statement there in the group as to how I could incorporate IBE in Maths and one of the Science teachers in the group responded and she actually made me realise that IBE is not only for Science, but I can use it in any of the subjects whenever I teach in the near future".

Lisa highlighted the motivational effect of IBSE,

> "To me really this method, I have a feeling that it can make the learners want to do Physical Sciences. Because I believe that doing Physical Sciences is a practical subject, I don't even want to lie to you. You know this time of my life sometimes it is difficult even to maybe to think since I started teaching the practical it's only twenty percent of my lesson that I am doing. But now I really wanted to go back. Even if you can look at our school, our learners. And I told myself this is the last thing I am going to push that we must put all our equipment in the right way".

Many teachers face short lesson periods and large class sizes in their schools. This was alluded to in Sections 2.5 and 3.4 when the South African context was explained. Too little time and large class sizes is a result of the under resourced school environments and the poor socio-economic conditions in SA (Bantwini & Feza, 2017; Chisholm, 2005c; Onwu & Stoffels, 2005; Spaull, 2013). If lesson periods are too short it becomes difficult for teachers to effectively run a session where they need to allow learners to discover. This leads to the implementation of inquiry being constrained (Ramnarain, 2016). Lisa explained these challenges as follows,

> "The first challenge is the time and you know the number of learners that you are teaching. Because when you do the practical you must group them. And sometimes the others they will call you on the other side and sometimes you need to look at them. You know, I do know my learners are disciplined but at the end of the day I must make sure they are doing what I tell them to do. So I should think the main problem is the time for me and the number of learners I am teaching during that time". *Lisa*

The RPTs also experienced the extent to which the IBSE process demands careful and thorough planning. They needed to know exactly what their aims were with the lesson, and how long they needed to spend on each activity in order to manage the class and time well. This was highlighted by Rose,

> "When I first heard about IBE it sounded exciting, but when it came to the implementation it was not easy. I find that one has to be well organized to be able to do this effectively".

This realisation by the RPTs was a positive outcome as effective delivery of a Science lesson by following the IBSE approach can only occur through thorough preparation and planning to the finest detail (Shamsudin *et al.*, 2013; Von Glasersfeld, 2005).

### *d. RPTs' views about teaching Science*

The RPTs took up the challenge to allow learners to actively do more in the Science lessons, and they were pleased with the response of the learners and the outcome of the lessons. Learners actively participating in their own learning through doing and engaging is the main focus of the IBSE approach (Kang *et al.*, 2016; Minner *et al.*, 2010). Rose referred back to her earlier practices,

> "(In the past) I used to do all the talking and then they (the learners) just had to listen to me. I then proceeded by working through an example on the board to show them how it must be done. Examples of what they now needed to do. / *(In die verlede) ek al die praatwerk gedoen en dan het hulle nou net geluister na my. Dan het ek 'n voorbeeld op die bordgesit van hoe dit gedoen moet word. Voorbeelde van wat hulle nou moet doen*".

After engaging learners in lessons they eagerly participated. Rose gave the following description:

> "That day there was a buzz in the class. The children, the whole group participated. The whole group, they were actually, the groups were in competition with each other. / *Daai dag was daar 'n buzz in die klas. Die kinders, die hele groep was betrokke. So die hele groep, hulle was eintlik, die groepe was in kompetiese met mekaar".*

This is evidence of learners being interested in and focused on what they were doing. Learners were engaged in a social activity in which they could experience, share ideas and learn from one another (Artigue *et al.*, 2012; Levy *et al.*, 2011; Minner *et al.*, 2010). The fact that they were 'in competition' with one another is an indication that they could spur one another on.

Lisa had a similar experience when she allowed her learners to do a practical themselves instead of her demonstrating it.

> "They were excited. They were also very active. 'There's a change! This is acids and base! This is what is happening! There's a colour change' Oh, they became excited."

Lisa reflected on her previous practices, and how her practices had changed after being introduced to IBSE,

> "There was a change because before I used to give them a demonstration. I do the practical then they must tell me what is happening now. Then after I came to IBE I give them everything. Then they must do it and they must be the ones who are giving me feedback. As a teacher then I need to guide to elaborate what they are telling me to see what that is. At the end of the day they need to write the exam so they use also those science terminologies".

Lisa also commented on the positive effect of the IBSE approach on learners' performance,

> "And I also feel that if my lab can be equipped, I am telling you our learners are smart. They just look at the procedure and the instructions then they will do it. Immediately they give you 'Miss, this is what is happening'."

The RPTs' response to IBSE as an approach was overall very positive and, with the small steps they took to attempt to implement what they learnt, they could first-hand experience the difference it can make to teaching and learning. Some of the comments they made illustrate this:

Firstly, Pat's comment below eludes to the fact that by implementing IBSE the subject of Science is not presented as cold hard facts, but IBSE allows for the facts to be presented in a way where learners can grasp a better understanding and see it within context.

> "You know, the IBE approach it took Science from being a conceptualised thing and made it real. It brought it closer to the learners. Because you see from the textbook, all the information is written there, but the learners are too scared to explore what is written in the textbook".

She also mentioned, looking back on her own experience during the first workshop I held with them in Cycle 1, as well as from what she observed with the learners when implementing components of IBSE, that the process is one that encouraged thinking. This is what Pat said on two occasions about IBSE 'opening' the mind:

> "Before we started none of us knew what was about to happen but from the time you started handing those icepacks out and we're wondering you know, and that eventually triggered our minds. We were able to think from our own as to what it is that we can expect from the lesson. But prior to that we knew absolutely nothing".

> "Then I could see they were recalling the information they learnt in previous years, but it made my lesson much more effective and much simpler for them to understand. The IBE approach actually you know it opens the mind. It makes one think. Not just taking the information from the textbook and presenting it just like that".

Lisa indicated that she learnt through this project how she can use strategies which does not need equipment and still engage the learners to learn in a more practical way.

> "The problem is most of the lessons that I am doing now they want, they need a practical. But to me ever since I attended your sessions at least I got an idea, even if there is no equipment."

Rose's comment that "This should be done as from primary school level". Is a strong indication of her believing in the value that IBSE holds to teaching and learning, and that educators should consider engaging learners in learning in this way from as early as possible.

If one compares both the observations and the responses of the RPTs prior and post their learning and exposure to IBSE programme, it is evident that there has been a changes in their perception of Science and teaching Science, as well as a marginal change to their practice. I regard the change in practice as marginal as the RPTs only implemented the IBSE approach to a minimal extent. The RPTs did so by generally getting learners to actively participate in the lesson. These activities were also planned and set up by the RPTs, which indicates a structured inquiry. Other components of Inquiry-based Education (IBE) includes learners framing their own question, planning their own research or investigation, implementing the planned activities themselves and collaborating with others (Artigue et al., 2012; Bell & Linn, 2000; Kang et al., 2016; Keys & Bryan, 2001; Levy et al., 2011; Minner et al., 2010). Further levels of IBE are guided and open inquiry (Alake-Tuenter et al., 2012; Bell & Linn, 2000; Levy et al., 2011).

### 5.5.3. RPTs' descriptors of Science teaching

On both occasions when the RPTs were interviewed individually, the interview ended with an exercise containing descriptive words. The RPTs were asked to circle the words that would describe how they feel about Science and teaching Science. This group of words was included in the interview schedules as given in Appendices 5 and 8. Below, in Figure 5.6, is a copy of this particular section of the interview schedule.

> Which of the following words/phrases will you chose to describe how you feel about teaching science? Circle **ALL** the ones you feel apply to you now:
>
> **fun, hard work, a joy, too much preparation, dull, cool, boring, great,**
>
> **hum-drum, pleasurable, tedious, gratifying, dreary, rewarding,**
>
> **curious, heavy labour, predictable, exciting, tedious, creative,**
>
> **challenging, stimulating, routine, interesting, mundane**

**Figure 5.6: Descriptors of Science teaching presented to RPTs**

I used a web-based word-cloud generator, WordItOut[19], to represent their responses as this would graphically display the most favoured words in the largest font size and the least favoured words in the smallest font size with varying sizes in between. In order to make a fair comparison, I decided not to include all five RPTs' responses in generating the word-cloud, but selected only the responses of the three RPTs who completed both the interviews prior to and post the introduction of IBSE.

The word clouds in Figure 5.7 demonstrate that at the start of the project, before being introduced to IBSE, RPTs mainly felt that Science is stimulating, interesting, creative, exciting, challenging and fun, but also requires hard work and too much preparation. 'Rewarding' also came through strongly, but 'pleasurable', 'a joy', 'predictable', 'tedious' and 'curious' were selected to a much lesser degree. However, none of the RPTs regarded Science to be dreary, routine-like, hum-drum, heavy-labour, boring, dull, mundane and also not cool, great or gratifying.

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[19] Web-based word-cloud generator url: https://worditout.com/word-cloud/create

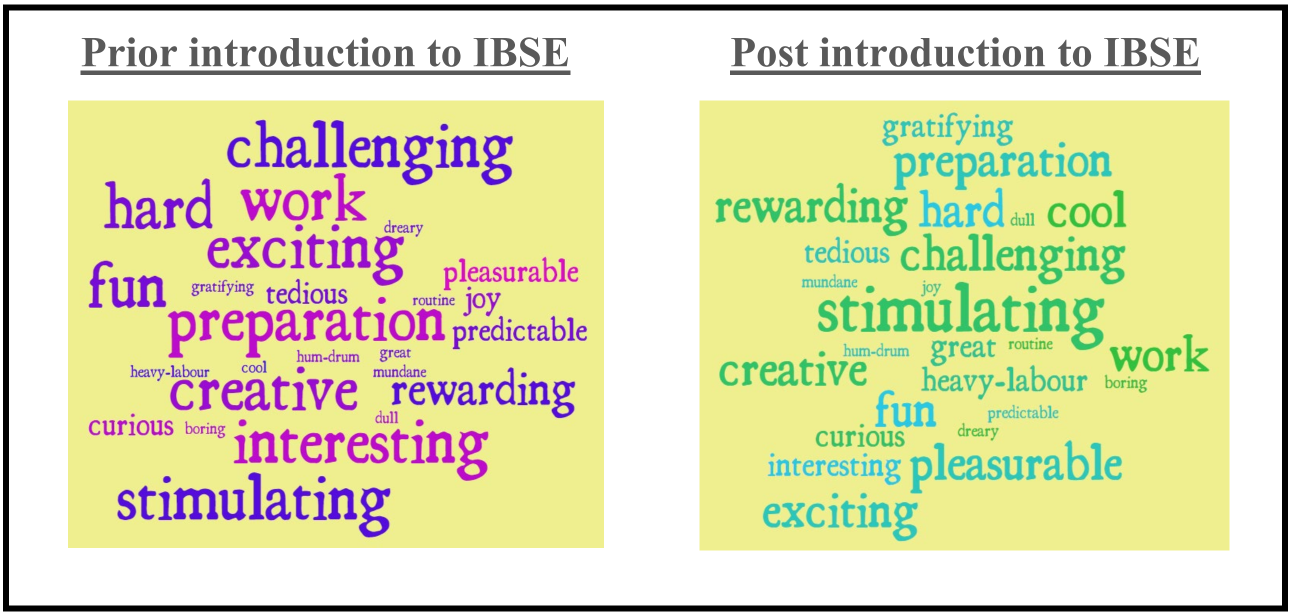



**Figure 5.7: The RPTs' perspectives on Science prior and post to being introduced to IBSE**

Even though the word 'interesting' diminished as an option after the introduction and implementation of IBSE, the RPTs then still described Science to be stimulating, creative, exciting, challenging, fun, yet still requiring hard work with too much preparation. However, the descriptors 'rewarding', 'great', 'cool' and 'gratifying' were favoured more after the RPTs were exposed to IBSE than before. One also notices that 'heavy-labour' became more favoured post IBSE. What is most encouraging is the fact that 'pleasurable' has become much more favoured and 'predictable' was not selected at all. This is a good shift, as it indicates that the RPTs had a positive experience with IBSE and underwent a positive shift in their perspectives of Science teaching. It is not surprising that the phrase 'heavy labour' became more dominant, and that 'hard work' and 'too much preparation' were still selected, as IBSE does require careful planning and preparation. IBSE demands that the teacher takes on a total new role of guiding learning processes instead of transferring knowledge (Hyslop-Margison & Strobel, 2007; Kang *et al.*, 2016; Shamsudin *et al.*, 2013). Yet, this word cloud analysis shows that the RPTs' experience of using the IBSE approach was rewarding, gratifying and pleasurable. This shows much promise for taking the process forward.

## 5.6. Conclusion

The five participants that were eventually recruited gave me a good spread of participant features. Up until the middle of Cycle 2 all five participants cooperated well and strong sets of data were collected. This gave a good picture of the RPTs' perception and practice before the TPL session. The findings also showed that the RPTs' responded well to the TPL sessions. They all became enthused to try something new and different. Data collected on practice and impressions post the TPL sessions displayed that there had been a shift in both practice and perceptions. It did, however, also indicate that further learning and support was required, but generally the RPTs were keen to learn more and willing to make adjustments when they saw that the changes had a positive effect on the learners. In the last chapter I interpret the findings that I presented here and make my final conclusions.

