An Evaluation of a Science and Indigenous Knowledge Systems Project at a Western Cape University

A full thesis submitted in fulfilment of the requirement for the degree of Doctor of Philosophy (Science Education)

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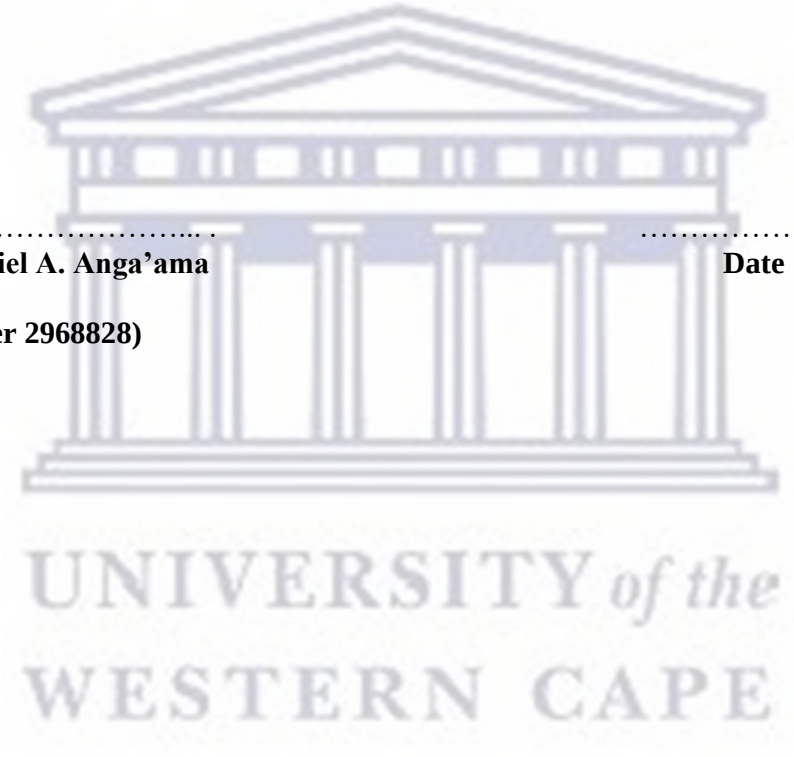
DECLARATION

I declare that "**An Evaluation of a Science and Indigenous Knowledge Systems Project at a Western Cape University"** is my own work; that it has not been submitted before for any examinations or degree purposes in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.



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DEDICATION

I dedicate this work to the Lord who granted me the grace to finally end this long, adventurous journey during such perilous times

To the memory of my mother Maria Bassah, my father-in-law Paa John Ngwa Nfonidoro, and brother Wilson Angaama, and

To that of my close comrades, Drs Simasiku Siseho and Chris Diwu whom I will never see again till, by His grace, we meet at Abraham's bosom

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ABSTRACT

This study was an evaluative case study of a Science and Indigenous Knowledge Systems Project on the Project (SIKSP) at a Western Cape University, South Africa. It was an internal evaluation from the perspectives of the project participants, with the aim of assessing (1) the opportunities and challenges faced by the participants (in-service teachers), (2) the effectiveness of an argumentation-based strategy (DAIM) used by some of the in-service teachers to integrate science and IKS, (3) the manner in which the trained teachers actually taught using the DAIM, and (4) the impact of SIKSP on the participants' professional development and research capacities. I used a hybridised version of Stufflebeam's (2003) context, input, process, product (CIPP) as well as Guba and Lincoln's (1989) Constructivist evaluation models to guide the study, within a constructivist-pragmatist paradigm. I used a questionnaire, semi-structured interviews, reflective diaries, and document analyses to collate the data from 22 in-service participants, as well as from the project director. The analyses were done using mixed methods, though largely dominated by qualitative approaches.

The results suggest that: through the use of multiple sources of engagement in conceptual, practical, and discursive activities, SIKSP enabled the participants to change their views about science and IKS – from a largely positivist to a more dualistic worldview that considered IKS as a source of valid knowledge in science classrooms. SIKSP activities also enabled the participants to acquire the largely student-centred, discursive, interactive DAIM approach of teaching and learning to effect an inclusive science-IK curriculum. The teachers used DAIM to teach science, mathematics as well as socio-scientific topics, each teacher applying it differently. SIKSP had many positive impacts on the participants – psychological, social, intellectual, pedagogical and professional. Through SIKSP, many participants obtained higher degrees, advanced professionally, and some have become researchers in science and IKS; with two of the postdoctoral fellows now carrying on similar research at other universities in South Africa and beyond. An unanticipated outcome of SIKSP was the creation of the African Association for the Study of Indigenous Knowledge Systems (AASIKS) which is now pursuing an inclusive science-IKS vision at a much larger scale. Overall, in the view of the participants, SIKSP was very successful project, and its DAIM approach, though difficult to master, has many advantages that could be explored in-and-out of science classrooms.

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ABBREVIATIONS USED IN THE STUDY

SIKSP: Science and Indigenous Knowledge Systems Project

CIPP: Context, Input, Process, Product

IKS: Indigenous knowledge systems

IK: Indigenous knowledge

PD: Professional development

DAIM: Dialogical Argumentation Instructional Model

TAP: Toulmin's Argumentation Pattern

CAT: Contiguity Argumentation Theory

AASIKS: African Association for the Study of Indigenous Knowledge Systems

NOS: Nature of science

NOIKS: Nature of Indigenous Knowledge Systems

NOSIKS: Nature of Science and Indigenous Knowledge Systems

NARST: National Association for Research in Science Teaching

SAARMSTE: Southern African Association for Research in Mathematics, Science and Technology Education

KEY WORDS

Case study

Evaluation

Indigenous knowledge

In-service teachers

DAIM

CIPP model

Constructivist evaluation

Perceptions

Participants

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

In 1994 a democratic government was elected in South Africa to replace the apartheid regime which was characterized by segregation in all spheres of life. During the apartheid era, for example, South African education was divided along racial lines (Harley & Wedekind, 2004; Ogunniyi & Mushayikwa, 2015); with laws prohibiting learners from enrolling into schools outside those designated for their own racial groups. However, the political changes since 1994 resulted in many radical changes in the educational settings across South Africa. As the racially segregated apartheid laws were abolished, the erstwhile racially homogenous classrooms suddenly became more complex; reflecting the multi-racial post-apartheid society. The new context required science teachers to adopt new ways of teaching that would take into account the different backgrounds of their learners. Unfortunately, the teachers were ill-prepared to manage these multicultural classroom contexts (Ogunniyi & Mushayikwa, 2015). To complicate matters further, the post-apartheid government introduced many radical changes in the education system that required teachers to make a paradigm shift. For instance, teachers were expected to relate science to the indigenous knowledge (IK) of learners – something that was not even recognised as useful knowledge in the former curriculum.

The new curriculum known as Curriculum 2005 (C2005), which was based on what was popularly known at that time as Outcome Based Education (OBE), went into operation in 1997. C2005 differed markedly from the previous curriculum in that it was learner-centred instead of teacher-centred. The teacher was supposed to become a facilitator instead of the sole authority in the science classroom as was the case in the former curriculum. Also, critical thinking and inquiry were to replace the rote learning prevalent in South African classrooms under the apartheid system. Due to many criticisms (Jansen, 1998; Maodzwa-Taruvinga & Cross, 2012; Mason, 1999) the post-apartheid curriculum had undergone several revisions, resulting in several versions - the Revised National Curriculum Statement (RNCS), the National Curriculum Statement (NCS), and the Curriculum and Assessment Policy Statement (CAPS) (Department of Education [DoE], 2002, 2004; Department of Basic Education, [DBE], 2011). Although the details of the curriculum reforms fall beyond the scope of this study, it can be noted that in each of these revised forms, linking science to the indigenous knowledge of learners was still considered very relevant.

1.1.1 The place of IK in the new curriculum

In order to make use of learners' home background knowledge, the new curriculum in Learning Outcome Three (LO3) demanded that science teachers should relate science and technology to learners' socio-cultural environments or indigenous knowledge systems (IKS). This modification was a significant departure from the previous curriculum, which did not recognise indigenous knowledge as valid knowledge in science classrooms. Meanwhile, the new post-apartheid government policy recognised and defended the inclusion of the indigenous knowledge of learners in science classrooms. The curriculum planners of the post-apartheid era recognised the multiple worldviews that learners might bring to the classroom from their home cultures and the usefulness of IKS as a source of knowledge. They also regarded IKS as a source of knowledge worth preserving; acknowledging that it had been neglected for centuries before, and was in danger of being lost (Department of Education [DoE], 2002).

According to the new curriculum designers, IKS deserved inclusion in the science curriculum because it was a reflection of the knowledge of indigenous people of South Africa which had sustained them for millennia. They also argued that since much of this valuable wisdom is believed to have been lost in the past 300 years of colonization, it had to be rediscovered in order to improve the lives of South Africans (Ogunniyi, 2007a).

Another reason given for demanding the inclusion of IKS in the school science curriculum was based on the differing worldviews held by the learners who navigate between the two worldviews of school and home. The argument advanced by the Education Department was that many learners, just as different individuals and scientists, went through multiple cultural experiences and therefore needed to have their worldviews recognised in the science curriculum (DoE, 2002; Ogunniyi, 2004).

1.1.2 The challenges of the new curriculum

Although C2005 had so many positive innovations, it also caused many frustrations among teachers and other stakeholders, drawing much criticism (Jansen, 1998; Ogunniyi, 2004, 2007a, 2007b; Onwu & Mosimege, 2004). Firstly, it was designed and imposed on teachers in a top-down manner, disregarding the involvement of the teachers who had to implement it. Secondly, it did not take into consideration the uneven terrain in the schools in terms of human and material resources, which could mar the implementation process. Thirdly,

it did not take into consideration the fact that the training received by teachers under the old system was very inadequate to enable them implement the new curriculum in its present form, because the new curriculum was vastly different from whatever pedagogical knowledge and skills they had acquired previously.

In response to these criticisms, the new South African government carried out some revisions to C2005. As mentioned earlier, the Revised National Curriculum Statement (RNCS – Grades R - 9), the National Curriculum Statement (NCS – Grades 10 – 12), as well as the Curriculum and Assessment Policy Statement (CAPS) are indications of the government policy in search of an improved working curriculum (Department of Education, 2002; Department of Basic Education, 2011). In all forms of the revised curriculum, the integration of science with indigenous knowledge remained as a key component. Despite this policy to include IKS, implementation remained a major challenge because the teachers did not know how to go about it practically; nor did they know which IK to include in their lessons (Ogunniyi, 2004; Onwu & Mosimege, 2004).

In order to help teachers to implement the new curriculum, the government departments of education engaged in organising short courses for in-service teachers, workshops, and seminars to give them some basic skills to implement the science-IK curriculum. However, most of these in-service teacher professional development initiatives proved to be unsuccessful (Ogunniyi, 2004, 2007a). This meant a more effective way of training science teachers was needed if they had to implement the integration of IK with science in their classrooms more effectively.

This search for a more effective way of training science teachers to implement the new science-IK curriculum in South African classrooms was one of the main objectives of the Science and Indigenous Knowledge Systems Project (SIKSP) which came into existence in 2004. Projects are initiated to carry out defined purposes; each project having certain distinguishing characteristics (Nicholas & Steyn, 2012). According to Nicholas and Steyn, such characteristics might include:1) a clear goal or purpose, 2) uniqueness, 3) novelty and risk, 4) utilization of special talents and skills from relevant professionals, 5) a definite time duration 6) a high degree of risk and uncertainty. In the case of SIKSP, there were precise goals clearly stated in the funding documents. These include, among others, the goals to equip science teachers with the necessary knowledge and skills to enable them to implement the science-IK curriculum, and to act as researchers and consultants in the area of science-IKS.

1.2 The Science and Indigenous Knowledge Systems Project

As I have just mentioned above, the Science and Indigenous Knowledge Systems Project (SIKSP) came into existence in 2004 in response to the plight of science teachers who were struggling to include indigenous knowledge (IK) in their science classrooms as the Revised National Curriculum Statement RNCS (RNCS) Grades R-9 Policy Statement demanded of them. Their inability to enact the science-IK curriculum could be explained by the fact that the training they had received during their time in teacher training institutions was focused on the science content, without any mention of indigenous knowledge (Ogunniyi, 2004; Onwu, 2009; Onwu & Mosimege, 2004). Therefore, the teachers needed a different type of training in order to be able to implement the integration of science and IK in their classrooms.

In response to this need, one of the main goals of the SIKSP was to train and equip science teachers with the requisite knowledge and skills to integrate science and indigenous knowledge (IK) as specified by Learning Outcome Three (LO3) of the RNCS. The same requirement is represented by Specific Aim Three of the Curriculum Assessment Policy Statement (CAPS) (Department of Basic Education [DoBE], 2011). In order to satisfy this need of science teachers struggling with the curriculum, the SIKSP had as part of its vision, to empower science teachers in South Africa by equipping them with the necessary skills to integrate science and IKS in their classrooms. This can be seen in the aims of the project.

. The aims of the project as stated in the project documents included the following:

- To study all IKS in each of the provinces of South Africa and to use the knowledge to integrate IK in the classroom
- To create an online IKS repository where interested persons can access IKS resource materials
- Create a catalogue of all IKS studies carried out in South Africa
- Develop IKS resource materials to assist teachers from the foundation phase to the FET phase
- Pilot and evaluate IKS materials
- Engage in building the capacities of teachers in IKS
- Equip masters and doctoral students with research skills in the domain of science and IKS.
- Engage in multi-disciplinary research at the level of high schools (Langenhoven, 2014, p. 30-31).

In the aims of the project during the last phase (from 2011 to 2013), the 5th objective was "to build up a community of practice in an area where research capacity is very low… [and to]

equip masters, doctoral and post-doctoral students with research skills in an authentic South African context." (IKS 2011 Call, p.5).

Since the inception of the SIKSP, there have been three cohorts of in-service teachers recruited and trained to integrate science and IK in their classrooms. The first phase of the SIKSP was carried out from 2004 to 2007, the second from 2008 to 2010, and the third from 2011 to 2013 (Langenhoven, 2014). The aim of this section was to introduce the SIKSP. More details of the project and some intended as well as unintended outcomes will be given in chapter 3 under the 'context of the study' (Section 3.4.1).

1.3 Problem Statement

Much research has taken place at SIKSP on how to practically implement a science-IK curriculum in science classrooms at various levels of schooling. Although I cannot mention all of them here, it is necessary to mention a few to buttress the point. Some studies have reported on the experiences of pre-service teachers (e.g. Ghebru & Ogunniyi, 2017; Langenhoven, 2014; Siseho, 2013).

Siseho's (2013) study investigated the effect of Dialogical Argumentation Instructional Model (DAIM) on pre-service teachers' ability to integrate science and IK. The study sought to know what informed the pre-service teachers' knowledge of IK and how they interpreted and implemented the integration of IK with science in their classrooms. Sixteen pre-service teachers were taught a Bachelor of Education module for 6 months to enable them integrate science and IK. After the training, three of the pre-service teachers were observed as they applied the theoretical knowledge in the classroom in four schools in Cape Town. The results showed that the three pre-service teachers implemented science-IK integration differently. One pre-service teacher used an assimilationist approach in which IK was used to validate science; another one used a segregationist approach in which both science and IK were used side-by-side; and the third one used an integrationist approach in which connections were made between science and IK during the lesson. The study thus confirmed similar results obtained by other researchers (e.g. Naidoo & Vithal, 2014) that the implementation of a science-IK curriculum is teacher-specific.

The study of Langenhoven (2014) investigated the impact of DAIM as an intervention teaching strategy to assist pre-service science teachers to teach integrated science-IK lessons

during their 7 weeks of teaching practice at schools in the Western Cape, South Africa. The research was a case study involving 30 PGCE students of a combined science methods class preparing to teach science at high school level. The study focused on investigating the pre-service teachers' pre-post conceptions of the nature of science (NOS) and the nature of indigenous knowledge systems (NOIKS), as well as their self-efficacy to teach a science-IK lesson using the DAIM. The results showed that the pre-service teachers were more aware of the NOS and NOIKS after the course and could use DAIM to implement integrated science-IKS lessons, although they also expressed some difficulties when using DAIM.

More recently, Ghebru and Ogunniyi (2017) report on a study to determine the effects of an argumentation-based instructional method on 25 Eritrean pre-service science teachers' understanding of argumentation as a tool to implement a learner-centred curriculum. The results showed that the argumentation-based course that the pre-service teachers had before teaching practice helped them to change their perceptions of argumentation. They changed from a perception of argumentation as a debate to win a case, to one where they became more aware of argumentation as a means of constructively reaching consensus based on evidence in science classrooms.

Other studies at SIKSP have focused on the application of the argumentation mode of teaching in the classroom at high school level where IKS was integrated with science (e.g. Angaama, 2013; Diwu & Ogunniyi, 2012; Riffel, 2015). Riffel's (2015) study took place at a secondary school in an Afrikaans-speaking community in a Cape Town suburb. The experimental (E) group (N=17) was taught some meteorological concepts using *a* DAIM-based strategy for 4 weeks while the control (C) group (N=12) was taught the same content using the lecture method. The results showed that the E group developed more positive attitudes towards the integration of science and IK, and a better understanding of NOS and NOIKS than the C group.

Some studies at SIKSP have focused on the project's activities (e.g. Hewson & Ogunniyi, 2011; Ogunniyi, 2011a, 2011b) while others have reported on the reflections of in-service teachers and the effects of the project on their pedagogical practices; especially their abilities to integrate science and IKS (Dinie et al., 2013; Ghebru & Ogunniyi, 2014, 2013; Langenhoven & Stone, 2013; Nhalevilo & Ogunniyi, 2014a, 2014b; Ogunniyi, 2004, 2007b, 2013, 2014; Ogunniyi & Hewson, 2008) .

Dinie, February and Kroukamp (2013)'s study reports on the results of 19 in-service teachers who learned to integrate science and IK through an argumentation-based courses, as well as workshops for two years. At the end of the course, the teachers were required to state, with justification, whether or not they had opposed an inclusive science-IK curriculum in South Africa. They were also to disclose if they had changed from their initial positions with regards to the integration of science and IK. The results showed that nine of the teachers were originally opposed to the inclusive science-IK curriculum as they enrolled in the postgraduate programme. The study also showed that at the end of the programme, only four teachers still opposed the integration while fifteen were in favour. Thus five of the teachers who originally opposed the integration had changed their views as a result of the programme.

Nhalevilo & Ogunniyi (2014a) explored in-service teachers' feelings towards the SIKSP by interviewing nine teachers who had participated in the project. Although most of them expressed the difficulties of mastering argumentation strategy initially, they felt that the project had helped to raise their awareness about IK, as well as highlight its relevance to contemporary life; making them feel emancipated and empowered as a result.

An analysis of data from in-service teachers' interviews, questionnaires and reflective journals reveals a general trend where the teachers' knowledge of IK, NOS, NOIKS, increased after taking part in the argumentation-based (DAIM) workshops and activities. Also, the teachers encountered perceptual shifts from a dominant science worldview at the beginning, to shifts towards accommodation of both science and IK worldviews after their participation in SIKSP. Arguably, it could therefore be suspected that the project generally had a positive impact on the in-service teachers as they struggled to practically implement a science-IK curriculum. Although some attempts had been made to get the feelings of the participants about SIKSP (Nhalevilo & Ogunniyi, 2014a), there has been no comprehensive evaluation of the project. This is a gap that needs to be filled.

1.4 Rationale

Although several studies have reported on the activities of the SIKSP and its success at training science teachers to integrate science and indigenous knowledge as just indicated above, there has been no systematic evaluation of the SIKSP to determine its merit and worth in equipping in-service teachers to integrate science and IK in their classrooms. Yet, the evaluation of education projects and programmes such as the SIKSP is a worthwhile practice

(Booher-jennings, 2005; Ladd & Lauen, 2010; Rockoff & Turner, 2010). Many reasons exist in the literature for carrying out such evaluations (Love, 2010; National Oceanic and Atmospheric Administration, 2009; Struhkamp, 2005). For instance, educational evaluations might be carried out with the aim of helping management to improve a programme, gaining knowledge about programme effects, responding to political pressure, rendering accountability, or generating knowledge (Rossi, Lipsey, & Freeman, 2004; Wholey, 2015). Other evaluations might be carried out to determine the relative effectiveness or merit of a project, or to determine if the design, content, and activities of the project are effective. Still, other evaluations are carried out to document project accomplishments, or to furnish information about the needs and effectiveness of the project to decision-makers in order to enable them make informed decisions to continue, improve upon, or stop the project (Rockoff & Turner, 2010).