# Chapter 6: **INTERPRETATION OF FINDINGS AND CONCLUSIONS**

## 6.1. Introduction

My aim of this study was to explore the effects of introducing Science teachers to Inquiry-Based Science Education (IBSE). The overall result was good and filled with promise. The research participating teachers (RPTs) responded positively to the experience they had with the practice-based learning programme, and to the outcome of their own implementation of components of IBSE. The findings, however, also highlighted aspects that require more attention in order to arrive at a model which will be more effective and which could lead to even greater success.

In this section, I interpret the findings that were presented in Chapter 5 and draw conclusions. I firstly discuss my findings regarding the effect the introduction to IBSE had on the teachers. I do this discussion according to the themes that I had identified and reported the data on. I then proceed to discuss the transformational components the process evoked since the action research method that was used and that was explained in Section 4.3, has transformative powers. I also evaluate the teacher professional learning framework that I used to introduce IBSE to the RPTs, as described in Section 3.5.6. I then discuss the implications of the findings and finally propose further work that could be done in this respect, by taking into account both the positive responses with which IBSE was received, and the shortcomings which were identified.

## 6.2. Thematic interpretation

The purpose of this study was to explore IBSE in a teacher professional learning (TPL) programme for Science teachers. In Section 3.5.5 I alluded to the fact that educational reform will not take place unless teachers' attitudes and practices change (Anderson, 2002; Garm & Karlsen, 2004). My central research question was, "What are the effects of guided learning in and implementation of IBSE on Science teaching in the South African secondary school context?" This led me to investigate whether introducing a Science teacher to the IBSE approach would affect the teacher's perceptions of Science and Science teaching, as well as the teacher's teaching practice in the classroom and if so, how. This resulted in me exploring the following themes by means of an action research process:

1. The teacher's view of Science as a subject;
2. The teacher's view of learners in Science lessons;
3. The teacher's view of teaching; and
4. The teacher's view of teaching Science.

The abovementioned themes one and two specifically consider the effect on the RPTs' perceptions, while themes three and four consider the effect on the RPTs' practice of teaching Science. In Section 4.8, I explained how I would use observations, interviews and a focus group discussion to gather data. In Section 4.9, I outlined how I would use this data to draw comparisons between data collected from the RPTs before the introduction to IBSE and after, and how the use of different sets of data would ensure that the findings are trustworthy. In Chapter 5, the findings were presented comprehensively with Sections 5.3.2 and 5.5.2 devoted to the main themes referred to here.

### 6.2.1. RPTs' views about Science as a subject

Comparing findings from interview sessions before (Section 5.3.2) and after (Section 5.5.2) the TPL programme gave me insight into whether the RPTs' perception of Science as a subject was affected. From the onset, the RPTs all had a very positive view about Science as a subject indicating that it is an important and necessary school subject. Some of the reasons given to highlight the importance of Science as a subject was that Science forms an integral part of everyday life and the recognition of the importance of having trained scientists and science professionals like doctors and engineers.

The RPTs reckoned that learners should be encouraged to take Science at school to ensure that more scientists will be trained. At first the RPTs also strongly felt that teaching Science was hard work and required much preparation, as it was seen as a difficult subject in which learners had trouble understanding the content. The practical nature of the subject was also strongly emphasised by the RPTs, and one RPT pointed out the value of learners 'doing'.

> "You know, so I just like the hands-on type of things. As a subject, Physical Science is a subject of experimenting." *Pat*
>
> "When you do something with your hand it's not easy for you to forget." *Sally*

The RPTs felt that effective Science teaching will best occur when learners can engage in practical work and experience the Science they are learning about. They were concerned about the fact that schools lacked the equipment required to do Science in a practical way. This made teachers feel that they could not effectively teach Science. However, after the introduction to and implementation of IBSE, the RPTs realised that the subject can still be explored without doing an experiment. This points to a more positive outlook on the subject Science and shows that taking the RPTs through the process of experiencing IBSE somewhat changed their perception of the subject.

### 6.2.2. RPTs' views about their learners

Here too, I depended on the interview responses to gain insight about the RPTs' views of learners. This theme saw a significant change in perception. At the start of the project the RPTs' views of learners were limited and negative. Evidence that the RPTs saw the learners as lazy, disruptive and not interested in Science, was provided in Section 5.3.2.b. In the opinion of the RPTs the learners also possessed a very low level of scientific knowledge.

The RPTs also indicated that they believed that learners are able to work on their own when they are interested in the subject. However, according to the RPTs, it was only a handful of learners who truly showed interest.

After implementing IBSE the RPTs' perceptions of learners significantly changed. The RPTs now indicated that learners show a great interest in Science and found learners to be fascinated by Science. The RPTs also recognised learners' prior knowledge which they were able to draw upon when given a challenge. Further detailed evidence of this is provided in Section 5.5.2(b). The fact that learners became more interested, fascinated and more engaged in science learning is one of the benefits of using the IBSE approach to teaching (NASAC, 2015). The fact that learners are not empty vessels, but do have prior knowledge and can use it for learning, is in-line with constructivist learning approaches like IBSE (Dewey, 1933; Driver *et al.*, 1994; Von Glasersfeld, 2005; Pardjono, 2002). Guiding and allowing RPTs to implement IBSE caused the RPTs to have a more positive belief about learners' attitude towards Science and learning, as well as the learners' learning capabilities.

### 6.2.3. RPTs' views about teaching Science

Once again, the interview sets were used to draw conclusions about the RPTs' views of the teaching of Science. At the start of the project the RPTs' views about teaching and teaching Science in particular as described in Section 5.3.2(c), were very inconsistent. On the one hand they made statements which indicated that they believed that the best way to teach Science was to get the learner to think. On the other hand, every RPT referred to at least one traditional, teacher-centred way of teaching as the way they would go about teaching.

The RPTs also repeatedly highlighted experiments and practical work as the activities, which would either lead to effective Science teaching or would be the way to make learners think. The lack of appropriate spaces and resources for teaching Science at their respective schools (Section 5.2.4) was, in their opinion, the reason for Science teaching being less effective and them being unable to interest the learners in the subject. Other factors mentioned by the RPTs that stood in the way of effective Science teaching was the need for sufficient time to teach the subject well. Some RPTs mentioned that periods at school were often too short to allow them to do theory and practical work as well.

It was evident that prior to being introduced to IBSE the RPTs limited the practical work they did merely to scientific demonstrations. This could have been due to the practical challenges they had in terms of lack of space, equipment and time, and large class sizes. However, when the RPTs did allow learners themselves to do some practical tasks, scientific as well as non-scientific, it overwhelmingly led to an increased interest by the learners in the subject. One of the key shifts made by the RPTs, after they were introduced to IBSE and given an opportunity to implement it, was to realise that for learners to inquire, investigate and discover goes beyond experiments and does not need to be limited to an experiment.

The RPTs also recognised other educational benefits to following the IBSE approach. For example, by allowing learners to do group work and to present their findings, they required the learners to speak about the subject and this improved learners' use of scientific language while giving them more confidence. To a degree, the implementation of IBSE allowed RPTs to notice that they as teachers could be freed up in class to interact with learners, and that learners can learn from one another too.

After teachers had an opportunity to teach the IBSE way, they realised that there were other elements that can be drawn upon to make one's lesson interesting, more exciting and get learners to be fascinated. As pointed out in section 5.5.3(c), the RPTs discovered that by merely engaging the learners, in one way or another, in the lesson automatically made learners to become curious and interested. Examples of engagement are for learners to take measurements themselves instead of being given measurements, or presenting their ideas to one another. Engaging the learners - compared to letting the learners sit passively to be 'filled' with information - stimulates the learners and hence brings about an enhanced educational outcome. This is what the RPTs experienced during their brief encounters with IBSE in their classrooms, resulting in them viewing both the subject and their learners differently.

### 6.2.4. RPTs' teaching practice

The data collected from the classroom observations provided the evidence of teachers' teaching practice. For the most part Teachers had a talk and chalk approach, and heavily relied on the textbook (Section 5.3.1.b). This indicated that the transmission mode was the order of the day. This means that there was generally a teacher-centred approach to teaching and learning amongst the RPTs with the emphasis on transferring of facts (Fosnot & Perry, 2005). Both the interview as well as class observation data prior to introducing the RPTs to IBSE, confirmed this. The lecture mode, the classroom arrangements and the closed-ended questions were the three most evident indicators thereof.

The RPTs' initial perceptions of learners had a great influence on how they conducted their lessons. In Section 5.3.2 it was mentioned that the RPTs saw learners as lazy, not interested and with poor prior knowledge of Science. These are the beliefs that led to the RPTs previously arranging their benches in straight rows demanding learners to sit passively, while they presented learners with lectures as they needed to transfer information and knowledge to learners so that their level of knowledge would increase. There was also evidence of a lack of consideration for differing learning and thus teaching styles. At this stage there was no evidence which indicated that any of the RPTs used IBSE strategies in their lessons. (Table 5.3)

All the RPTs, irrespective of the schools they came from, encountered a number of challenges in their profession as Science teachers. Lack of adequate space and resources, large class sizes and too little class time were some of these challenges (Section 5.2.4). There are not necessarily immediate solutions to these problems and the RPTs seemed to be at a loss for innovative ideas to make Science come alive in the classroom if they were unable to, for example, do an experiment or allow the learners to do practical work. They did, however, indicate that the use of technology could be used to supplement experiments and practical work, but also recognised that this was not ideal and that first-hand experience would still be best.

After being introduced to IBSE the RPTs' responses to the IBSE approach, during the focus group session and from the responses in the semi-structured interview, were overwhelmingly positive (Section 5.4.1). They did not only emphasise that they enjoyed the TPL learning experience, but also mentioned that it provided them with new ideas and made them think differently about teaching Science. Every RPT attempted to make changes to her practice after the introduction to IBSE. They included activities in their lessons that allowed learners to engage with and experience Science. This is indicated in Table 5.12, which shows that initially none of the RPTs included elements of IBSE, but after the TPL programme learners were given the opportunity to do their own research and present their findings. These are aspects of a structured inquiry (Bell *et al.*, 2005). However, the RPTs did not quite progress to an adequate level of IBSE implementation. They included activities that could be part of an IBSE approach, but full IBSE implementation requires the teacher to arrive at the point of relinquishing their space and control, allowing learners to take control of their own learning, and as subject specialist play the role of facilitator in the process of learning. I did however notice that the older RPTs struggled a bit more with the less structured IBSE classroom. This could be due to their belief that learning can only occur when learners are quiet and listening attentively.

During the interview sessions after the introduction to IBSE the RPTs highlighted a number of aspects about the subject and teaching the subject which they now saw in a positive light (Section 5.5.2). These included:

- When learners are interested in what they are doing it takes the fear of the subject away;
- Both learners and teachers can be 'free' with the subject. By this the RPTs meant that one does not always have to follow the same routine with teaching and learning Science; and
- When learners engage with the subject it leads to better understanding (Shamsudin *et al*., 2013).

Table 6.1 gives a comparative summary of the RPTs' perceptions prior to and post the introductory TPL programme in IBSE and what was discussed in Section 6.2.

**Table 6.1: Comparison of RPTs' interview responses prior to and post the introduction to IBSE**

| Theme | Prior to IBSE TPL programme | Post IBSE TPL Programme |
|---|---|---|
| Science as a subject | Science is an important subject.<br>Science is a practical subject and therefore, RPTs are unable to teach it properly as they lack resources. | Science is an important subject.<br>Active learner participation is possible even when resources are lacking.<br>Learners can overcome their fear of Science.<br>Learners can understand Science. |
| Learners | Learners have a low level of background knowledge in Science.<br>Learners' energy is seen, in a negative way, as disruptive.<br>Learners are lazy and disinterested. | When learners are engaged in learning, it stops learners from holding back; and it encourages learners to question and share ideas.<br>Learners do take an interest.<br>Learners can build on their prior knowledge. |
| Teaching | Learners should be interested.<br>Learners should understand.<br>Learners should think for themselves.<br>This can be achieved through practical work, which is hampered by a lack of scientific equipment.<br>Teaching equals transferring facts from teacher to learners. | Teaching can be flexible.<br>Learners can learn from one another. By doing the above learners' language and verbal skills are also being developed.<br>Careful, thorough planning is a crucial.<br>Lack of scientific equipment need not hinder learner-centred approaches. |
| Teaching Science | Teaching Science requires that the teacher knows the subject well.<br>Teaching Science requires access to scientific equipment.<br>Teaching Science requires much time.<br>Using technology can make up for the lack of equipment as the teachers could then still 'show' the learners what will happen. | RPTs allow learners to actively participate and learn through discovery.<br>RPTs allowed learners to take control of their learning despite the lack of facilities or large class sizes.<br>RPTs experienced that learners where able to take control of their own learning and that learners responded well.<br>RPTs could also see the educational benefit from doing this. |

**(Own table)**

The final conclusion regarding the RPTs' views of Science as a subject and the teaching of Science is that the positive view they had prior to the IBSE TPL programme, was strengthened. This was evident in their choice of descriptive words at the end of each interview session before and after the IBSE TPL programme. The word cloud in Section 5.5.3 illustrates the RPTs responses. Initially mainly positive descriptive words like "stimulating", "interesting", "creative", "exciting", "challenging" and "fun" were opted for. After the introduction to IBSE, the RPTs still chose these positive words to describe Science but now "pleasurable" increased in preference, with "predictable" being dropped all together. This indicates a slightly more positive view of Science and the teaching of Science.