It was hoped that an evaluation of the SIKSP would provide systematic, defensible information necessary for sound decision-making about similar projects in South Africa. Such information could provide a means of knowing what is working, and what is not working well in the project, in order to make necessary adjustments and improvements. Thus an evaluation involves the systematic collection and analysis of information about the project (its needs, aims, resources, activities, and outcomes) in order to make informed decisions about it (Ofek, 2016; Patton, 2002; Rossi et al., 2004).

According to Patton (2002), the evaluation of a project such as the SIKSP is a useful way of obtaining information necessary for assessing the way participants' knowledge is impacted, assessing the strengths and weaknesses of the project theory, processes or activities; shedding light on how and why the project works, and so forth. These decisions may lead to the improvement of the project's effectiveness, a scale up, or termination of the project in its entirety. At times, the funding of the project simply stops because the funds are not available, since for example, in the case of state funded projects, there could be too many urgent needs vying for the same amount of money within tight budgetary constraints. The SIKSP was fortunate to have received funding from the National Research Foundation (NRF) for 10 years (from 2004 to 2013). Although funding terminated several years back (in 2013), the activities have continued till today, seven years afterwards. An evaluation of the project would most probably be helpful to people involved in similar initiatives elsewhere in South Africa and beyond. By learning from the successes as well as failures of SIKSP's design, strategies,

methodologies, activities, etc., researchers and educators would be in a better position to improve on similar projects in comparable contexts.

Funding agencies desire to know how effectively their scarce resources have been put into effective use and the impact that the targeted group of individual needs have been met as a result of the project (Cook, 2010; Mathison, 2018). Such knowledge is best gathered through a systematic evaluation of the project. Hence it was hoped that this evaluation was necessary to provide useful information to stakeholders about the degree of success of the SIKSP in training science teachers to achieve the goal of integrating science and IK in their classrooms. The information gathered from the evaluation of the SIKSP could enable interested stakeholders to understand SIKSP's methods of integrating science and IK, as well as the strengths and weaknesses of these methods.

An important goal of an evaluation is knowledge generation (Rossi et al., 2004). It was hoped that by critically evaluating the theory, design, methods, activities and outputs of the SIKSP, the research would generate knowledge for possible replication and improvement in other parts of South Africa. This suggests that an evaluation might play the role of marketing the project to others in the knowledge space.

1.5 Purpose of the Study

The purpose of this study was to evaluate the Science and Indigenous Knowledge Systems Project (SIKSP), which was funded by the National Research Foundation (NRF) of South Africa, at the Western Cape University from 2004 to 2013. The study sought to do so by extending the reflections on the effects of the SIKSP, such as the effects of the project on participants' knowledge of IK and their abilities to implement a science-IK curriculum. The study also intended to provide a holistic evaluation of the SIKSP from the view of the participants. Since the project was huge, it would have been rather preposterous to think of evaluating the entire project. Hence the study mainly focused on points 6 and 7 of the aims of the SIKSP, namely, 1) to evaluate how the SIKSP fulfilled its aims of building the capacities of in-service science teachers and teacher trainers in IKS, and 2) equipping masters and doctoral students with research skills in the domain of science and IKS integration in the South African context.

The study systematically gathered and documented valuable evidence useful in making judgments about the merit and worth of the SIKSP as a means of equipping in-service science teachers to implement an inclusive science-IK curriculum across South African science classrooms. I used concepts from Guba and Lincoln (1989)'s Fourth Generation evaluation, and Stufflebeam's Context, Input, Process and Product evaluation model (Stufflebeam, 2003; Stufflebeam & Zhang, 2017) as a guiding framework (to be elaborated upon later). According to Stufflebeam (2003) an evaluation is expected to:

> Assess intended and unintended outcomes and positive and negative outcomes ... It should gather and analyse judgements of the program by stakeholders and relevant experts and should view outcomes from several vantage points: in the aggregate, for subgroups, and sometimes for individuals (p.50-51).

The main aim of this study was to assess the extent to which the SIKSP accomplished its mission to train science teachers to implement an inclusive science-IK curriculum as demanded by the new South African curriculum using the dialogical instructional model (DAIM).

1.6 Research Questions

The research questions that guided this study were aligned with the aims of the study and the CIPP evaluation model. Accordingly, the questions guiding the study were the following:

1. What opportunities and challenges emerged for the SIKSP participants as they were being trained to implement a science-IK curriculum?
2. What were the participants' perceptions of the effectiveness and challenges of using DAIM as an instructional tool for implementing a science-IK curriculum?
3. How did the in-service teachers apply DAIM in their classrooms?
4. To what extent did SIKSP enhance the participants' professional development and ability to carry out science-IKS research?

1.7 Methodology

I used a case study design in this research. Case studies are the method of choice where an in-depth study of the phenomenon is required (Martinson & O'Brien, 2015; Yin, 2003). They have the advantage of being flexible, and are well known for their use of multiple instruments and rich, in-depth qualitative data. Case study data are obtained through the use of multiple instruments like interviews, focus group discussions, and similar instruments

(Martinson & O'Brien, 2015; Yin, 2003, 2009). They are often characterised by the use of small sample sizes, and are generally suitable where an in-depth investigation of a phenomenon or event is required (Creswell, 2014; Martinson & O'Brien, 2015; Yin, 2009).

In this study, the instruments for data collection included questionnaires, interviews, and document analyses. I will provide details of the methodology in chapter three.

1.8 Conceptual Framework

The conceptual framework guiding this study was drawn from four constructs within the paradigms of constructivism and pragmatism. From the field of evaluation, I chose Stufflebeam's (2003) Context, Input, Process, Product (CIPP) evaluation model to give the structure while Guba and Lincoln's (1989) Fourth Generation (or Constructivist) evaluation formed the general approach or worldview. Reflexivity was built into the design and analysis of the research. These concepts are elaborated upon in chapter two (section 2.10). I will expand on the CIPP model further in the following sub-section.

1.8.1 The CIPP evaluation model.

In this study, I used the Context, Input, Process, Product (CIPP) evaluation framework (Stufflebeam, 2003a) as a guiding framework to give it a structure. According to Stufflebeam (2003, p. 245), 'the CIPP model is a comprehensive framework for guiding formative and summative evaluations of projects, programmes, personnel, products, institutions, and systems.' The model is useful for carrying out internal evaluations by an organization's evaluators, as well as for external evaluations. The CIPP evaluation model is a holistic framework that has been widely used in evaluating educational programmes and projects (Eseryel, 2002). It is a comprehensive model that was developed in the late 1960s to be used in US urban and semi-urban schools with the aim of improving teaching and learning (Stufflebeam, 2003a). In this model, the key concepts are context, input, process and product evaluations.

1.8.1.1 Context evaluation.

According to Stufflebeam (2007) the context evaluation component involves a careful assessment of the needs, assets and problems within the environment in which the project is embedded, including the socio-political and socio-cultural contexts (Stufflebeam, 2003a). It

also involves the gathering of data that could lead to the identification of the educational needs and problems of a specific environment as assessed. Thus, the model enables evaluators to come out with intended goals to be met in order to address the needs of that particular community. Some evaluators refer to this step as a needs assessment (Rossi et al., 2004).

1.8.1.2 Input evaluation.

Input evaluation assesses the available strategies, work plans and budgets to determine if they are capable of meeting the objectives identified from the context evaluation (Lippe & Carter, 2018; Zhang et al., 2011) Input evaluations also assess the alternative strategies, designs and budgets of approaches chosen for implementation, and help to make necessary decisions and improvements in these plans.

1.8.1.3 Process evaluation.

Process evaluations monitor and document the actual procedures or activities while the project is being implemented for programmes and projects in progress, or whether a terminated project was implemented as planned (Stufflebeam & Coryn, 2014; Stufflebeam & Zhang, 2017) The process evaluation seeks to know the perceptions of the stakeholders about the project activities and documents any abnormalities or poorly functioning parts of the system for accountability purposes.

1.8.1.4 Product evaluation.

According to Stufflebeam and Coryn (2014) 'Product evaluations identify and assess the intended and unintended outcomes of the implemented project, providing grounds for stopping, continuing or modifying the program' (Stufflebeam, 2003a; p.35). Rossi, Lipsey, and Freeman (2004) divide the product stage in the CIPP model into three sub-levels: 1) *outcomes or short-term results,* 2) *impact or* long-term results, and 3) *program efficiency*.

Some evaluators divide the product evaluation phase into short-term, medium-term, and long-term outcomes (Stufflebeam & Coryn, 2014; Zhang et al., 2011). In the present study, the we are dealing with the long-term outcomes or impacts of the project. These outcomes refers to 'the change in attitudes, behaviours, knowledge, skills, status, or levels of functioning' (Parsons, 2002; p. 17) of the SIKSP main beneficiaries (in-service teachers, teacher-trainers,

lecturers, curriculum advisers, and post-doctoral fellows) which can be attributed (at least in part), to their involvement in the SIKSP.

Many evaluators are of the view that one cannot effectively carry out a product evaluation without first understanding the context of the intervention, the input, and whether the implementation was effected as actually planned (Rossi et al., 2004; Rovai, 2003; Stufflebeam, 2003a). In other words, one cannot carry out a product evaluation in the absence of the preceding types of evaluation that led to the outcomes of the intervention. As stated above, I used the Stufflebeam (2003a)'s CIPP model as well as Guba and Lincoln (1989)'s Constructivist or Fourth Generation Evaluation to structure and guide this study. These evaluation approaches were augmented with concepts of reflectivity (as will be explained later in chapter two).

1.8.2 The place of constructivism

Constructivism forms the main tool of analysis in this study. Constructivism is a complex concept to define because there are many notions of it. It is used in many fields, including educational psychology, philosophy and sociology. In the context of this study, the notion of constructivism is concerned with learning, teaching and evaluating. Constructivists believe that learners do not passively wait for someone to fill their heads with knowledge, but actively construct meaning, making use of their prior knowledge (Bozkurt, 2017; Schrader, 2015). In the social constructivist view of learning, the learners make sense of the world by learning from more knowledgeable others. Learning takes place when the learner actively constructs meaning by participating in the community activities. Learning is mediated through language and culture.

Constructivist teaching is done by providing suitable environments where learners can work in groups, and actively make meaning of the world (Knapp, 2019; Schrader, 2015). The teacher of a constructivist approach acts as a facilitator in the knowledge building process and not the sole authority giving out knowledge. Constructivist teaching is thus learner – centred (Zielinski, 2017). In the context of the SIKSP, the DAIM was designed to provide such learning environments in the science class.