Each of the above thematic outcomes in Table 6.1 leads to the conclusion that introducing teachers to IBSE by means of a TPL programme affected their perceptions of the subject, the learners as well as teaching practice and resulted in both the RPTs and learners having a more meaningful experience in the classroom. It also highlighted how the learning programme could have been approached differently to have a better outcome. This will be discussed in the sections that follow.

## 6.3. Transformational relationships

The aim of this action research study was to potentially bring about change in the perception and practice of the RPTs. The action research model was good for the purpose of this study because it is transformative and hence allows change.

I thus settled on adopting the transformative paradigm to research. I chose this paradigm for its emancipatory nature which can lead to reform and social action (Scotland, 2012). In Section 4.2.3, I explained the features of the transformative paradigm. These features include being participatory, emancipatory, empowerment, issue- and change-orientated and interventionist (Noffke & Somekh, 2009; Rahman, 2008). When I reflect on the action research process, I can safely say that it contained each of these features. Firstly, the RPTs actively participated in the process. Not only did they attend the learning programmes, but they could also give input during mentoring sessions and offer ideas and advice to one another. Evidence of this is found in Section 5.4.2 where findings of the focus group session are shared.

Secondly, due to established values and beliefs teachers are often set in their ways (Johnson, 2006). This research process allowed RPTs to learn, implement and reflect, thus making room for reconsidering their beliefs and practices and resulting in them feeling free to make a shift.

Thirdly, the professional learning programme that the RPTs participated in, further equipped the RPTs with new pedagogical skills. The RPTs who mainly engaged a more traditional, lecture style of teaching and learning were introduced to a more learner-centred IBSE approach (Minner *et al.*, 2010). The RPTs were empowered by being introduced to a framework to inform their inquiry instruction methodology (Bell *et al.*, 2005).

Finally, the process had a specific focus and so was issue-orientated. The focus was moving the RPTs towards a learner-centred approach in teaching. This would entail the RPTs having to first adjust their perceptions and then their practice. As it involved 'moving' teachers, it was also change-orientated. This was not an easy undertaking and consisted of a number of elements of intervention to break through the barriers. These elements of intervention included a hands-on experience with IBSE, a mentoring session where the RPTs could share and discuss, an opportunity to learn from theory by means of an e-lesson and a number of opportunities to implement the new approach themselves.

The action research process has many characteristics. The main reason for choosing this research method was for its transformative nature to achieve the above-mentioned objectives. The cyclical nature of action research, which gives the opportunity for reflection and reconsideration, was well suited to reaching the objectives of the TPL programme. Very importantly, the action research process gave me as the researcher an opportunity to participate in the research and not just be an observer, and it allowed for RPTs not to be study objects, but to also learn and make contributions (McNiff & Whitehead, 2010). The fact that the researcher also has the opportunity to learn from the research process allows for change in the action of the research too. I use the format proposed by McNiff and Whitehead (2010), to now present the change indicated by the findings. Figure 6.1 provides an illustration hereof.

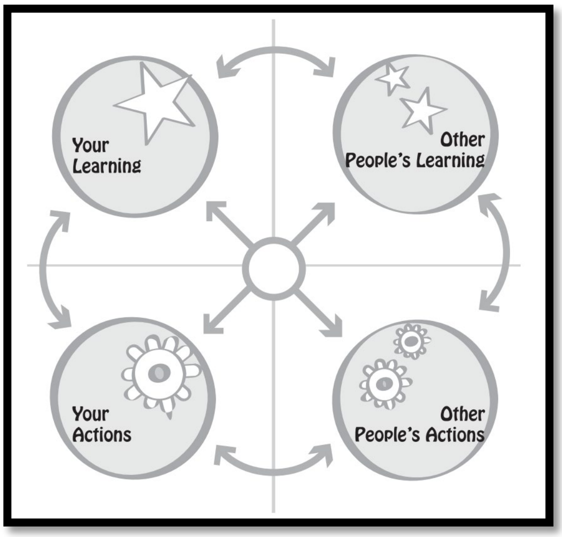



**Figure 6.1: Transformational relationships in an action research study**
**(Source: McNiff & Whitehead, 2010:144)**

The arrows in the diagram indicate how learning can lead to changed action and vice versa. They also demonstrate that the researcher's learning and actions would impact the participants' learning and action and vice versa. The arrows indicate the interconnectedness between the learning and actions of researcher and participants.

Sections 6.3.1 and 6.3.2 that follows, together with Figure 6.2, demonstrate the learning and subsequent actions of both the researcher and the RPTs. The figure displays that there is also an interconnectedness between the learning and resulting action by both researcher and research participants.

### 6.3.1. My own learning and subsequent actions

The challenges in Science education, such as dwindling interest and poor learner performance, motivated me to explore and learn about other options to teach Science like IBSE. This led to the development of a TPL framework to introduce teachers to IBSE.

The observations and interviews (Sections 5.3.1 and 5.3.2) prior to introducing teachers to IBSE gave good insight into the RPTs views, approaches to and experience of teaching and learning of Science. Observations of lessons by the RPTs and comments made during interviews with the RPTs highlighted the large extent to which the RPTs still followed the transmission mode of teaching and learning (Brown, 1994; Levy *et al.*, 2011) (Section 3.2). The overwhelmingly negative view the RPTs had of learners could be a direct result of these teaching and learning strategies, which the RPTs generally followed. Literature has indicated that the transmission approach often leads to learners being disinterested and this could be the reason for the RPTs' experience of their learners being difficult to control and lazy (Shamsudin *et al.*, 2013). Just as indicated in literature, the RPTs too did not recognise that learners had prior knowledge (Pardjono, 2002).

As I presented the first learning session and observed the teachers, I became aware of the misconceptions they still held which highlighted the importance of continued support to teachers, and led to the follow-up learning sessions. The focus group discussion and further training session (Sections 5.4.1 and 5.4.2) strongly highlighted the challenges that teachers face to effectively learn about and implement new teaching and learning strategies.

There is no doubt that teachers are keen to learn and would like to change to more effective and exciting ways to teach their learners, but they seem to struggle to find time to learn, plan and then also to implement. Teachers are scared of falling behind with the annual teaching programme provided by the DBE. I would suggest that any further professional learning programme consider this

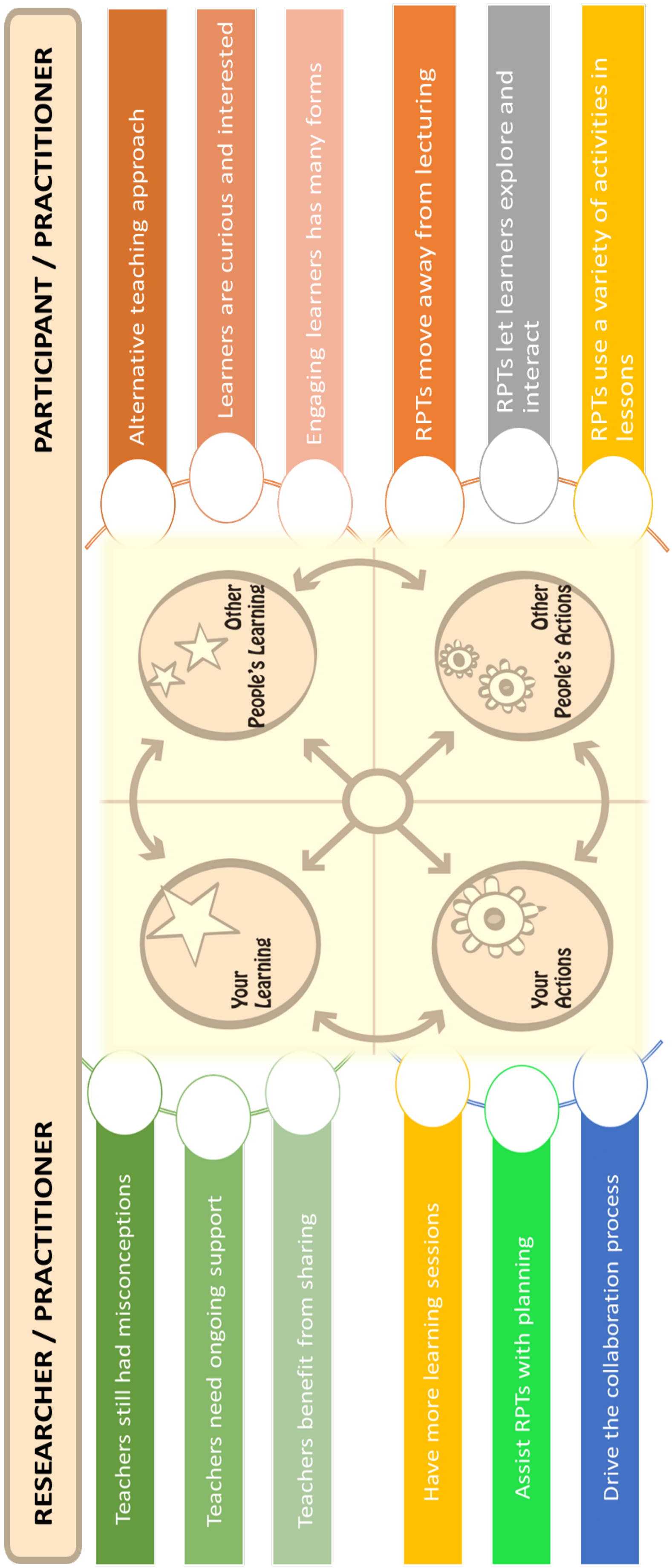



**Figure 6.2: Learning and actions of both the researcher and RPTs**

and find ways of integrating teacher professional learning with the general teaching programme in schools more effectively. I also concluded that the contact sessions with the RPTs were too far apart. I did not want to encroach on their time and programmes and therefore kept my distance. However, in reflecting I realised that the RPTs were invigorated and excited once contact had been made and ideas shared, but then their enthusiasm waned when they had to struggle with implementation by themselves. More regular meetings with the RPTs could have resulted in a better outcome to the learning programme. I further learnt that teachers would not automatically engage with one another to form a community of practice even if platforms for that purpose exist. I had hoped that the WhatsApp group that was set up would be used more by the RTPs to engage with one another and ask questions. I realised that one should be more strategic with this platform and use it to drive discussion. I came to the conclusion that a collaborative process should be driven more actively, especially at the start of the process. This leadership should be taken by the researcher.

### 6.3.2. Learning and subsequent actions by the RPTs

The RPTs became aware of another way to approach Science teaching. This assisted them to move away from their traditional way of teaching Science. The RPTs were given the opportunity to learn about teaching in a more active way whereby learners discover instead of learners being given facts though a lecture format. Initially the RPTs held the belief that learners were disinterested, lazy and not very knowledgeable (Section 5.3.2). By implementing IBSE, even on a small scale, the RPTs discovered that learners were interested and able to discover for themselves. This led to the RPTs allowing learners to engage in exploratory activities, and to discover and share more and more (Section 5.5.2.d). This was the resulting change in their action. The collaborative session gave the RPTs a chance to share a variety of ways to engage learners with one another. It provided a further opportunity for learning from each other and they took action by implementing one another's ideas.

### 6.3.3. Interconnections

My learning about IBSE led to me taking action to develop a TPL programme for the RPTs. This, in turn, caused the RPTs to learn about IBSE and it resulted in the RPTs attempting to follow this teaching approach. In doing so the RPTs learnt that they were not necessarily correct in their view of the learners. It caused the RPTs to continue to teach in a more active way. With my further engagement with the RPTs, I learnt that RPTs held misconceptions about IBSE and this resulted in me taking further action through a follow-up learning session for the RPTs. This demonstrates that the combination of the transformational paradigm and action research worked well to bring about the desired effect.

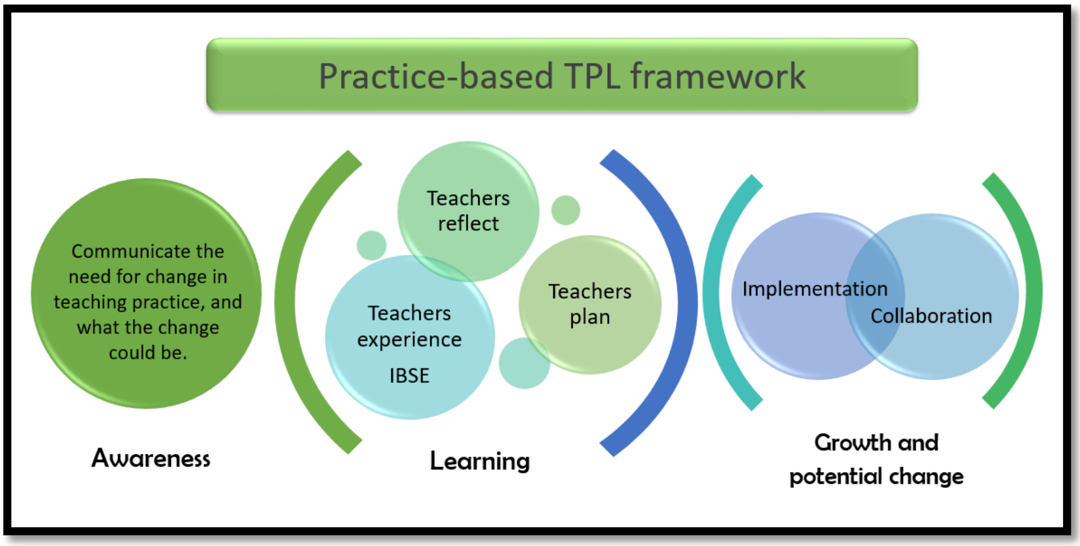
## 6.4. Evaluating the TPL framework

I realised that bringing about a change in the classroom needs to start with the teacher. The teacher is the one who determines what and how things happens in the classroom. The teacher is also the one who is in control of the classroom. It may be due to the lack of support of the teacher that school education largely remains unchanged. To bring about change in the classroom also requires a change or a shift in the teachers' beliefs. In my capacity of Physical Sciences facilitator and part of the TPL team at SUNCEP, I embarked on developing this introductory learning opportunity for teachers in IBSE. My aim was to introduce teachers to IBSE, support them in implementing the approach and at the same time, gather information to ascertain the effect of this learning opportunity.

I set out doing this project by developing and implementing a TPL opportunity to introduce teachers to IBSE. The framework that I used was situated in an action research context and was practice-based. The features and suitability of action research were discussed in Sections 4.3.2 and 4.3.3 I chose this methodology as it meant that,

- I, as the practitioner, will be able to be the researcher; The teachers would be active players in the research, guiding me, in some instances, as to what the next course of action would be;
- The action could lead to change, specifically educational transformation, because of its boundary crossing nature; and
- The teachers could gain first-hand experience in their own context, i.e. it was practice-based.

A TPL framework, as described and illustrated by Figure 3.4 in Section 3.5.6 was devised. For reference purposes I display the same figure as Figure 3.4 here again.



The implementation of the first three parts of the framework was very effective. This included making RPTs aware of the need to change and IBSE as an option, taking teachers through an IBSE experience and allowing teachers to reflect on this experience. The RPTs' response to IBSE at the face-to-face sessions and at the focus group discussion was overwhelmingly positive (Sections 5.3.3 and 5.4.1). Their eager, active participation at the face-to-face learning session and comments indicating that it was stimulating, inspirational, profound and informative attest thereto. This was an indication that teachers welcomed new ideas and were eager to consider trying new strategies. Their comments that it was informative and easy to follow is an indication that the learning presentation of the IBSE was efficacious. I would therefore conclude that taking teachers through the IBSE process as if they were learners was a good model to demonstrate to them not only how to go about following the IBSE approach, but also that it does work as a teaching method. They were intrigued by the effectiveness that it holds for learning, and said that for learners to engage they must want to do so, and that the approach presented to them made them 'want to do it'.

The last part of the Learning phase (teachers plan) and the Growth phase, while theoretically sound, could have been implemented more effectively. Unfortunately, the face-to-face session ran out of time and the planning of IBSE activities by teachers for their implementation lessons could not take place during the face-to-face sessions (Sections 5.3.3 and 5.4.2). This meant that the RPTs did not have the full benefit of collaboration and guidance for their first round of IBSE lesson planning. The implementation period also happened very much on an individual basis as the RPTs were a bit hesitant to make use of social platforms, such as the WhatsApp group that was set up to share ideas, ask questions and generally collaborate with one another. I now realise that getting teachers to engage with each other in order to collaborate, required much more coercion than initially given. This should have been encouraged soon after the face-to-face session, which in turn would have given more momentum to the implementation of IBSE. However, the fact that the introduction to IBSE session was practice-based and that teachers could implement it directly in their own classrooms was very effective. This meant that teachers could immediately assess how to apply it within their own context and make adjustments suited to their environment. If practice model lessons in IBSE were conducted in an 'ideal' science classroom set up it would be difficult for the RPTs to experience success and benefit of IBSE as they may have attributed the success to the ideal set up as opposed to the IBSE approach and thus doubted the effectiveness of the approach.

The focus group session delivered excellent results (Section 5.4.1) and my reflection on its benefits leads me to believe that it would have been good to have two or three shorter focus group sessions. The fact that the RPTs shared ideas and made suggestions to those who highlighted what their challenges were, held much value. My input as practitioner was good, but feedback from those who are in virtually the same situation as the participants, carried even more significance for the participants as they could relate to the challenges. The suggestions shared by the participants were very practical and in line with the current teaching context in the South African Science classroom.

The e-learning session was well received, with most of the RPTs indicating that it was a good format in which to provide further information on IBSE. However, only two of the five RPTs managed to complete all the tasks required by the e-learning session (Section 5.4.1.e). The rest indicated that personal matters, tight schedules and disruptions at school prevented them from completing the tasks. In this respect I would suggest a more structured mentoring phase initially where RPTs could meet on a more regular basis to share and have discussions. This could have kept the RPTs on task with the e-learning session, as well as given them an opportunity to build stronger relationships with one another, possibly resulting in them feeling more confident to collaborate on virtual platforms.

## 6.5. Implications of the transformative action research study

Research literature emphasises that action research has a knowledge generating component and a component which leads to transformative action (Somekh & Zeichner, 2009). In addition, action research has three foci, namely political, personal and professional (Noffke, 1997). This is in line with the transformative paradigm in which I placed this study, and which contains an action agenda for reform "that may change the lives of the participants, the institutions in which individuals work or lives, and the researcher's life" (Creswell, 2009:9). This means that one expects to learn from action research in a way that will lead to change. I now consider implications arising from this project according to each focus mentioned above.

### 6.5.1. Implications for teachers

Here I consider the transformation that research brings to the lives of the participant. It can also be regarded as the professional focus of action research that is concerned with generating knowledge to benefit teachers. In this case, I arrived at the following conclusions:

Firstly, teachers need to reconsider their mostly negative preconceptions about learners. Comparing the RPTs' views of learners at the start and at the end of the project indicated marked differences (Sections 5.3.2 and 5.5.2). At the start, the RPTs viewed learners as energetic with an inability to focus, having low levels of background knowledge and being lazy. At the end of the project, after IBSE was introduced and implemented, the RPTs' views of learners shifted to seeing learners as able to recall prior knowledge when stimulated, as being fascinated by Science, being able to find information by themselves, and being willing to ask relevant questions despite being shy or having a language barrier.

Teachers also learnt that IBSE demands careful and meticulous planning. This is to ensure that teachers keep learners focussed, and maintain good time management and discipline, so that educational outcomes for the lesson are ultimately reached. Yet, the RPTs learnt first-hand that following the IBSE approach leads to a number of educational benefits. These include developing learners' scientific language, developing verbal skills and building their confidence. For the teachers it frees up time in the class to attend to learners who may be struggling.

Teachers can benefit much from collaborating. Sharing ideas and resources can save teachers considerable time. As the saying goes: 'a burden shared is a burden halved'. Teaching has become a highly time consuming, demanding and stressful profession with much administration over and above the general planning. If teachers can share the load in preparing lessons or get together on a regular basis to help when their colleagues are at a loss for ideas, this will provide practical as well as psychosocial support.

### 6.5.2. Implications for educational support structures

The focus in terms of educational support structures can be either political or personal. The political focus wants to bring about change that will lead to greater equity and democracy, while the personal focus wants to affect the understanding of one's own practice (Noffke, 1997).

#### *a) Education departments (Political Focus)*

The Department of Basic Education has already put in place a sound policy regarding Science education (DBE, n.d.). They must, however, ensure that their schools are provided with the required resources for this policy to be effectively implemented. Their first priority should be to ensure that enough qualified teachers are available. Education departments could use incentives to draw young students to choose to become Science teachers. Another suggestion could be to ensure that if a Science teacher leaves his or her post that the post will be filled by a qualified Science teacher and not to simply reshuffling remaining teachers' posts at the school. This often leads to a teacher, who is not qualified to teach Science, being assigned to a Science post. Even in this RPT group, this was the case. Pat, Rose and Sally, as indicated in Section 5.2.2 and summarised in Table 5.2. were qualified in fields other than Science, but had been assigned to Science teaching posts. Effective implementation of IBSE requires that it be offered by a Science expert as the teacher will have to, among others, redesign curriculum delivery (Kang *et al.*, 2016; Levy *et al.*, 2011).

Secondly, education departments should ensure that schools are provided with adequate, purpose-built spaces with resources to teach Science. The lack of adequate Science teaching spaces and equipment at the schools of all the RPTs was a recurring challenge mentioned during all interviews as reported in Section 5.3. Such spaces I would say, should double up as one for instruction and research as well as scientific experiments. This is to make provision for a more flexible teaching space instead of traditional, inflexible rows of desks. The department could also consider setting up banks of Science resources per region, which could be borrowed by teachers like books from a library.

Thirdly, provision should be made for teachers who are interested to learn about, implement and be supported in IBSE. This is because teachers would need much support to make the shift from traditional teaching and learning approaches. This will require the training and development of mentors in IBSE as well as the development of materials that could be made available to Science teachers.

### *b) School management (Political focus)*

Another political arena, but one on a more local level, is the school management. School leadership teams need to make effective Science teaching a priority by:

- insisting on qualified Science staff or ensuring that present, qualified staff be used optimally;
- making adequate spaces and resources available to Science teachers, or ensure that a portion of the budget is reserved for resources for Science; and
- allowing Science teachers to arrange their spaces to make them conducive for IBSE.

All the schools represented, irrespective of their quintile, seemed to suffer from a lack of adequately qualified staff as well as spaces suitable for Science teaching. It is vital that school leadership teams ensure that every effort is made for their learners to receive quality education.

### *c) Teacher professional learning units, including SUNCEP (Personal focus)*

One thing that sets action research apart from other methodologies is the fact that it provides the opportunity for the researcher to also be affected. This means that the researcher's life will also be transformed. This is the personal focus of action research that affects the understanding of one's practice (Noffke, 1997).

Personally, I have learnt that to sustain effective implementation of IBSE by teachers, beyond introducing them to IBSE, requires regular, purposeful and structured support. Firstly, teachers responded very well when they were introduced to IBSE and eagerly participated in the project (Section 5.3.3). The learning session was very successful, but it was not enough. They struggled when they had to implement IBSE themselves, and it became apparent that after the initial introduction they, to a large extent, still lacked understanding of what IBSE entails.

Secondly, even though teachers were provided with resources, namely the e-lessons they could refer to when back in their own teaching environments, they did not effectively consult these resources (Section 5.4.1.e). They also did not make effective use of virtual platforms, like WhatsApp, that was set up to collaborate and engage with myself or other the RPTs. I would suggest that for any future endeavours of this kind the TPL practitioners themselves should participate much more actively in the implementation in the classroom as well as on virtual platforms. This could mean that TPL practitioners actively encourage collaboration by setting up meetings or dedicated online chat sessions. I noticed that even though the teachers were quiet and not engaging when left by themselves, when any activity was initiated by myself, as practitioner, they participated willingly.

## 6.6. Further work

I believe that the model of this study as an introduction to IBSE, is a sound approach, and that teachers are open to learning more. However, introducing teachers to new methods and providing resources are not enough to effectively change practice. More ongoing work is required to bring teachers to a level where they would implement IBSE more fully and with confidence (Alake-Tuenter *et al.*, 2012; Fitzgerald *et al.*, 2016; Onwu, 2015; Penuel & Means, 2004; Ramnarain, 2014). The introduction was successful in opening the RPTs' minds to a new approach, but there were still large gaps and misconceptions in the understanding of what IBSE really entails (Section 5.4.1). Teachers require more learning sessions as well as regular support and mentoring. Further development of the model with a stronger emphasis on collaboration and more regular participant input would be of great value.

This study only explored the effect on teachers. It would be interesting to consider the effect of regular, consistent implementation of IBSE on the learner. In this study teachers reported positively on the initial response of the learners to the changes in practice which the RPTs implemented. It will be valuable to know whether the new approach influences the progress of the learners though. This will demand a study over a long period as one firstly has to lead the teacher to regularly implement IBSE and then follow trends of learner experience and progress.

## 6.7. Final concluding remarks

Science education worldwide is exploring ways in which it can achieve better performance and progress (Section 2.4). Low levels of interest at secondary school, as well as poor learner performance are major concerns (Trna *et al.*, 2012). Learners generally see science subjects as complicated and demanding and thus shy away from them. In South Africa there is also the added concern that the lack of resources in many schools could see Science become a subject that would only be accessible to some, more privileged learners (Section 2.5).

Continuing with traditional methods of teaching is not aiding the turnaround of the trend of declining interest in the Sciences and weak learner performance. Therefore, there is a need to introduce teachers to, and assist teachers to adopt new, more effective pedagogical approaches. However, the school educational realm has been very reluctant to make shifts away from traditional pedagogy. With new ways of teaching, Science education can be made more interesting to all learners even when resources are not always available.