Guba and Lincoln (1989) applied the idea of constructivism to evaluation. They argued that an evaluation of an educational object or programme should not be the decision of an

expert, but should rather be the joint construction of all the stakeholders. This will be elaborated upon in chapter two (section 2.10.2).

1.9 Significance of the study

This study provides some information needs of curriculum developers, education departments, policy makers, and other education stakeholders. More specifically, the study would:

- Provide baseline data for further studies in the field of evaluation of educational projects and programmes in South Africa, something which is very much lacking at the moment;
- Provide useful information to science teachers who had been eager to implement a science-indigenous knowledge systems curriculum as recommended by the new curriculum in South Africa;
- Add to science teachers' repertoire of new approaches aimed at making science more relevant to learners of all cultural backgrounds;
- Contribute to enhancing the credibility of the SIKSP in integrating science and IK. This would be achieved by identifying the strengths and weaknesses of the project's methods and processes. The study could probably enable education stakeholders and experts to seek ways of working to overcome the weaknesses of the SIKSP in order to improve on the performance and effectiveness of the methods that have been used in the SIKSP for over 15 years. When such a process is achieved, the SIKSP would likely be regarded as a more credible source of training science teachers to teach in today's multicultural contexts.
- Motivate researchers and education stakeholders to experiment with the SIKSP methods in other parts of South Africa. Such an endeavour would possibly help science teachers to implement a science-IK integration which the education policy has been advocating for over twenty years.
- Inspire science education researchers to adopt what has been found to work elsewhere and possibly adapt it to their contexts.

1.10 Delimitations of the Study

The delimitations or scope of the study spell out the boundaries set for the research; what is covered in the study, and what is not (Simon & Goes, 2013). The SIKSP was a big project involving 5 universities in different provinces of South Africa. I limited this study to just one case in one of the universities. Since the project had many objectives, I also limited the study to the sixth and seventh objectives of the aims of the project, namely, the objectives (1) to engage in building the capacities of teachers in IKS and (2) to equip masters, doctoral and post-doctoral students with research skills in the domain of science and IKS.

The study was a case study, involving participants who had been part of the SIKSP at some time in the past, or who were still involved in one way or the other, in the project activities. The study did not include the project's training of undergraduate pre-service teachers to integrate science and IK in their classrooms, nor did it involve the learners who were taught by the in-service teachers after graduation. The study did not also get into cost-benefit analysis issues.

1.11 Limitations of the Study

Research design: This evaluation research followed a case study design. In the extant literature on evaluation, randomised control trials (RCTs) are considered as the 'gold standard' or most credible designs in programme or project evaluations, followed by quasi-experimental designs (Boruch, 2007; Mouton, 2007; Witte, Wolf, Cowen, Carlson, & Fleming, 2014). RCTs are evaluations where the participants are randomly assigned to the experimental and control groups in order to control for extraneous variables. Therefore, it is believed that RCTs have the least possibility of introducing bias in the data collected; unlike case studies which are seen as highly subjective, biased and context-dependent. Furthermore, it is also believed that in RCTs, there is a high probability of the sample being a true reflection of the target population. Hence, RCTs have greater external validity (Torgerson et al., 2015). As a result, the inferences drawn from RCTs can more easily be generalized to the population.

On the other hand, some evaluators and researchers are aware of the limitations of RCTs. At times it is not feasible to carry on RCTs because of conditions posed by ethical and social considerations. Futhermore, case studies are also acknowledged as the preferred design for evaluation studies (Martinson & O'Brien, 2015; Yin, 1992) because they permit the use of multiple methods and instruments to collect and analyse data for in-depth analyses to reach a

more holistic conclusion. This latter perspective largely influenced the methodology adopted for this study (Martinson & O'Brien, 2015; Simons, 2015).

Purposive sampling: I used purposive sampling procedures. Purposive sampling is highly dependent on the researcher's judgement of sources deemed important to provide the right kind of information. One criticism levelled against purposive sampling is that if the researcher is mistaken in his or her judgement, the validity of the findings would be reduced (Fraenkel & Wallen, 2008; Palinkas et al., 2015).

Financial accountability issues: Financial issues are generally sensitive and need a high level of expertise and authority. External evaluators endowed with the mandate and financial resources can best carry this out. This evaluation does not cover cost effectiveness or finance-related issues.

1.12 Operational definitions

Context evaluation

A context evaluation refers to the assessment of the socio-political, socio-cultural and socio-economic environment in which the project is taking place.

Input evaluation

An input evaluation is the evaluation of the resources – human, financial, material, and intellectual - that are at the disposal of the project in order to carry out the intervention and solve the identified educational problem.

Process evaluation

Process evaluation is a form of evaluation designed to determine whether the project was delivered as originally intended to the target recipients. It is an evaluative study that answers questions about programme operations, implementation, and service delivery (Rossi et al. 2004).

Impact evaluation: An evaluative study that answers questions about long term programme outcomes and impact on the social conditions it is intended to ameliorate (Rossi et al., 2004).

Merit: Merit is a measure of an object's quality, intrinsic value or level of excellence without necessarily referring it to something else (Stufflebeam & Coryn, 2014).

Worth: Worth is the extrinsic value or quality of an object within a given context. It refers to how needful or useful an object is to a particular group (Stufflebeam & Coryn, 2014).

Effectiveness: Effectiveness refers to the ability to produce intended results. An effective programme is one that produces the intended outcomes when carried out.

1.13 Thesis outline

The aim of this study was to evaluate the Science and Indigenous Knowledge Systems Project (SIKSP) at a South African university. The research sought to determine the effectiveness or not, of the project in equipping science teachers to enact a science-IK curriculum in their classrooms. Project participants (in-service teachers for the most part) and other stakeholders formed the sources of data collection. The outline of the thesis was be as follows:

In chapter one, I provided the background of the study and introduced the framework guiding it. I briefly sketched the wider context which gave rise to the need for the integration of science and IK in South Africa, and then focused on the SIKSP whose main aim was to improve science teachers' capacities to implement the new science-IK curriculum as the new educational policy demanded. I reviewed some of the work that had taken place in the SIKSP, pointing out the gap that still had to be filled, in order to situate the present study.

In chapter two, I provide a review of the relevant literature pertinent to the study in line with the purpose of the study and the research questions. I focus on the theoretical and practical concepts about the integration of science and IK. I also review literature on evaluation which forms a central theme in the conceptual framework used for the study.

In chapter three I present the methodology that I used to carry out the study. This includes a description of the design, sampling, as well as the instruments used to collect data. In this chapter, I also describe the methods taken to increase trustworthiness and dependability of the data collection and analyses.

In chapter four I present the results in line with the research questions. They are first presented using the voice of the participants as far as possible; then followed later by discussions. Chapter five presents the conclusion, implications and recommendations for further study.

CHAPTER TWO: LITERATURE REVIEW

This research is about the evaluation of the Science-Indigenous Knowledge Project (SIKSP) at a Western Cape university. In this chapter, I will review the relevant literature to the study, beginning with the issues that surround the integration of science and indigenous knowledge in schools. This is necessary to enable the reader understand the challenges within which SIKSP operated. Next, I will review the literature on the evaluation of educational programmes and projects, giving an illumination of the conceptual framework. Finally, I will round up the review by taking into consideration practical issues, focusing on the theoretical framework and the research questions. Admittedly, a limitation of the approach is that the wider scope of the review might mean less depth since I will endeavour to keep a delicate balance between the breadth and depth. To proceed, it is necessary to understand the meaning of some of the terms as used in the context of this study.

2.1 What is Science?

The notion of science is rather contentious and complex as it may mean different things to different people. There may be wide, inclusive definitions as well as narrow exclusive ones; depending on the angle from which it is perceived. From the widest perspective, the word 'science' comes from the Latin word *scientia* which means *knowledge* (Gondwe & Longnecker, 2014; Massey & Kirk, 2015; Mpofu, Otulaja, et al., 2014; Snively & Corsiglia, 2001). This definition of *science* is very inclusive and does not associate *science* with any geographical or cultural boundaries. In another perspective, s*cience* is taken to be empirical knowledge that excludes anything metaphysical. In that sense, any knowledge that falls outside the 'testable' knowledge is not deemed as science. Hence, since the knowledge of many cultural societies does not exclude the metaphysical components, cultural knowledge is not deemed as science. In such a classification, *Scientia* is divided into 'science' and 'indigenous knowledge'; with the latter not considered as 'science'. However, some researchers who see knowledge as a whole disagree with such divisions of science into different areas (Agrawal, 1995). Some other researchers like Ogawa (1995) look at science from three perspectives – a personal science, a societal science and what he calls Western Modern Science (WMS) (Aikenhead & Ogawa, 2007; Ogawa, 1995).

In this perspective, the Western modern science (which is itself a contentious issue) is associated with what is accepted or agreed upon by the "scientific community"; a sort of excusive group of individuals. WMS then refers to science as construed by European and North Americans of European origin. Admittedly, this view is a very contentious issue as one can argue that today's science is a combination of the science of many cultures, including Egyptian and Hindu-Arabic origins (Kawagley et al., 1998). A clear example to demonstrate that the so-called WMS is actually a combination of knowledges from several other cultures is the number system used in 'science' today, which is of Hindu-Arabic origin.

This WMS, known some authors as Euro-centric science (Aikenhead & Ogawa, 2007), is regarded as universally valid, objective, culture-free, and validated through the rigorous procedures of the Scientific Method. These assertions have been strongly put to question by the writings of Bauer (1992) who rubbishes the claims of the so-called Scientific Method. In a similar vein, Aikenhead strongly adds his voice against the universalist view of Euro-centric science when he asserts that science-teaching is culture transmission (Aikenhead, 2002a, 2006; Aikenhead & Elliott, 2010).

With the coming of European colonization, South Africa, like all African countries that were colonized by European nations, inherited this Euro-centric version of science. This is what has been taught in her schools since independence, with minor modifications. In this study, the concept of science or school science will mean the Euro-centric version of science that is taught in South African schools, as informed and directed by the National Curriculum Statement and CAPS documents (DoBE, 2011; DoE, 2002).

2.1.1 The Nature of Science.

It is important that all teachers, especially at school level where learners are introduced to scientific approaches, have a basic understanding of the nature of science (American Association for the Advancement of Science [AAAS], 1990). It is now almost universally accepted that an exclusive, narrowly defined notion of science is losing ground to more liberal ideas of science literacy. The reason might be that the latter seems to prepare citizens better for participation in the events that concern most people, for instance, the environment and policies (AAAS, 1990). The AAAS, in its statements on the nature of science, states four fundamental assumptions which are worthy of note. First, the world is viewed as understandable; meaning that nature is predictable. The second view is that scientific ideas are subject to change. This

means that science laws are also bound to change in order to explain changes in nature and new situations in the face of more convincing evidence. The third perception is that scientific knowledge is durable. This assumption is supported by the fact that most of the scientific ideas have remained correct and viable for a long time from the time they were discovered by early scientists. However, the durability assumption does not say that scientific knowledge is the truth. The fourth assumption is that science cannot provide complete answers to all questions. This fourth assumption leaves room for other knowledges to contribute to the universal pool of knowledge. In fact, Snively and Corsiglia (2001) put up an argument for the inclusion of IK in science to this effect. They argued that Traditional Ecological Knowledge offered a solution to environmental sustainability that the present science did not have, hence its contribution to knowledge should be recognised.

2.2 What is Indigenous Knowledge?

The idea of Indigenous Knowledge Systems (IKS) is a complex concept that is not so simple to define. The complexity is caused by the fact that IKS means different things to different people. According to Semali and Kincheloe (1999), the term has various meanings to the colonialist, such as "primitive, the wild, the ignorant, and the natural" (p.3). The people associated with such knowledge by the Western colonialists were consequently viewed as inferior and primitive. According to Semali and Kincheloe, when the colonised people saw themselves in the light of the descriptions of the Western colonialists, they tended to think of themselves that way. In other contexts such as Australia and North America, indigenous knowledge is associated with Aboriginals or Natives.

According to Odora Hoppers (2002), IKS refers to knowledge systems that existed in non-western communities prior to colonialism. Such knowledge was acquired by the people over time as they lived and studied to cope with their environment. In her view, just as many others, IKS includes social, physical, spiritual components of non-western people. It is context-dependent, but adapting to changes in the environment; thus, enabling the continued survival of the communities for long periods of time (Odora Hoppers, 2002; Ogunniyi & Ogawa, 2008; Onwu & Mosimege, 2004).

The term IKS therefore refers to 'a conglomeration of knowledge systems' (Ogunniyi, 2007a). A smaller subset of IKS, is indigenous knowledge (IK) which has been defined variously as 'local knowledge unique to a given culture or society and is acquired through the

accumulation of experiences, informal experiments, and intimate understanding of the local environment' (Warren and Rajasekaran, 1993 cited in Hewson & Ogunniyi, 2011; p.681); and as "the complex set of activities, values, beliefs and practices that have evolved cumulatively over time and is active among communities and groups who are its practitioners" (Owuor, 2007; p. 23). This study agrees with several others (e.g. Getty, 2010; Khupe, 2014; Ngulube, Dube, & Mhlongo, 2015; Paris, 2012; Shizha, 2010) that such knowledge is not static but dynamic since it enables its practitioners to adapt with the changes that time brings. This dynamic nature of IK calls to question the notion by some that IK is archaic or deals only with the past.

2.3 Why Teach IK in Science Classrooms?

When one talks of integrating IK with science, a question often arises: What is the use? Such questions are often motivated by two underlying assumptions. The first is that science has developed to an extent that it can solve most problems without the need of any other type of knowledge. A second is that IK is outdated, cultural or historical stuff that has no place in a modern, advanced world of science and technology. Never the less, it is very important to answer such questions in order to establish the relevance of IK in science – a very necessary concept for learner motivation to learn it. A relevant study in this case is that which was carried out by Seehawer (2018). In response to the question of relevance of science-IK integration, the participants in Seehawer's study identified five important reasons – decolonisation of the mind, increase in relevance of science to learners, widening of the science worldview to include IK, sustainable management of the environment, and increased dignity of non-western learners.

Decolonisation of the mind of the African science teacher is needed so that IK is not seen as inferior to science. I agree that the mind of the African science teacher needs to be reprogrammed to think rightly. In fact, one of the legacies of colonisation was teaching the Africans that they and everything that they had was necessarily inferior to the colonialist and their own ways of thinking – a sort of brainwashing. As Semali and Kincheloe (1999) had noted, this notion made the African science teacher to reject every form of knowledge from the African cultural background as worthless superstition that did not merit to be classified as science. Even though many African nations gained independence many decades back, the educational systems had followed the colonial legacies and most science teachers do not value their IK as scientific (Ogunniyi, 2004; Shizha, 2007). Therefore, they first need to be persuaded to see that IK is not as worthless as they had been made to believe, before they can teach it to

their learners. Such a task is difficult to achieve since it is not easy to change a teacher's mind set and practice (Davis, 2003). However, research points to some degree of success through persuasion and dialogical argumentation-based strategies (Hewson & Ogunniyi, 2011; Ogunniyi, 2007a).

Relevance is a necessary for motivation to study new concepts. In fact, many studies have concluded that the poor performance of non-western learners in science is largely caused by the fact that they are taught science in ways that denigrate their cultural knowledge. They often do not relate to such science in daily life. On the other hand, including aspects of the learners' cultures in science lessons results in greater interest, participation and performance (Angaama, 2013; Diwu & Ogunniyi, 2012; Mawere, 2015).

Aikenhead & Elliott (2010) arguing for integration of science and IK, believe that integration of the two knowledge systems would provide a wider perspective of interpreting experience than when only one worldview is presented. I agree with this view, but with some reservation. Whenever science has been brought together with IK, as Cobern & Loving (2001) argue, science tends to play a dominant role. So, there needs to be safeguards to ensure that one worldview is not used as a reference and the other judged by that standard. Other researchers have recommended that IK should be integrated with science for sustainable development of local communities (Kaya, 2013; Kaya & Seleti, 2013). This view is largely welcome since many communities had lived for many centuries in the same environments, and in harmony with nature. This means that school science could tap into such environmental sustainability knowledge; and the communities too would learn from science. Connecting with community leaders and IK knowledge holders would give the community as well as the learners a sense of pride in their cultural values as they see their cultural knowledge contributing to solving contemporary human problems.

2.4 Some Underlying Differences Between Science and IK

Several studies have distinguished key assumptions that characterise IK from those that characterise conventional Eurocentric science that is typically taught in schools (Ogunniyi, 2004; Owuor, 2007). Some of these assumptions concerning natural phenomena are that: science is basically atomistic and reductionist while IK is holistic and anthropomorphic; scientific laws are generalizable, universal, impersonal, and context-independent while IK is localized, person- and context-dependent; science is culture-free and value-free while IK is embedded in both culture and values. These are some of the differences that underpin the two

worldviews and thus make them so disparate that it seems impossible to bridge the gap between them. Hence talking of integrating science and IK may sound very strange at first.

2.5 Some Challenges of Integrating Science and IK

The integration of science and IK faces a number of challenges which need to be overcome for effective implementation of an inclusive science-IK policy to take place. These obstacles involve many facets- the science teachers, the school system, and learners. For any integration of science and IK to be effectively implemented, the science teachers need to have a positive attitude towards such an endeavour. In this case, they need to have a positive impression about the usefulness of IK in the science curriculum. However, the reality is that most science teachers themselves have a dominant Eurocentric worldview of science. This is understandable since they were educated in the Eurocentric worldview inherited from the colonial masters. The science introduced to them by the colonialist approach taught them to value school science (which adopted the Eurocentric worldview) as the only valid type of knowledge in the science classroom (Ogunniyi, 2004, 2005; Shizha, 2007, 2008).

With the dominant Eurocentric worldview underpinning their beliefs, most of the science teachers are alienated from their own cultures (Dziva, Mpofu, & Kusure, 2011; Ogunniyi, 2004; Semali, 1999). Most of them believe that school science is universally valid because it is tested and approved, empirical, objective and culture-free, etc. On the other hand, they regard IK as superstitious, unscientific, mystical, and not qualified to be taught as science (Ogunniyi, 1988, 2004; Semali & Mehta, 2012; Shizha, 2007, 2008). With this state of affairs, the first step in integrating IK with school science would be to convince the science teachers to change their worldviews. That is, the science teachers first need to be convinced that science is not absolute or universal, value-free truth as some of them they believe; but a tentative, value-laden human enterprise (Kind, 2015; Lederman et al., 2014; Ogunniyi, 2004, 2006). Secondly, they also need to accept that IK contains valid knowledge that can be useful in science classrooms (Baquete et al., 2016; Emereole, 1998; Ogunniyi, 2007a, 2007b; Ogunniyi et al., 1995; Snively & Corsiglia, 2001). This is a daunting task because it is very difficult to change one's view (Davis, 2003; Gay, 2010; Lee et al., 2007; Pajares, 1992), and any change needs much time and effort to accomplish (even partially) through professional development initiatives.

Another challenge to the integration of science and IK is that during training, most science teachers were taught the science content knowledge and how to transmit that knowledge to learners as a collection of scientific facts (Bricker & Bell, 2008; Duschl & Osborne, 2002). Their most common mode of teaching is teacher-centred, as opposed to learner-centred methods that give learners the opportunity to construct knowledge in the science classroom, based on their prior knowledge and understanding. Many science teachers are therefore used to teaching according to the textbook, which in most cases covers the science content, to the exclusion of IK (Shizha, 2007, 2008). The teachers were not also taught how to incorporate IK in science during their training. Consequently, most of them lack the confidence to enact a science-IK curriculum, even if they had the desire to do so. After accepting IK as valid knowledge worthy of integration in school science, the teachers would then need some effective pedagogical method of carrying out the integration practically.

Thirdly, for integration of science and IK to be feasible, the science teacher must have knowledge of both the science and IK corpuses, as well as an idea of the IK of their learners. However, most science teachers might have a mastery of the science knowledge, but not the IK because of the way they were taught to teach science (Ogunniyi, 2004). Also, the science textbooks have little or nothing about IK. If some do, they do so just as an appendage or an application of science where appropriate. Besides, with the multicultural classrooms prevalent today in South Africa and beyond, the teacher might have daunting challenges since there are so many IKs in the country, depending on the cultures of the learners. Worse still, most science teachers have little or no knowledge of IK or how to integrate it with science (Ogunniyi, 2004, 2007a, 2007b). So a question that arises is, "How can a science teacher integrate what he/she does not know?"