Prior research has shown that IBSE can lead to a heightened interest and participation by learners. Its features of constructivism, whereby learners' thinking processes and skills are developed resulting in deep learning, is what made this an attractive approach for me. For years researchers have been providing evidence of the effectiveness of alternative teaching and learning methods as opposed to the traditional way of lecturing and presenting facts.

This study provides evidence that one such approach, namely IBE and in Science specifically IBSE, can add much value to Science education at secondary school level. The RPTs found the introduction to IBSE refreshing. This led to the teachers taking small steps to implementing IBSE and gave them an opportunity to see that learners are interested in the subject and that they love to explore. They also learnt the value of allowing learners to take control of their own learning. This learning experience for Science teachers did result in change, on a number of levels, in the RPTs' perceptions of teaching Science. Their practice of Science teaching was also influenced and the changes they made had educational benefits for the learners.

Therefore, to answer my research question, the introduction to IBSE through a TPL programme with Science teachers did cause the RPTs to reconsider how they approach their lessons, and their view of the learners. This change in perception and practice, even though small, was noticeable. The RPTs did not quite acquire a full understanding of IBSE since it was only an introductory exercise. Yet, the project provides sufficient evidence that a TPL programme with the supportive elements of collaboration and regular mentoring can have far-reaching effects in bringing about change in the classroom. It would be worthwhile to continue with the process and to look at ways to further encourage and support teachers to adopt new pedagogies. This support should not only lie with TPL practitioners, but also with school management teams and education department officials who can inform and affect policy. I would like to end off with a statement from one of the RPTs:

> "When are you going to roll out this training to everybody? This will really change the Physical Sciences teaching in South Africa. It will make things so much easier, because it is learner-centred and the learners can benefit from it a lot. It is not just about them (learners) just sitting at their desks and working out practice problems". *Lisa*

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# APPENDICES

## Appendix 1 – Research approval from the Education Department

Western Cape Government
Education

Directorate: Research

Audrey.wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

**REFERENCE:** 20160107-6348
**ENQUIRIES:** Dr A T Wyngaard

Mrs Danelda Van Graan
63 Tharina Street
Somerset Park
Somerset West
7130

**Dear Mrs Danelda Van Graan**

**RESEARCH PROPOSAL: EXPLORING INQUIRY-BASED EDUCATION IN A PROFESSIONAL LEARNING PROGRAMME FOR SCIENCE TEACHERS**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **01 March 2016 till 30 September 2016**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    **The Director: Research Services**
    **Western Cape Education Department**
    **Private Bag X9114**
    **CAPE TOWN**
    **8000**

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
**Directorate: Research**
**DATE: 08 January 2016**

Lower Parliament Street, Cape Town, 8001
tel: +27 21 467 9272 fax: 0865902282
Safe Schools: 0800 45 46 47
Private Bag X9114, Cape Town, 8000
Employment and salary enquiries: 0861 92 33 22
www.westerncape.gov.za

Western Cape Government
Education

Directorate: Research

Audrey.wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
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**REFERENCE:** 20160107 – 6348
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Mrs Danelda Van Graan
63 Tharina Street
Somerset Park
Somerset West
7130

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**RESEARCH PROPOSAL: EXPLORING INQUIRY-BASED EDUCATION IN A PROFESSIONAL LEARNING PROGRAMME FOR SCIENCE TEACHERS**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **16 January 2017 till 29 September 2017**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:
    **The Director: Research Services**
    **Western Cape Education Department**
    **Private Bag X9114**
    **CAPE TOWN**
    **8000**

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
**Directorate: Research**
**DATE: 14 October 2016**

Lower Parliament Street, Cape Town, 8001
tel: +27 21 467 9272 fax: 0865902282
Safe Schools: 0800 45 46 47
Private Bag X9114, Cape Town, 8000
Employment and salary enquiries: 0861 92 33 22
www.westerncape.gov.za

# Appendix 2 – Permission letter for school principals

Private Bag X1
Matieland
7602
danelda@sun.ac.za
__________ 2016

*School Name*
*Street Name*
*Suburb*
*Town/City*
*Postal Code*

***Re: Permission to conduct research within the above mentioned school***

Dear _________________ *(name of principal)*

I hereby ask you for permission for ____________________ *(name of Science teacher),* currently a Science teacher at your school, to participate in my research project which forms part of the formal requirements of the M Phil (Higher Education Studies), Faculty of Education for which I'm currently enrolled.

The title of the project is 'Exploring Inquiry-based education in a professional learning programme for Science teachers'. The project involves introducing and evaluating the effect of the Inquiry–based education (IBE) approach in Science teaching. Science school results have been concerning. Due to poor learner results more and more Science teachers feel that they are under the spotlight. Therefore a large component of the project involves that the teacher receives training in an alternative teaching strategy which may combat this trend. This will give the teacher an opportunity to gain new ideas of how to approach the teaching of Science which could lead to a more positive attitude towards teaching Science. Teachers will be equipped with more skills. This new approach in the classroom may also lead to more learners choosing to do Science and performing better in Science.

Teachers who volunteer to participate in this study, will be asked to do the following things:

A. Complete a Teacher Professional Learning (TPL) training unit on the Inquiry-based Education approach in Science teaching. This will include:

    1. a contact training session in April/May 2016
    2. an short e-learning session with an assignment to be completed by end May 2016
    3. a mentoring programme from April to July 2016

B. Participate in individual interviews:

1. Prior to training in 2016
2. After completion of training programme in July 2016

C. Consent to class observations by the researcher:

1. Prior to training in 2016
2. After initial training and at the start of the mentoring process in April/May 2016
3. Towards the end of the training programme in July 2016

D. Participate in a total of two mentor group discussion sessions in May 2016 and June 2016

The study has been submitted to the Faculty for Ethical clearance and was reviewed and approved by the Ethical committee on 15 March 2016. I also submitted an application regarding this research project to the WCED and I was granted their approval on 8 January 2016.

Included with this request for permission is a summary of my research proposal as approved by the Faculty of Education, as well as a letter of support from my supervisor. I hope that you will consider my request favourably.

Kind Regards,

**Danelda Van Graan**
Physical Sciences Facilitator
Centre for Pedagogy
Faculty of Education
Stellenbosch University
Tel: 021 808 9197
Cell: 072 232 5282

# Appendix 3 – Ethics Approval

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**Approved with Stipulations**
**New Application**

15-Mar-2016
Van Graan, Danelda DC

**Proposal #: SU-HSD-001886**
**Title: Exploring inquiry based education in a professional learning programme for Science teachers**

Dear Mrs. Danelda Van Graan,

Your **New Application** received on **09-Mar-2016**, was reviewed
Please note the following information about your approved research proposal:

Proposal Approval Period: **15-Mar-2016 -14-Mar-2017**

The following stipulations are relevant to the approval of your project and must be adhered to:
**The researcher is reminded to only commence data collection and observations at the schools where written permission has been granted. Copies of these permission letters should be submitted to the REC for record-keeping.**

Please provide a letter of response to all the points raised IN ADDITION to HIGHLIGHTING or using the TRACK CHANGES function to indicate ALL the corrections/amendments of ALL DOCUMENTS clearly in order to allow rapid scrutiny and appraisal.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your proposal number (**SU-HSD-001886**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

**Included Documents:**
DESC Report
REC: Humanities New Application

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

**REVIEWER TEMPLATE**

**REC: HUMANITIES**
**REVIEWER COMMENTS**
OVERVIEW
This is a generally well written study that aims to answer the question: In what ways can training a Science teacher in the inquiry based education approach affect the teacher's perceptions of science teaching and teaching practice in the classroom?

SCIENTIFIC VALIDITY/ METHODOLOGY/ RELEVANCE:
Action research. Procedures include a teacher professional learning unit, individual interviews, class observations, as well as mentor group discussions. All these procedures are relevant to the study. The cyclical nature of the study is well explained and integrated in the procedures envisioned.

PARTICIPANT SELECTION AND RECRUITMENT
Choice of population justifiable and the recruitment method is discussed in sufficient detail in the proposal. Five individuals registered as Grade 9 science teachers in the SUNCEP programme. The participants will be carefully selected through purposive sampling to ensure that the group is diverse in terms of age, race, length of teaching service, gender and school location.

PROTECTION OF PARTICIPANTS PRIVACY (Access to information that the 'data subject' would regard as privileged) AND CONFIDENTIALITY (Transferring information provided in confidence to the researcher to a third party)
Explained satisfactorily

PROTECTION OF DATA, (BOTH PAPER AND ELECTRONIC)
Explained satisfactorily, but should be added that the information will be password protected on a computer.

INFORMED CONSENT AND ASSENT PROCESSES AND FORMS
Adequate

ADEQUATE MITIGATION OF RISK; COUNSELLING SERVICES ETC?
Adequate

INSTRUMENTS (QUESTIONNAIRES, SCALES, INTERVIEW OUTLINES etc. )
The study questionnaire/interview outline consists of both closed and open exploratory questions and is well aligned with the study objectives and quite thoughtful. However, the instrument is deemed as an interview schedule, but some of the questions are better suited to a questionnaire (but the supervisor would be the best judge in this regard). The observation schedule is well formulated and presented.

OVERALL RISK LEVEL AND RISK /COST-BENEFIT ASSESSMENT
The DESC assesses the risk level of this project is low/minimal. However, as participants may well benefit directly from the study the risk level is viewed as favourable.

INSTITUTIONAL AND EXTERNAL PERMISSIONS
Attached (WCED)

ADDITIONAL COMMENTS:

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# Approval Notice
## Progress Report

29-Nov-2016
Van Graan, Danelda DC

**Proposal #: SU-HSD-001886**
**Title: Exploring inquiry based education in a professional learning programme for Science teachers**

Dear Mrs. Danelda Van Graan,

Your **Progress Report** received on **21-Nov-2016**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **29-Nov-2016** and was approved.
Please note the following information about your approved research proposal:

Proposal Approval Period: **29-Nov-2016 -28-Nov-2017**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**SU-HSD-001886**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

# Appendix 4 – Consent form for research participants

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**STELLENBOSCH UNIVERSITY**
**CONSENT TO PARTICIPATE IN RESEARCH**

*Title of the study:* Exploring inquiry based education in a professional learning programme for Science teachers

You are asked to participate in a research study conducted by Danelda Van Graan BSc, HDE, from the Stellenbosch University Centre of Pedagogy (SUNCEP). I am currently enrolled as an MPhil in Higher Education Studies student and the results of this study will be used to complete my master's thesis. You were selected as a possible participant in this study because the project will be investigating Science teaching.

**1. PURPOSE OF THE STUDY**

The project involves introducing and evaluating the effect of the Inquiry–based education (IBE) approach in Science teaching.

**2. PROCEDURES**

If you volunteer to participate in this study, you will be required to do the following things:

A. Complete a Teacher Professional Learning (TPL) training unit on the Inquiry-based Education approach in Science teaching.

   This will include:

   1. a contact training session in April/May 2016
   2. an e-learning session with an assignment to be completed by May 2016
   3. a mentoring programme from April to July 2016

B. Participate in individual interviews:

   1. Prior to training in March 2016
   2. After completion of training programme in July 2016

C. Consent to class observations by the researcher:

   1. Prior to training in March 2016
   2. After initial training and at the start of the mentoring process in April/May 2016
   3. Towards the end of the training programme in July 2016

D. Participate in mentor group discussion sessions in April 2016 and June 2016

### 3. POTENTIAL RISKS AND DISCOMFORTS

You will be required to share your personal opinions and views in individual interviews. What you share will be held confidential and when reporting on my results all participants will remain anonymous.

I will also observe you in your classroom while teaching and this may make you feel uneasy. The purpose of the observations is to gather data for the research project and not to grade you as a teacher or to give a report to any teaching official.

### 4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

It is foreseen that participating in this project will give you as a Science teacher an opportunity to gain new skills and ideas of how to approach the teaching of Science which could lead to a more positive attitude towards teaching Science. This new approach in the classroom may also lead to more learners choosing to do Science and performing better in Science.

### 5. PAYMENT FOR PARTICIPATION

There is no payment for anyone participating in the research. The training however will be at no cost.

### 6. CONFIDENTIALITY

Any information that is obtained in connection with this study, and which can be identified with you, will remain confidential and will be disclosed only with your permission or as required by law. I will at all times maintain confidentiality by means of keeping data password protected on my laptop and an external hard drive. Only my supervisors and I will have access to the data. When I quote statements from your interview in my thesis, your identity will not be disclosed. I will use my cell phone to record the interviews or parts of it and transcribe it for the purpose of this study. On completion of my degree I will destroy all the copies of the audio recordings.