A formidable challenge that has been cited as a possible obstacle to the integration of science and IK is the nature of the official curriculum. In some cases, the curriculum is Eurocentric and does not take into consideration the cultural knowledge of learners from indigenous communities, thus alienating them from science professions. Aikenhead (2002) for example, criticizes Canada's 1997 science education framework, for not taking into account Aboriginal students' needs. He argues that science is a cultural event and that the learning of science is 'enculturation' into the science worldview. To him, as well as many other science education researchers (e.g. Ogunniyi, 2004), science is not value-free as purported by scientism. Instead, even the science curriculum is economically-, socially-, culturally- and

politically- motivated (Aikenhead, 2005). Hence, any curriculum that does not take into consideration the culture of students is defective because its aim might be to indirectly transmit the Western worldview to non-western students of science. This agenda is implemented through the portrayal of science as real, empirical, rational and universal (Aikenhead, 2002b; Aikenhead & Ogawa, 2007).

However, it is apposite to say that the integration of IK with science is not so simple. Even when the curriculum policy makes room for the integration of science and IK, such as in South Africa, it is not obvious that the teachers and other stakeholders who are supposed to implement such policies would practically do so easily. In some cases, the curriculum policy to integrate science and IK may be shallow and unclear (for political or technical reasons) as to how the integration should be done, leaving the teachers in a state of confusion (Semali, 1999). This has been a prominent complaint against the IK policy as found in the South African policy statements since the end of the apartheid government (Ogunniyi, 2007a; Onwu, 2009; Onwu & Mosimege, 2004). In most cases, professional development initiatives such as workshops and seminars organized to remedy the situation have hardly achieved their purpose.

In some cases, the integration of science and IK may be impeded by the nature of assessment and control mechanisms (Castagno & Brayboy, 2008). An assessment-driven curriculum places much value in the performance of an institution on official examination scores, such as the Matriculation Examination in the South African context, to the neglect of the process of teaching and learning science. The pass rate alone is thus used in many other ways by the state and other education stakeholders to reward the schools or to classify them as high performing. This makes the Education Inspectors to put pressure on the school administrators to 'cover the syllabus' at a pace that is usually determined by the Inspectors or Curriculum Advisers themselves and implemented by the school principals to ensure that the learners cover what would be tested in the national examinations. This practice puts the school principals as well as science teachers under enormous pressure to complete the syllabuses. The time constraint and energy required to teach at the prescribe pace therefore leaves little room for including IK, which up till now, does not carry any weighting in the Matric examinations (Ogunniyi, 2004, 2007a; Onwu, 2009).

The nature of the assessment tasks could also be a challenge for integrating science and IK. In the case of the United States, Barnhardt, Kawagley and Hill (2000) frown at the fact that the examinations are usually multiple choice or short answer questions, leaving out many

important aspects of the curriculum. This narrow focus of the tested curriculum, they argue, forces the teachers to choose between teaching the whole range of learning outcomes and teaching to pass the examinations. In most cases, when teachers face such a dilemma, they choose to teach what would result in good pass rates. Such a choice seems to be the universally preferred choice. Shizha (2007, 2008), for example, reports that primary school teachers in Zimbabwe prefer to teach to the test in order to have greater rating at the official examinations. Both principals and classroom teachers make that choice because the performance of the school in official examinations results in greater respect and reputation for the school as highly performing. Therefore, since IK is hardly tested in the final examinations, it is often ignored or at best, glossed over in haste.

Teachers and school administrators also face other problems, which hinder them from implementing science and IK besides the curriculum. Baynes and Austin (2012) examined some issues with the Australian Integrated Curriculum at the implementation level. Heads of secondary school science departments were interviewed while other teachers got involved in the Implementation project to integrate IK in science classrooms in Australia. The interviews with HODs revealed a mixture of feelings towards inclusion of IK in science curriculum – from a view that IK was not science to one that accommodated and acknowledged some valuable knowledge in IK. Similarly, the science teachers were also divided, some for integrating IK with science, and others rejecting integration on the grounds that there was no IK in the textbooks. This project encountered challenges such as the pessimism of some HODs, lack of curriculum materials to support the change, the teachers' mixed reactions, an examination-driven curriculum, and the fact that there was no input from the Indigenous people who were supposed to be the main beneficiaries of the project. When there are so many challenges, finding a strategy to integrate science and IKS may be a daunting task.

2.6 Argumentation as an Instructional Tool in Science Education

Many science education researchers have long endorsed the use of argumentation-based strategies to improve the teaching and learning of science (Berland & Reiser, 2009; Driver et al., 2000; Kuhn, 1993, 2010; Newton et al, 1999). This view fits into the shift from teacher-centred methods to learner-centred, constructivist approaches. In the former approach, the teacher's goal was to dish out as many science facts as possible to the learners. On the other hand, the learners were construed as empty vessels, sitting passively, waiting to imbibe the

scientific facts from the knowledgeable teacher. However, constructivism teaches that learners use their prior knowledge, together with what the teacher and the school provide, to make sense of the world. Such an approach has huge benefits, but also some challenges. Argumentation-based strategies are founded on the constructivist principles of the learner co-constructing knowledge in the science classroom (Driver et al., 2000; Kuhn, 1993; Newton et al., 1999).

2.6.1 Benefits and challenges of argumentation as an instructional tool

There is much evidence in literature to support the claim that teaching and learning science through argumentation has many benefits. For example, many studies have shown that engaging in science teaching and learning through argumentation promotes critical thinking, reflection, evaluation of evidence, revision of claims and science content learning (Bathgate et al., 2015; Kuhn, 2012; Lin, 2014; Lubben et al., 2010; Osborne, 2010).

In particular, dialogical argumentation is an instructional approach that has been found to benefit learners if well managed. For instance, a recent study by Hemberger and colleagues showed that scaffolding dialogic argumentation led to the improvement of low-performing middle school learners in argumentative essay writing; with the learners being able to support their claims more easily than their counterparts in less supported comparative groups (Hemberger et al., 2017).

In another study, Kuhn and Crowell (2011) used electronically conducted dialogues for two years with two cohorts of learners on social topics. The dialogic group demonstrated more gains in argumentation quality and could transfer their argumentative skills to new topics more easily than comparison groups. In that study, it was found that the sustained involvement in dialogical argumentation with peers enhanced meta-level understanding of argumentative discourse. Also, the learners in the intervention group demonstrated greater understanding of counterarguments and supported claims with evidence to a greater extent compared to a comparative group that did not take part in dialogic argumentation.

Other studies have come to the conclusion that dialogical argumentation is a promising tool to effect conceptual understanding and conceptual change in science classrooms (Asterhan & Schwarz, 2007, 2009, 2016; Mehmet Aydeniz et al., 2012; Jonassen & Kim, 2010; Nussbaum & Sinatra, 2003;Osborne, 2010; Schwarz & Asterhan, 2010). Aydeniz and colleagues' study took place in a Turkish university where two groups of science education

pre-service teachers from two general chemistry courses were taught by the same lecturer. The intervention group was taught using argumentation while the control group was taught using the lecture method. At the post-test, the experimental group students performed significantly better than the control group students. Also, less than 50% of the control group students abandoned their alternative conceptions as identified by the authors as compared to 80% of the students in the intervention group at the end of the intervention. In as much as argumentation has benefits such as those mentioned above, it also has some challenges.

Some studies have shown that learners need science content knowledge to engage in elaborate dialogical argumentation practices in science classrooms (Hemberger et al., 2017; Sadler & Zeidler, 2005). Understandably, a learner who does not possess the necessary content knowledge will not be able to draw from such knowledge to justify claims in an argument. Also, it is difficult for such learners to focus on the opponents' claims and supporting evidence in order to find a rebuttal. Instead, they would more commonly elaborate on their own explanations (Hemberger et al., 2017).

Effective learning that makes use of argumentation strategies in constructing scientific knowledge takes time. For example, in a study by Kuhn and Moore (2015), middle school students involved in a dialogical argumentation curriculum for two years (meeting twice a week), were better able to support claims with evidence than a comparison group. Another study by Martin and Hand (2009) showed that change in pedagogical practice is very difficult and requires much time. In the said study, it took 18 months for any significant pedagogical shift to be observed in the teacher's pedagogical practice. Arguably, the experienced teachers had over the years developed 'tested and proven' pedagogical practices which had become deeply entrenched in them, and which were possibly easily available even at short notice. Therefore, it is but normal that these teachers should be reluctant to give up their tested teaching strategies for new ones. Applying this to the South African context, it would be expected that teachers should resist abandoning the chalk-and-talk methods which they have been using for so many years and adopting the argumentation-based instructional approach.

The teacher plays a crucial role in the success of argumentation-based instruction (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Fishman et al., 2017; Osborne et al, 2004). The teachers' role in designing argumentation tasks, scaffolding, prompting and questioning puts them at a key position to determine the success or failure of the argumentation experience. During argumentation-based instruction, the teacher is also expected to use many

skills to guide the class so that they do not completely derail from the goal of the lesson. Thus, the teacher has to play the role of a facilitator and guide in the argumentation-based class. The challenge is that if the teacher fails, then the whole argumentation lesson also fails.

2.6.2 Science-IK integration in South African classrooms using argumentation

The use of argumentation-based instructional methods to integrate science and IK in South African classrooms is almost becoming a matter of consensus (Hewson & Ogunniyi, 2011; Nhalevilo & Ogunniyi, 2014a; Ogunniyi, 2007b, 2014; Ramorogo & Ogunniyi, 2010). Ogunniyi (2007a) reports on a study to find out the effectiveness of a Practical Argumentation Course (PAC) designed to enhance the understanding of in-service teachers and their ability to implement a science-IKS curriculum. The results suggested that the PAC enhanced teachers' understanding of NOS and IKS, as well as made them more aware of the need to integrate IK and science. PAC made the teachers to be more sensitive to the socio-cultural and prior knowledge of the learners. In a second part to the same study (Ogunniyi, 2007b), the Practical Argumentation Course was used to equip a cohort of in-service science teachers with the knowledge and skills to enact a science-IK curriculum in their classrooms. The results suggested that the argumentation course enabled the in-service teachers to better understand the NOS and IKS, and also to shift from seeing science and IKS as polar opposites to a position where they could see the possibility of the two complementing each other in the science classroom.

In another study by Ogunniyi and Hewson (2008), nine in-service teachers were subjected to an argumentation-based course for six months with the aim of enhancing their understanding of the NOS and IKS, as well as their ability to implement a science-IK curriculum in their classrooms. Using pre-post assessments of the teachers' understandings, it was found that the argumentation course contributed in making the teachers more willing to accept IKS as legitimate knowledge in the science classroom. Also, as a result of the study, the teachers were better able to distinguish between science and IKS, and to determine the appropriate contexts suitable for either science or IKS.