### 7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

### 8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Danelda Van Graan [*Principal Investigator]* and/or Prof. Magda Fourie-Malherbe *[Supervisor].* Contact details are as follows:

| | | |
|---|---|---|
| Name: | Danelda Van Graan | Magda Fourie-Malherbe |
| Position: | Principal Investigator | Supervisor |
| Office tel number: | 021 808 9197 | 021 808 3908 |
| Cell number: | 072 232 5282 | 083 645 4471 |
| Email address: | danelda@sun.ac.za | mfourie@sun.ac.za |

## 9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

**SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE**

The information above was described to me by Danelda C. Van Graan in Afrikaans/English and I am in command of this language. Where necessary it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

________________________________________

**Name of Subject/Participant**

________________________________________

**Name of Legal Representative (if applicable)**

________________________________________ _______________

**Signature of Subject/Participant or Legal Representative** **Date**

**SIGNATURE OF INVESTIGATOR**

I declare that I explained the information given in this document to ___________________ [*name of the participant]* and/or his/her representative _____________________ [*name of the representative].* He/she was encouraged and given ample time to ask me any questions. This conversation was conducted in Afrikaans/English and where necessary this conversation was translated into _______________ by ______________________________.

________________________________________ _________________________

**Signature of Investigator** **Date**

# Appendix 5 – Interview questions prior to IBSE introduction & implementation

## Interview Questions

**Title of research:**

**Exploring inquiry-based education in a professional learning programme for Science teachers**

**Name of teacher:** ______________________________

**Subject:** ______________________________________

**Teaching grade:** _______________________________

**Date:** _________________________________________

**Stage in research process: Prior to training.**

**Investigator: Danelda van Graan**

5. Can you please give me some background information to your career as a Science teacher?

   ***Prompting questions***

   a. How long have you been a Science teacher for?
   b. How long have you been teaching this particular grade?
   c. What are your professional qualifications?
   d. Where did you study?

6. Please describe your approach to planning and delivering Science lessons and mention what you find easy and what you find challenging.

   ***Prompting questions***

   a. How will you describe your Science lessons?
   b. How much time on average, do you spend on preparing for a Science lesson?
   c. What do you enjoy most about teaching Science?
   d. What do you find the most difficult about teaching Science?
   e. What will you change about your current approach to your Science lessons?

7. What are your perceptions of Science as a subject and the teaching of Science?

   ***Prompting questions***

   a. Why have you become a Science teacher?
   b. Do you regard Science as a necessary school subject? Why?
   c. What were your ideas of Science teaching before you taught your first class?
   d. After so many years of teaching what are your current ideas of teaching Science?
   e. If you could do something other than teaching Science tomorrow will you opt to do? Why?

8. Which of the following words/phrases will you chose to describe how you feel about teaching science? Circle **ALL** the ones you feel apply to you now:

**fun, hard work, a joy, too much preparation, dull, cool, boring, great,**

**hum-drum, pleasurable, tedious, gratifying, dreary, rewarding,**

**curious, heavy labour, predictable, exciting, tedious, creative,**

**challenging, stimulating, routine, interesting, mundane**

# Appendix 6 – Lesson Observation Schedule (Prior and post IBSE introduction)

SUNSEP • SUNCEP
UNIVERSITEIT • STELLENBOSCH • UNIVERSITY

## Lesson Observation Schedule

**Name of teacher:** ______________________ **Subject:** ______________

| **Grade of learners:** | | **No. of learners in class:** | | **No. of learners present in class at time of lesson:** | |
|---|---|---|---|---|---|

**Purpose of observation:** ________________________________________

Indicate with a tick each time you observe the actions mentioned below during the lesson observation.
*If possible more detail may be provide in the space provided for actions marked with an asterisk.

| **Lesson Structure** | **Observed** | **Comment** |
|---|---|---|
| Reviews previous lesson | | |
| Introduces current lesson by means of overview | | |
| Summarises main content points covered | | |
| Directs learners' preparation for next class | | |
| Maintains good pace during lesson | | |
| **Methods Used** | | |
| Asks open ended questions | | |
| Asks closed ended questions | | |
| Provides well-designed materials* | | |
| Employs non-lecture learning activities* (i.e. small group discussion, student-led activities) | | |
| Organises the classroom/seating plan well | | |
| Invites class discussion | | |
| Employs other tools/instructional aids* (i.e. technology, computer, video, overheads) | | |
| Delivers a lecture | | |

| | | |
|---|---|---|
| Is inclusive to all learners and their specific needs* | | |
| **Teacher-learner Interaction** | | |
| Actively encourages learner participation | | |
| Monitors learner understanding | | |
| Involves a variety of learners | | |
| Listens to learners and responds appropriately | | |
| Demonstrates awareness of individual learner educational needs | | |
| Ensures an environment that is conducive to learning | | |
| **Subject Content** | | |
| Has good content  knowledge of the subject | | |
| Appears well organized | | |
| Explains concepts clearly | | |
| Relates concepts to learners' experience | | |
| **Learner Participation/activity** | | |
| Learners are given an opportunity to gather their own resources* | | |
| Learners are given an opportunity to do their own research* | | |
| Learners are given an opportunity to synthesise their own information* | | |
| Learners are given an opportunity to present their findings* | | |
| Learners are given an opportunity to reflect on their own learning* | | |

**Observer Signature: ___________________________________**

**Date: ____________________________**

**Place: __________________________**

# Appendix 7 – Focus group session semi-structured interview schedule

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UNIVERSITEIT • STELLENBOSCH • UNIVERSITY

## Follow-up Questionnaire

**Title of research:**

**Exploring inquiry-based education in a professional learning programme for Science teachers**

**Name of teacher:** ______________________________

**Subject:** ________________________________________

**Teaching grade:** ________________________________

**Stage in research process:** **Post training and during implementation phase.**

**Investigator:** **Danelda Van Graan**

1. Was the contact training beneficial and why? ____________________________________________________

_______________________________________________________________________________________________

_______________________________________________________________________________________________

2. Could you complete the e-learning session?

| YES | | NO | |
|---|---|---|---|

If no, why not?

_______________________________________________________________________________________________

_______________________________________________________________________________________________

_______________________________________________________________________________________________

3. Please give comments about the e-learning session?

- Positive comments: ______________________________________________________________________

  _____________________________________________________________________________________________

  _____________________________________________________________________________________________

- Negative comments: _____________________________________________________________________

  _____________________________________________________________________________________________

  _____________________________________________________________________________________________

- Suggestions to improve it: _______________________________________________________________

  _____________________________________________________________________________________________

  _____________________________________________________________________________________________

  _____________________________________________________________________________________________

4. Have you used some aspects of IBSE in some of your lessons?

| YES | | NO | |
|---|---|---|---|

If YES:

a) Give a brief description of what you have done. ____________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

b) How was it received by the learners? ________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

c) Did the activity lead to effective learning? Why? ___________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

d) Will you do more such activities in the future? _____________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

If NO:

a) Give reasons for not implementing IBSE yet. _______________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

b) Do you need further support in implementing IBSE? Specify. ___________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

General comments:

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

# Appendix 8 – Interview questions Post IBSE introduction & implementation

## Interview Questions

**Title of research:**

**Exploring inquiry-based education in a professional learning programme for Science teachers**

**Name of teacher:** ______________________________

**Subject:** ______________________________________

**Teaching grade:** ______________________________

**Date:** _________________________________________

**Stage in research process:** **<u>Post training and implementation</u>.**

**Investigator:** **<u>Danelda Van Graan</u>**

1. What are your impressions of the IBSE approach to teaching Science?

   ***Prompting questions***

   a. Was it easy to plan the IBSE lessons?
   b. Is the IBSE approach an effective teaching strategy?
   c. How did the learners respond to this approach?
   d. Was the training on IBSE helpful and adequate?

2. Please describe how IBSE has affected your approach to planning and delivering Science lessons, if at all, and mention what you find easy and what you find challenging about implementing IBSE in teaching Science.

3. How has IBSE affected your perceptions of Science as a subject and the teaching of Science, if at all?

   ***Prompting questions***

   a. What are your ideas of Science teaching after your training and implementation of IBSE?
   b. If you could do something other than teaching Science tomorrow will you opt to do so? Why?

| |
|---|
| |

4. Which of the following words/phrases will you choose to describe how you feel about teaching Science? Underline **ALL** the ones you feel apply to you **now:**

**fun, hard work, a joy, too much preparation, dull, cool, boring, great,**

**hum-drum, pleasurable, tedious, gratifying, dreary, rewarding,**

**curious, heavy labour, predictable, exciting, tedious, creative,**

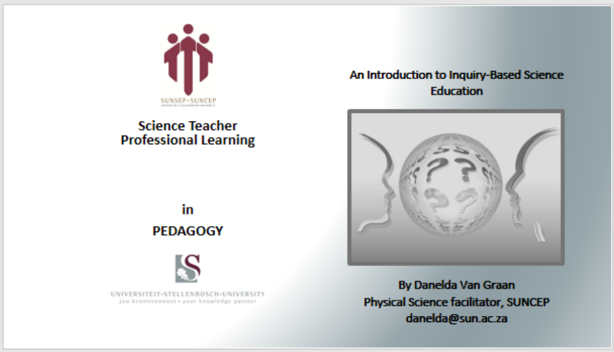
**challenging, stimulating, routine, interesting, mundane**

# Appendix 9 – IBSE TPL session lesson plan & PowerPoint slides

**Sciences contact session planning**

**Discipline: Pedagogy** **Concept: IBSE method of teaching** **Duration: 3h30min**

| Activity | Description | Resources/equipment required | Start time | Duration |
|---|---|---|---|---|
| Welcome & Intro | | | | 10 min |
| Background - Ppt lecture | Go over theoretical basis for using IBE to teach science; what IBSE entails; Video: What is IBSE? (7 min) | Data projector and laptop Slides 1 – 7 | | 20min |
| Group discussion & feedback | Let teachers discuss what they think about IBSE method of teaching. Some Questions: Do participants think there are benefits? What are the difficulties? | | | 20 min |
| Lesson experience | Heat packs, how do they work? Hand out heat packs – let teachers explore and experience. They need to write down What they know, What questions they have. Show Hot ice videos – does it answer some questions? Do they have more questions Hand out Text resources – One reads – others take notes – discuss. Use textbooks to further answer questions. Draw a poster to display what they have learnt (New knowledge) | Heat packs Poster paper Felt tips Resource books Internet Slide 9 | | 60min |
| Debriefing - Group discussion & feedback | What was this experiences like? Do they think that it can be used in their lessons? What would the challenges be, especially relating to their context? | | | 20 min |
| Video | Investigating solar panels. E.g. of IBSE activity in action | Slide 12 | | 15min |
| Planning for implementation | Teachers look at a lesson topic they will be doing in the near future and plan to include elements of IBE in the lesson. Teachers draft a plan that they will implement in their classes | Slides 13-16 as intro CAPS document, Lesson plans Textbooks Internet | | 45 min |
| Considerations of implementations and end. | Practical ideas of implementation in teachers own context Teachers share what could make implementation difficult in their context. Further considerations for implementation of IBSE activities. | Slides 17 – 21 | | 15min |
| e-Learning Task | Brief teachers to the e-Learning task prepared for them. | | 5 min | |

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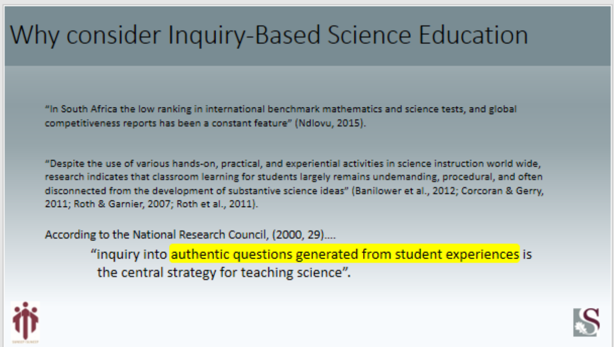


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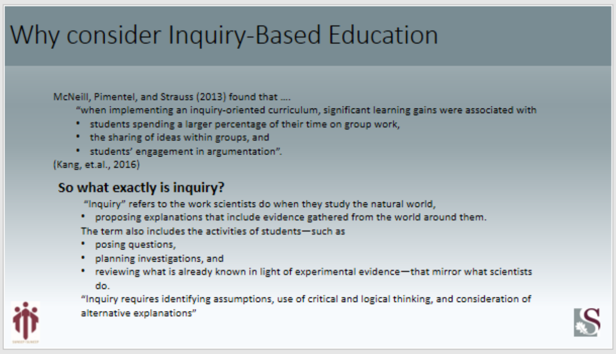


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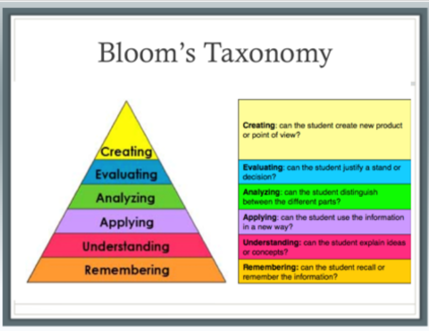


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## What is Inquiry-based Science Education?

Scientific inquiry or inquiry-based learning requires learners to frame their own questions, design and implement their own procedures, draw conclusions and results from evidence and mathematical and analytical tools, to derive a scientific claim (Olson and Loucks-Horsley 2000; Lunetta et al. 2007; National Research Council (NRC) 2000, 2012).