In the study by Ramorogo and Ogunniyi (2010), the conceptions of nine in-service teachers enrolled in a Master's of Science Education course based on argumentation were sought on some natural phenomena including the rainbow. The results showed that most of the teachers held both science and IK conceptions of the rainbow. The argumentation course

enabled the teachers to better acknowledge IK as valid knowledge, and to become more favourable to its integration with school science.

Still in another study by Hewson and Ogunniyi (2011), nine in-service teachers who had been involved in an argumentation-based project to introduce IK into science classrooms were interviewed. The results showed that the teachers had a good knowledge of IKS and argumentation. Also, the teachers identified several opportunities of using argumentation as a means of introducing IK in science classrooms. They held that argumentation was innovative in generating new ideas, demanded new teaching strategies, and was useful in introducing IK into science classrooms, as well as in improving the teaching of science. More recently, Govender (2014) used an argumentation-based strategy with 85 preservice teachers involved in a science methods course to help them to value IK and to be able to teach an integrated science-IK lesson. The pre-post-test results showed that the argumentation-based strategy helped the students to have more nuanced understanding of IK and to see the need to include it in the science curriculum.

All these studies using argumentation-based strategies to implement a science-IK curriculum are just some examples (among many others), to indicate how argumentation is used as a tool to integrate science and IK in South Africa. However, not every researcher in South Africa is comfortable with the use of argumentation as a tool to implement a science-IK curriculum. Òtúlàjà et al., (2011) raised many critical questions about the use of argumentation as a strategy to integrate science and IK. They identified two contentious issues – 1) the integration of science and IK and 2) using of argumentation as a pedagogical tool. According to them, these contentious issues needed to be resolved before one could talk of using argumentation to integrate science and IK. They suggested that instead of seeking to integrate the two seemingly disparate knowledge corpuses, researchers and teachers should concentrate on knowing the IK, valuing and documenting it, and ensuring its availability and accessibility to those who needed it, just as Western science is. The suggestion is very good, but there are potential challenges in its implementation. For example, before valuing IK as they suggest, science teachers need a paradigm shift because they were schooled in the science worldview which does not see any science in IK (Ogunniyi, 2004; Shizha, 2007). They need some form of process to convince them to make such a shift. That is where dialogical argumentation might play a crucial role.

Martínez (2011) points to two completely different scenarios where the use of argumentation can be good or bad. He suggests that the use of argumentation as a pedagogical tool is good since it can lead to multiple views and knowledge construction. On the other hand, he points to the situation where argumentation is used to validate learners' scientific knowledge as a deficit model that devalues their cultural knowledge while promoting the Western science worldview. Furthermore, he argues that the Western approach to argumentation is not compatible with South African culture; and that argumentation 'sets up' the students as it requires them to argue like scientists - a western concept (p.722). Finally, he proposes that for science teaching to include argumentation, the approach should consist of 'listening carefully' to students (which to him means valuing their cultural, linguistic and learning assets). Similar sentiments were shared by Lambe (2003) who argued that although indigenous pedagogies may include discussion and debate, they hardly took the form of argumentative discourse with rebuttals as is often the case in academic as well as other circles in the western worldview. I share this view with Lambe that the western form of argumentation is not universally applicable and therefore needs to be adapted to suit the African context. This can be done, for example, by including the Contiguity Argumentation Theory (Ogunniyi, 2004, 2007a & b) which a priori gives the two thought systems an equal status, or the *Ubuntu* approach (Scholtz et al., 2008) which focuses on reaching a group consensus.

In the cultures of many indigenous people, the aim of argumentation and discussions is to reach a consensus. This is partly because the collective interest of the community is primordial and takes precedence over individual rebuttals and counter arguments (as is often the case with Western forms of argumentation). Also, the opinion and the individual making the opinion are not easily separable in the indigenous worldview. Consequently, any rebuttal has to be considered carefully so as not to hurt the feelings of the person who advanced the argument. In certain situations, rebuttals may even be construed as culturally inappropriate, especially when an individual is talking to or referring to an elderly person. In many cases, the problem of how to put forward a rebuttal without appearing to be disrespectful becomes more important than registering the rebuttal itself. For these reasons, some authors have proposed different forms of argumentation in the South African context. An example is the *Ubuntu* form of argumentation (Scholtz et al., 2008). Another example that has also been proposed is for the Contiguity Argumentation Theory (Ogunniyi, 2004, 2007a & b) to supplement Toulmin's theory in order to make argumentation more amenable to the South African context.

2.7 SIKSP as a Professional Development (PD) Initiative

The SIKSP was a project whose very existence was the result of teachers' search for adequate training to enable them implement the new science-IK curriculum policy in South African classrooms. Since the training received by the teachers never included IK, let alone IK in science classrooms, these teachers had to learn completely new knowledge in the project. Hence, its activities were consistent with the needs of the in-service teachers and those of the new government policy. There were workshops and other activities that often included practical sessions where the teachers could interact and collaboratively arrive at conclusions. Postdoctoral fellows and other experienced science education experts were available to assist the in-service teachers throughout the two or more years spent for the master's programme or longer periods for the doctoral programmes. However, one might ask whether what went on at SIKSP was in line with good PD initiatives. To answer this, it might be important to briefly look at some characteristics of an effective PD initiative.

2.8 Characteristics of Effective Professional Development

Some researchers have defined effective professional development (PD) as structured professional learning by in-service teachers that results in their change of attitudes, knowledge and practices, and also a change in learner outcomes (Darling-Hammond et al, 2017). Borko (2004) identifies four key components of a professional development system: The professional development programme, the in-service teachers (who are the learners in the system), the facilitators (who guide the in-service teachers as they construct new knowledge and practices), and the context in which the professional development occurs. Relating this to the SIKSP, the in-service teachers were the learners while the facilitators and lecturers guided the in-service teachers in the context of integrating science and IK. The result of the PD is the product of the interaction between these elements, that is, the staff, the facilitators, the in-service teachers and the university environment.

The question is: what makes a PD initiative effective? Birman, Desimone, Porter, and Garet, (2000) undertook a survey of over 1000 mathematics and science teachers in the US to find out the factors that influenced effective professional development. The authors identified six factors of effective PD. These are: 1) the form of the PD, 2) the duration of the PD activities, 3) the type of participation by teachers, 4) the degree of active learning by teachers during the PD activities, 5) the extent to which the PD activities focus on content knowledge, and 6)

coherence between the PD activities, teachers' individual needs, and policy requirements. The study found that reform-focused instructional practices over longer periods were more effective than brief, once-off workshops or conferences. The study also concluded that collective participation involving groups of teachers from same school or district were more effective than situations where each teacher got involved in PD on an individual basis. The authors were of the view that reform activities were more effective because they were longer, and thus had a focus that involved greater amounts of content, active learning opportunities and coherence. However, the study also concluded that when traditional methods of PD (such as workshops and conferences) are longer, they are equally effective.

In a seminal study that still took place in the US, Garet, Porter, Desimone, Birman, and Yoon (2001) studied the effectiveness of PD on teacher outcomes using data from a Teacher Activity Survey conducted to evaluate the Eisenhower Professional Development Programme. This was a large-scale study involving over a thousand mathematics and science teachers in the United States, with the aim of making an empirical comparison of how different characteristics of professional development affected teachers' learning. The results suggest that three structural features set the context for effective teacher learning: a) form of activity, b) group participation of teachers according to same school, grade, or subject and c) duration of the activity. In addition, three core features of PD activities could positively influence professional learning. These include: 1) a focus on content knowledge 2) the inclusion of active learning, and 3) coherence of professional learning activities with other activities, and policies.

A decade after the previous studies mentioned above, Hunzicker (2010) provided a checklist of characteristics of effective PD. According to the checklist, effective professional development is supportive, job-embedded, ongoing, collaborative, and content-focused. Similar studies have been carried out by other researchers (Darling-Hammond et al., 2017; Desimone, 2011; Hennessy et al., 2018; Lauer et al., 2014). According to Desimone (2011), effective professional development should involve 1) Content focus: Where the activities focus on subject matter content and how students learn that content. 2) Active learning: Where teachers have opportunities to get involved in practical, collaborative, inquiry-type activities, such making observations, giving and receiving feedback, analysing student work, and making group or individual presentations. 3) Coherence: What teachers learn in any professional development activities should be consistent with their professional knowledge and beliefs, as well as the existing educational policies. 4) Duration: Professional development activities

should include at least 20 hours of contact time, and should be spread over a semester or longer. And 5) Collective participation: Teachers should get in professional activities in groups that have a common goal and relationship in order to easily form interactive learning communities after the professional development activities.

One study that has had an entirely different outcome for the characteristics of effective professional development is that of Guskey (2003). In this study, Guskey analysed 13 lists containing characteristics of effective professional development. The results showed that there was a wide difference in the frequency and type of individual characteristics included in the lists. No characteristic was consistently included in all the lists, and the research evidence supporting each included characteristic was inconsistent.

Apart from Guskey (2003)'s study, there seems to be a quasi-consensus by most researchers about some characteristics that are indicative of effective PD (Bayar, 2014; Desimone, 2009, 2011; Kraft & Papay, 2014; Mansour et al., 2014; K. Patton et al., 2015; Rogers et al., 2007). A close examination of these studies suggests that profession development initiatives with the potential of being effective are those which focus on content, involve the in-service teachers in active learning experiences, encourage collaboration among the trainees, make use of models and modelling, engage mentors and expert support, involve feedback and reflection on practice, take place for a sustained duration, and ensure coherence of the PD activities with teachers' needs, the curriculum and prevalent policies (Darling-Hammond et al., 2017; Desimone, 2011; Garet et al., 2001; Guskey, 2002; Ingvarson et al., 2005).

In the case of the SIKSP, there was a focus on the content of the NOS and IKS, something not common in normal science classrooms. The in-service teachers were involved in active learning experiences during the workshops and IKS materials development sessions. Collaboration between the in-service teachers was encouraged, and did take place, among the members teaching at similar levels. Also, SIKSP used models of lesson plans and the teaching approach (DAIM) to help teachers. The training took place over a long period of time during which the in-service teachers studied for higher degrees. The in-service teachers were also met with experts of science education and IKS through the international IKS workshops and conferences, while the post-doctoral fellows acted as mentors to guide the trainees. These activities suggest that SIKSP provided a suitable environment for professional development.