- frame their own questions,
- design and implement their own procedures,
- draw conclusions and results from evidence and mathematical and analytical tools,
- to derive a scientific claim

6

## What is Inquiry-Based Education – A video

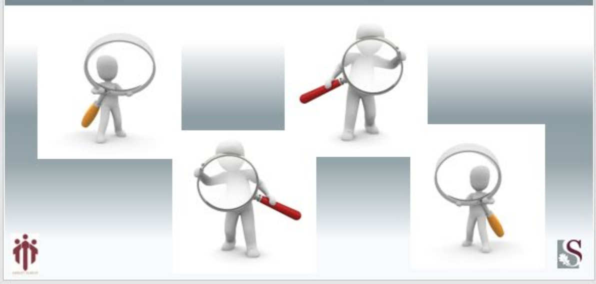

7

## Group discussion

Initial thoughts on IBSE & are there benefits?

8

## An Inquiry-Based Education activity



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## Hot ice


10

## Group discussion

Is IBSE feasible? What are the challenges?

11

## Starting an investigation on solar panels


Click here to watch this video as an example of guiding inquiry:
http://sciencelearn.org.nz/Teacher-Ideas/Hubs-in-Action/Making-predictions

12

## Ideas from Video lesson

- Concepts may be complicated
- Link it with concepts learners are familiar with and can identify with.
- Accept all the ideas put forward by any learner – Don't shoot off any idea.
- Guide learners with further questions to add any common information they might have missed and are required for the concept to be studied.
- Make use of Scientific terms to introduce it to the learners – Predictions
- Predictions = guess = always right until proven wrong.
- Value all their thoughts and contributions.

13

## Challenges in SA Schools

Efforts to offer learners high quality science education have been hampered by inadequate infrastructure and resources.

Socio-economic problems lead to poor discipline and lack of interest among learners.

14

## Keep in mind your learners similarities as well as their individuality.

15

## The reflective cycle


16

## Inquiry-based Science Education Principles

- Learners are active participants
- Learners are thinking.
- Learners share ideas and learn from each other and thus the learner owns the work.

17

## The Teacher & Inquiry-Based Science Education

- Role of the teacher shifts to that of facilitator of learning.
- You must know your subject well. This is important to guide learners, to recognise when they are going off course, to ask the correct leading questions.
- Source a problem which will draw on the learning material you want them to learn/discuss.
- Use a real life problem – It encourages and stimulates interest and a desire to know more - this immediately guarantees more interest.
- Plan very well – this will require much work beforehand.
- Use good examples to aid the process
- Find suitable resource material for the 'research' phase.
- Have a good set of facilitation questions lined up. – Pre-empt learners thought processes.

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## The Teacher & Inquiry-Based Science Education (cnt)

- At the start we know the learner does not know much about the topic, but the learner does come in with at least some background knowledge. When we use this as a starting point it leads to the learner feeling acknowledge as one with information. It demonstrates to the learner that they have the ability to use knowledge they do have to reason and makes the learner feel able.
- Have short lectures/ explaining sessions. Once learners were first engaged they will now be more interested in what the teacher has to say and be on the same page as you.
- Have a variety of activities, keep each activity to a time limit and move on even if some groups are lagging behind. Especially in the beginning. Learner groups will soon adapt to the new method and pace as they would want to be participants too.
- Use posters or information sets gathered by learner groups. This further endorses the learner and spur them on.

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## The Learner & Inquiry-Based Science Education

- Learners a curious and therefore interested and becomes actively involved in the learning process.
- Learners become actively involved in their learning process and experience.
- Learners learn from one another and feel enabled and acknowledged.
- Learners thrive when they recognise they can contribute, have ideas which are considered and trusted.
- Groups learn from each other which almost all the time increase the knowledge base by far.

20

## Benefits of Inquiry-Based Science Education

- Learners are immediately engaged. They become active participants – Compare this to when you do a lecture. Even if they are sitting still, are they necessarily taking an interest and taking in new information? We don't just want to deliver a lesson so that we can tick off a topic as covered.
- The student does the work in class – what would normally be give as homework are now done in class. Easier class notes with easy examples are given for homework. The learner feels more capable of doing homework and 'studying' for the subject becomes a joy.
- In class groups who function well and need less attention will only demand a little of your time, freeing you up to spend more time with learners who need more guidance.
- With the teacher moving around you get a better insight into the learner's strengths and weaknesses. It helps you to know what to focus on and what to skim over when you do consolidate.

21

## Disadvantages/challenges

- **Time**

  At first it may appear that more time will be needed, but since this method engages the learner from the start the time taken to finish off the topic speeds up. So you end up using the same amount of time or maybe even less.

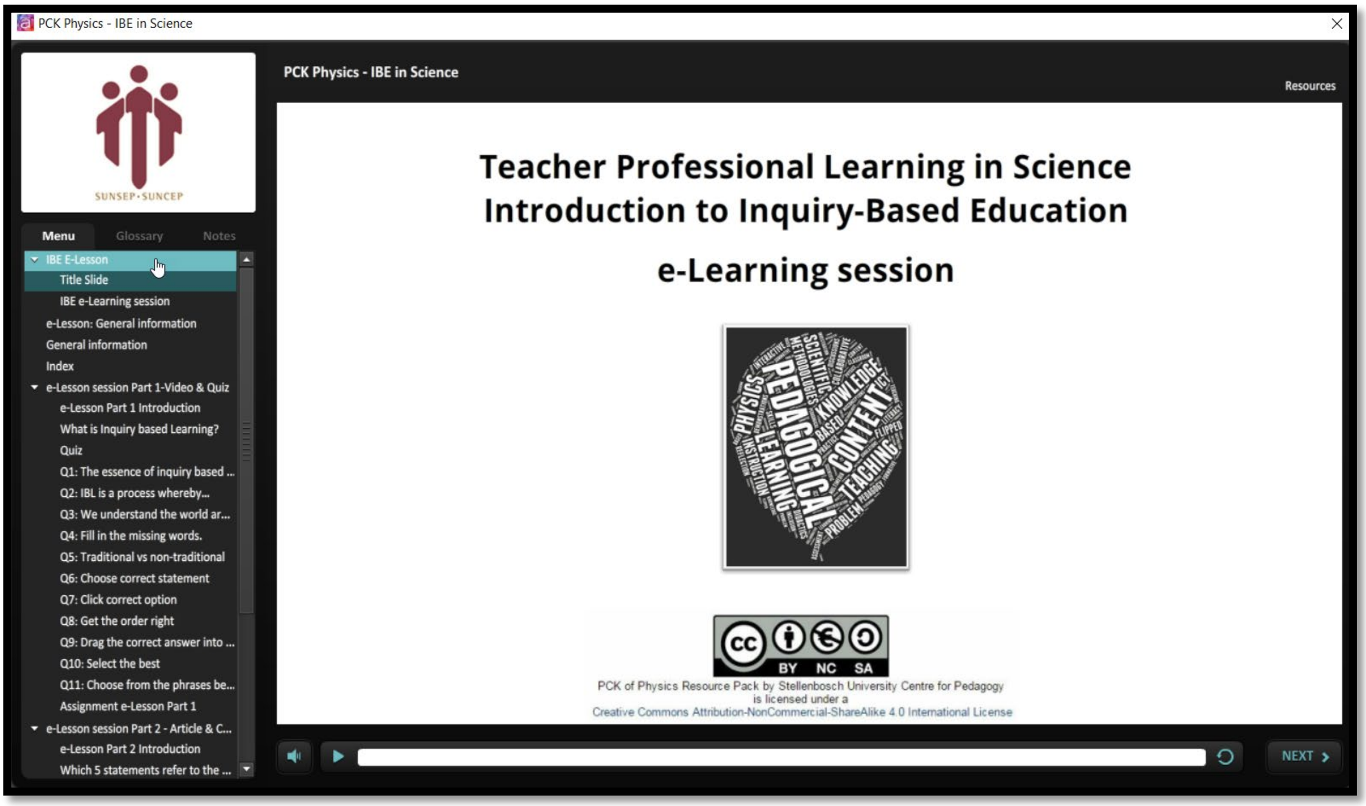
- **Discipline**

  Good planning and a keep-to-time approach will make sure learners stay on task.

- **Resources** and infrastructure which are poor

22

# Appendix 10 – Outline of IBE interactive e-Lesson



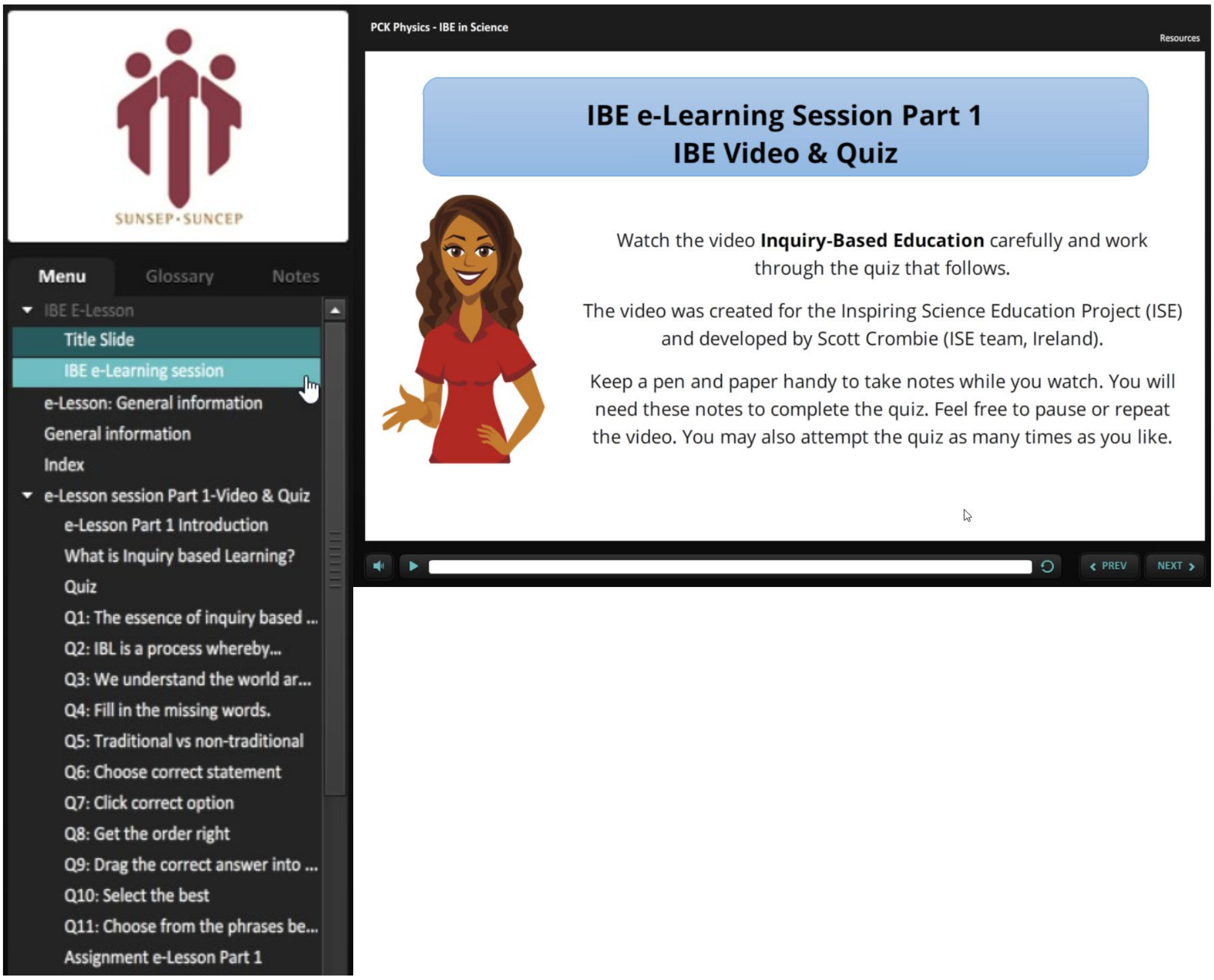

Instructions to use the electronic resource:

**Welcome to the e-Learning session on IBE!**

How to access the session.

1. Double click on the folder: **e-Session_PCK Physics - IBE in Science - Storyline output**
2. You will have all the contents of the e-session listed. In that list click on: Launch_Story.exe
3. Once the e-session has opened, read each slide carefully and when you are ready to proceed, click next in the bottom right corner to go to the next slide.
4. You will also be able to navigate your way around the e-session by using the titles in the menu list on the left hand side of the screen.
5. The INDEX slide is also a safe go to slide if you get a bit lost.
6. In the top right corner the word RESOURCES will be displayed. It contains support documents to the e-session content.
7. The pdf-files and word-docs will use the Internet Explorer to open with. So look out for the flashing icon on your computer when you have clicked on such a file in Resources.

Instructions to part 1 of the e-Lesson



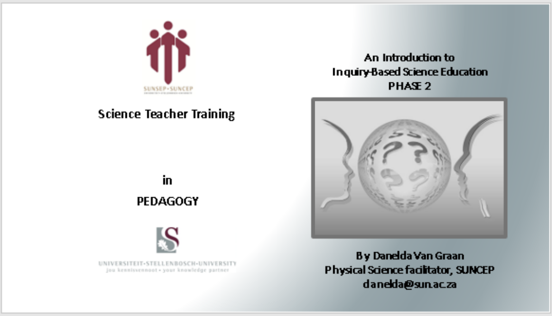

Instructions to part 2 of the e-Lesson

# Appendix 11 – Follow-up IBSE TPL session lesson plan & PowerPoint slides

**Sciences contact session Part 2** **Discipline: Pedagogy**

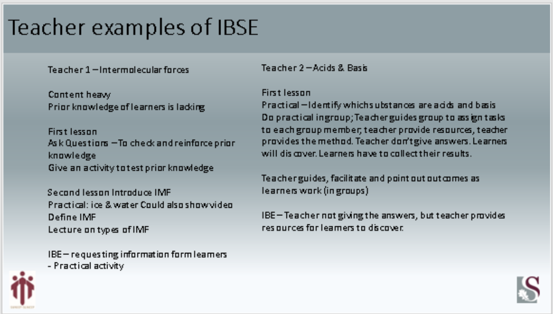
**Concept: IBSE method of teaching** **Duration: 3h30min**

| Time | Programme | Things to do |
|---|---|---|
| 9:00 | Welcome & coffee | |
| 9:15 | Ask teachers to brainstorm their topic and work out a basic lesson plan. | Request that teachers bring their topics, any prior planning and resources to the session |
| 9:45 | Teachers give feedback highlighting any IBSE they have included. | |
| 10:00 | Ask teachers to give their understanding of IBSE. Teachers write it down and then share. | |
| 10:15 | What is IBSE? Go over principles | Do ppt presentation |
| | • Point out from the texts given what IBSE is. | |
| | • Look at examples form LAMAP | Provide materials |
| 10:45 | Ask teachers to continue to work on their topic and incorporate elements of IBSE further. | |
| 12:00 | Feedback & suggestions | Group discussion |
| 12:30 | Lunch | |



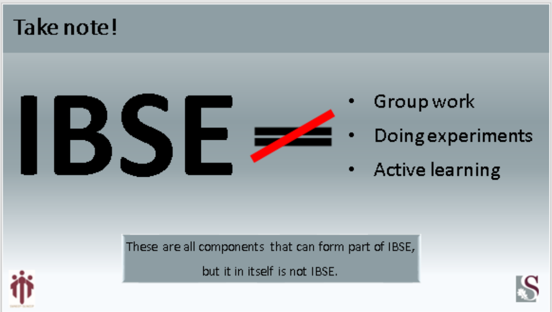
Science Teacher Training
in
PEDAGOGY
An Introduction to
Inquiry-Based Science Education
PHASE 2
By Danelda Van Graan
Physical Science facilitator, SUNCEP
danelda@sun.ac.za


1



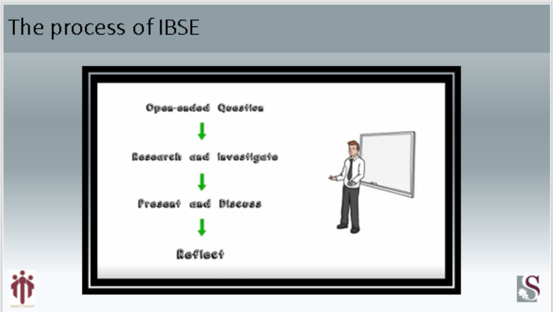
Teacher examples of IBSE
Teacher 1 – Intermolecular forces
Content heavy
Prior knowledge of learners is lacking
First lesson
Ask Questions – To check and reinforce prior knowledge
Give an activity to test prior knowledge
Second lesson Introduce IMF
Practical: ice & water Could also show video
Define IMF
Lecture on types of IMF
IBE – requesting information form learners
- Practical activity
Teacher 2 – Acids & Basis
First lesson
Practical – Identify which substances are acids and basis
Do practical in group; Teacher guides group to assign tasks to each group member, teacher provide resources, teacher provides the method. Teacher don't give answers. Learners will discover. Learners have to collect their results.
Teacher guides, facilitate and point out outcomes as learners work (in groups)
IBE – Teacher not giving the answers, but teacher provides resources for learners to discover.


2



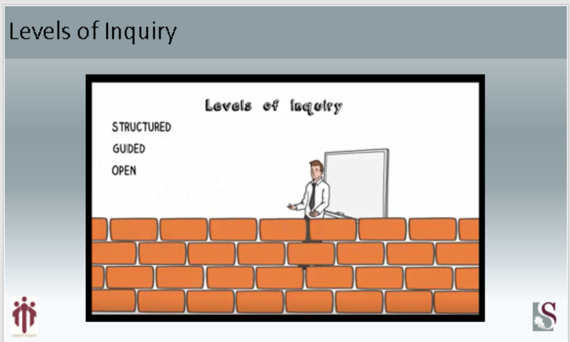
Take note!
IBSE
Group work
Doing experiments
Active learning
These are all components that can form part of IBSE,
but it in itself is not IBSE.


3



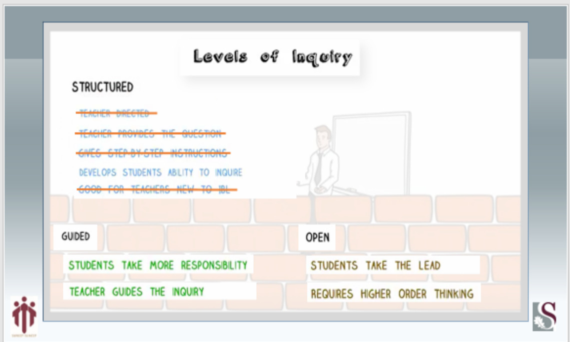
The process of IBSE
Open-ended Question
Research and Investigate
Present and Discuss
Reflect


4



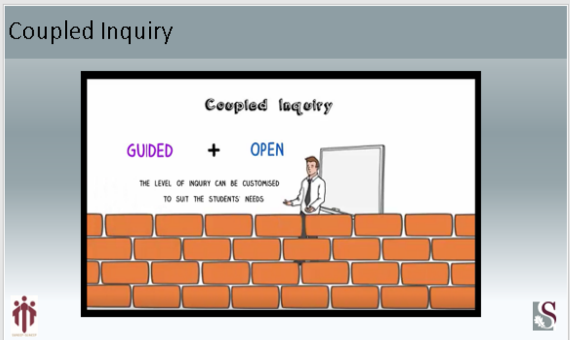
Levels of Inquiry
Levels of Inquiry
STRUCTURED
GUIDED
OPEN


5



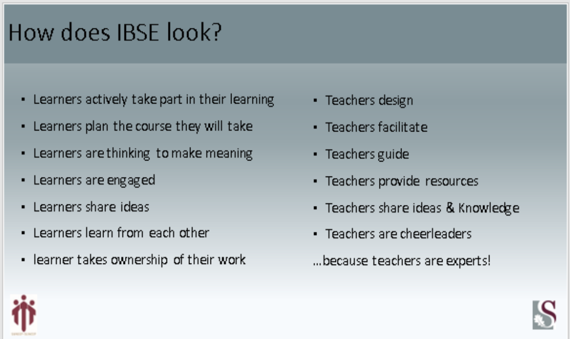
Levels of Inquiry
STRUCTURED
~~TEACHER DIRECTED~~
~~TEACHER PROVIDES THE QUESTION~~
~~GIVES STEP-BY-STEP INSTRUCTIONS~~
DEVELOPS STUDENTS ABILITY TO INQURE
~~GOOD FOR TEACHERS NEW TO IBL~~
GUIDED
STUDENTS TAKE MORE RESPONSIBILITY
TEACHER GUIDES THE INQUIRY
OPEN
STUDENTS TAKE THE LEAD
REQUIRES HIGHER ORDER THINKING


6



Coupled Inquiry
Coupled Inquiry
GUIDED + OPEN
THE LEVEL OF INQURY CAN BE CUSTOMISED
TO SUIT THE STUDENTS NEEDS


7



How does IBSE look?
Learners actively take part in their learning
Learners plan the course they will take
Learners are thinking to make meaning
Learners are engaged
Learners share ideas
Learners learn from each other
learner takes ownership of their work
Teachers design
Teachers facilitate
Teachers guide
Teachers provide resources
Teachers share ideas & Knowledge
Teachers are cheerleaders
…because teachers are experts!


8

# Appendix 12 – Permission to use video resources as training material – email communication

## Video on Inquiry-Based Learning, Inspiring Science Education project

Van Graan, DC, Mev <danelda@sun.ac.za>

**From: Sent: To: Subject:**

Scott Crombie <scottcrombie@gmail.com> 30 October 2014 17:03 Van Graan, DC, Mev <danelda@sun.ac.za> Re: IBL Video

Hi Danelda, When I created the videos my main goal was to explain IBL as clearly and simply as possible as I found that the literature does not explain it very well. Often teachers are confused about what IBL actually is and don't know how to go about incorporating it in their teaching. I found that the best way for teachers to start with IBL is through scaffolding, whereby the teacher slowly introduces the students to IBL and in the process the teacher develops a better understanding of how IBL works. Sharing ideas is also very important and that is what the ISE is attempting to do through it's portal. The more resources that teachers have access to the better the likelihood of them overcoming the barriers. With regards to the accent, the reason I mentioned it is because I am South African (from Durban), living in Ireland.

Kind regards,

Scott

On 30 Oct 2014, at 14:31, Van Graan, DC, Mev <danelda@sun.ac.za> <danelda@sun.ac.za> wrote:

> Dear Scott

> > Thank you for replying to my mail and for allowing us to use your material! We will definitely give the recognition as requested. > What I like about it is its clarity. The concepts are explained in such a clear concise way which is ideal. > I also think that the length of the video is good and not too long. Teachers do not have much free time with all their demands and therefore these features in training is important. > > The accent is perfect! It is a clear English accent that many in South Africa are able to understand especially taking into account that many of our teachers speak an indigenous African language! > > Thank you once again and best regards.

> > Danelda Van Graan

Physical Sciences Facilitator * Fisiese Wetenskape Fasiliterder
Centre for Pedagogy * Sentrum vir Pedagogie
Faculty of Education * Fakulteit Opvoedkunde
University * Stellenbosch * Universiteit
Tel: 021 808 9197 * Faks/Fax: 021 808 3000

-----Original Message----- > From: Scott Crombie [mailto:scottcrombie@gmail.com] > Sent: 30 October 2014 16:15 > To: Van Graan, DC, Mev <danelda@sun.ac.za> > Subject: IBL Video 1

> > Hi Danelda,

> > Thanks for the message and apologies for not replying sooner. > > I am pleased that you would like to use my video for your training course. The video forms part of a wider e-Learning course developed for STEM teachers in Europe. There is an increasing drive to encourage schools and teachers to incorporate IBL in their classrooms and this course forms an initial part of our training plans. > > It is no problem using the video to help with your training. I would ask that you acknowledge that the video has been developed for the Inspiring Science Education project. > > I will speak with my colleagues about the possibility giving you access to the e-Learning course that was developed. It incorporates a few other videos explaining why IBL is important for 21st Century Learning, the benefits of IBL and an example of the implementation of IBL in a science classroom. It may be a useful resource for you but I am not sure if it is possible to share. > > I hope you enjoyed the accent in the video!

> > Kind regards,

> > Scott

# Appendix 13 – Brief notes taken during lesson observations prior to introduction to IBSE

| Name | Description |
|---|---|
| **Joe** | Used questions to jog learners' prior knowledge.<br>A video and power point was used other than just lecturing.<br>Lecturing was the main mode of lesson activity.<br>She invites class discussion and learner participation by asking questions.<br>Various learners answered and not just the same learners every time.<br>She made use of a worksheet to consolidate and monitor learner understanding.<br>She relates the work to learner experience by using everyday examples<br>Very briefly provides information about the next lesson at the end.<br>There was very little evidence of differentiation.<br>Very little if none of IBE like activities were present. |
| **Rose** | Briefly states the 'type' of lesson at the beginning.<br>Predominantly lecture style.<br>Worksheet with problem examples was set and used.<br>Learner participation is encouraged and achieved through asking questions.<br>A variety of learners were called upon to answer.<br>Asking of questions is also used as a tool to monitor learner's understanding and knowledge.<br>Ran out of time – There was no time to bring lesson to close or lead into next lesson.<br>There was no evidence of differentiation.<br>Also none of the IBE like actions were observed. |
| **Lisa** | Brief reference was made to previous work.<br>Mainly lectured<br>Used the textbook as resource, no worksheet<br>Ask questions to invite participation and makes a point to ask a variety of learners and not only the same learners.<br>No evidence of differentiation.<br>Maintains good classroom discipline and organisation |
| **Pat** | Lecturing is main mode<br>Did make use of power point and worksheet.<br>No link between previous of next lesson<br>No differentiation<br>Do ask questions, more generally and mainly the same learners answer<br>None IBE-like activities present. |
| **Sally** | Links to previous lesson by asking questions.<br>Also use questions to check during lesson on learner's knowledge.<br>A variety of learners answer<br>Lecturing is mainly used even though a video is also shown to aid as a demonstration<br>No evidence of differentiation.<br>No evidence of IBE-like activities |