2.9 Evaluation of Educational Programmes and Projects

2.9.1 What is evaluation?

The concept of evaluation is rather illusive and not easy to define. This difficulty arises because different evaluators view it from slightly different perspectives depending on their backgrounds (Rossi et al., 2004). Although all the definitions have in common the systematic use of social research methods to effect evaluation, some definitions stress some aspects of social interventions more than the others. For example, Rossi et al. (2004) define programme evaluation as 'the use of social research methods to systematically investigate the effectiveness of social intervention programs in ways that are adapted to their political and organizational environments and are designed to inform social action in ways that improve social conditions' (p. 29). This definition emphasises the point that the context of an intervention plays an important role in the process and product of an evaluation.

In contrast to the above definition, Patton's (2008) definition of evaluation stresses on the use of evaluation results. Some of the most common definitions of evaluation stress the need of assessing the worth of an educational object. For example, Stufflebeam (2001) defines evaluation as "a study designed and conducted to assist some audience to assess an object's merit and worth." (p.9); while McMillan and Schumacher (2006) define it as "the application of research skills to determine the value and worth of an educational practice" (p. 439). In order to match the evaluation model or framework used for this evaluation study, I will use the definition of Stufflebeam (2003):

> *Evaluation is the process of delineating, obtaining, providing, and applying descriptive and judgmental information about the merit and worth of some object's goals, design, implementation, and outcomes to guide improvement decision, provide accountability reports, inform institutionalization/dissemination decisions, and improve understanding of the involved phenomena* (p.34).

The above definition suggests that the act of evaluation involves the assessment of the goals, design, implementation process, as well as the outcomes. This provides the types of evaluation foci of Context, Input, Process and Product in the evaluation framework. The definition also points to the fact that evaluation should include both formative assessment for improvement and summative assessment for accountability purposes. Also, the definition

expects the evaluator to collect both descriptive and judgmental information, suggesting that the evaluator should make use of both qualitative and quantitative data.

Another definition of evaluation which I find very useful is given by Lincoln, Lynham and Guba (2013) who posit that:

> *Evaluation is a form of inquiry whose focus is some evaluand (the program, process, organization, person, and so forth being evaluated) and which is aimed at the development of "merit" and/or "worth" constructions (value judgments) about that evaluand.* (Lincoln & Guba, 2013, p. 61).

In this study, I conceptualised evaluation in the light of the definitions provided Stufflebeam (2003) as well as Lincoln et al. (2013).

2.9.2 What educational objects can be evaluated?

A wide range of educational objects or "evaluands" (Scriven) can be evaluated. Educational evaluation objects include students, teachers, programmes, projects, educational materials, equipment, and so on. In educational evaluation literature, programme evaluations are more common than project evaluations such as the SIKSP. Although a project is generally considered smaller in scope than a programme, the methods of evaluating both have much in common. According to the International Labour Organisation,

> *Project evaluation is a systematic and objective assessment of an ongoing or completed project. The aim is to determine the relevance and level of achievement of project objectives, development effectiveness, efficiency, impact and sustainability. Evaluations also feed lessons learned into the decision-making process of the project stakeholders, including donors and national partners*. (ILO Technical Cooperation Manual – Version 1, p.3)

If one looks at this definition, one can see similarities with the definitions of programme evaluations cited earlier. Although there may be some differences, the CIPP evaluation model is a good model to use to carry out an evaluation of a project such as the SIKSP because it has been used successfully in a wide variety of contexts.

2.9.3 Types of evaluation

Educational evaluation is broadly classified as formative or summative. Formative evaluation carried out when the project or programme is still in progress, with the aim of improving the programme effectiveness. During formative assessment, one asks the questions:

What is working well, and what is not working well? The answers to these questions enable some parts of the programme to be maintained while changing others in order to improve on the quality of the products. On the other hand, summative assessment occurs at the end of the programme or project. It seeks to answer the question: Did the programme or project work? The evaluation of the SIKSP falls under the latter category.

2.9.4 Why evaluation?

Evaluation of educational programmes and project such as the SIKSP is carried out for several reasons. Most educational interventions come into existence as a result of some political decision to address a perceived need by a target population. Since the sponsors of such programmes have many alternative needs vying for the same funding, they would like to know if the money spent is worth the cost; if not they would better spend it on other projects. Rossi *et al.* (2004) believe that the purpose of evaluation is to 'distinguish worthwhile programs from ineffective ones, to launch new programs or to modify existing ones so that they become more profitable' (p.29). In the case of the SIKSP, the evaluation would provide useful information to stakeholders to be able to make informed judgments about its achievements, successes, as well as identify and correct its weaknesses.

2.9.5 Evaluation approaches.

An evaluation approach is a strategy that guides the evaluation activities so that credible data can be obtained and a useful report made (McMillan & Schumacher, 2006). Since evaluation practitioners are drawn from a wide range of academic disciplines and professions, with different orientations and methods (Rossi et al., 2004) there are bound to have many divergent views. The divergence may be so significant that a reconciliation of all views would be such a daunting task. For example, Zhang et al. (2011) estimates that there are 26 approaches often used in educational evaluation. These approaches, according to them, fall into five groups – pseudo-evaluations, quasi-evaluation studies, improvement- and accountability-oriented evaluation, social agenda and advocacy, and eclectic evaluation.

On the other hand, Eseryel (2002) identifies six approaches – professional review, quasi-legal, goal-based, goal-free, responsive, and systems evaluations. Stufflebeam (2001) on his part identifies 22 evaluation approaches, two of which are pseudo-evaluations. Greene (1992) identifies four prominent approaches to evaluation, which are underpinned by different

philosophical traditions. A similar view to that of Greene was suggested very vividly by Alkin and Christie (2004) who classified evaluations into three types – those that emphasized use, those that emphasized methods and those that emphasized values. To these three, a fourth type – social justice – was recently proposed (see Mertens & Wilson, 2019). I view evaluation in the light of these latter group of evaluators – along philosophical foundations.

Evaluation research is influenced by a number of underlying philosophies – positivism, interpretivism, critical theory, and pragmatism (Babbie & Mouton, 2001; Denzin, 2012). The positivist approaches to evaluation view experimental, scientific designs as the most authentic ways of doing evaluations. In order to fulfil the tenet of objectivity, impartiality, accuracy, and the validity of the information generated, they usually place an emphasis on randomized or quasi-experimental designs, and quantitative methods of data analysis. These approaches are most popular in the sciences, agricultural, and the medical fields. However, critics of such approaches argue against randomization, which works for objects that can be manipulated in controlled experiments. They argue that the evaluation of social intervention programmes such as that of the SIKSP would need other approaches, which take into consideration the fact that human subjects are intentional beings and can behave differently under different conditions.

The second approach to evaluation is that from the interpretivist, phenomelogical tradition (Babbie & Mouton, 2001) which prefers qualitative or phenomenological designs. These approaches to evaluation emphasize the importance of naturalistic observation and the value of subjective human action, reaction and interpretation in the evaluation process. The third approach follows the critical tradition and places an emphasis on the involvement of the target groups or participants in the evaluation process. The fourth approach is based on pragmatism, and uses both experimental and non-experimental designs as well as qualitative and quantitative methods to complement each other. However, the methods adopted depend on the nature of the study.

The use of both quantitative and qualitative methods has gained increased popularity in recent years. Although more demanding to the researcher, mixed methods have a great advantage in that the qualitative analysis adds flesh to the quantitative results, rendering the outcome more holistic or complete. Because of these advantages, this study adopted the interpretivist-pragmatic approach of mixed methods. While quantitative methods can form a skeleton for the research, the qualitative methods are more useful in providing rich details that add flesh and meaning to the quantitative data.

2.9.6 Evaluation standards.

The Joint Committee on evaluation (Stufflebeam, 2003; Stufflebeam & Coryn, 2014) has published a set of basic principles or standards meant to guide evaluations in educational settings. The document contains 30 standards that were formerly grouped into four basic principles to guide any sound evaluation in education. These four basic principles are utility, propriety, feasibility, and accuracy. In 2011, a fifth attribute – *evaluation accountability* was added (Stufflebeam & Coryn, 2014). It is appropriate for every evaluator in an educational project such as the SIKSP to adhere to the set standards. Adherence to the standards is a means of ensuring quality in educational evaluation.

As Stufflebeam and Coryn (2014) explain, the *utility* attribute requires that evaluations should be responsive to the needs of the different stakeholders involved in the project, and provide information that they would use within a reasonable period. The *feasibility* attribute demands that the evaluation be realistic, diplomatic, frugal, and achievable in a real-world setting, within the available time and budgetary constraints. The *propriety* standard requires that evaluations should follow ethical and legal norms, that the rights of stakeholders are respected and that the evaluation report is done in such a way as to provide a balanced account of strengths and weaknesses. The standard of *accuracy*, as they explain, requires the information provided by the evaluator be valid and trustworthy. This means that the instruments of data collection, as well as the procedures of analysis, should minimise personal bias. The recently added standard of *evaluation accountability* requires that the evaluator should do an internal evaluation to make sure that the evaluation meets the standards, document and keep all information about the evaluation, and to make this available for a meta-evaluation by an external evaluator when needed. While these standards provide implicit criteria to guide the evaluator, there are different models or approaches that have been followed in designing and carrying out evaluations.

2.9.7 Some evaluation models.

There are several models of evaluation which have been used in educational programmes and projects.

2.9.7.1 Tyler's model *(Tyler, 2002)*

One of the most influential figures in educational evaluation is Ralph Tyler. Coming up at the time when behaviourism was gaining popularity, his method was used for several decades in evaluating educational objects. Tyler's approach to programme evaluation followed behaviourist objectives-based accomplishments. The programme objectives were clearly determined and stated at the start of the programme, and the evaluation done by comparing the programme outcomes with the set programme objectives to see how many of the intended objectives had been attained in practice. Tyler's model comprises four parts which are the answers to four questions:

> 1)What education purpose should the school seek to attain? 2)What educational experiences can be provided that are likely to attain these purposes? 3) How can these educational experiences be effectively organized? And 4) How can we determine whether these purposes are being attained? (p.93).

In line with the above questions, the curriculum engages in:

1) defining objectives of the learning experience; 2) identifying learning activities aimed at meeting the defined objectives; 3) organizing the learning activities to meet the defined objectives; and 4) evaluating and assessing the learning outcomes.

Tyler's method of determining the objectives involved decisions of students, the society and subject matter. The students were required to define objectives that they thought relevant to their own needs. Although Tyler's model has been widely used in curriculum development and evaluation it had some fundamental weaknesses. Selecting behavioural objectives is complex, and it is difficult for the stakeholders to arrive at a consensus. Focusing on the product and objectives alone is too narrow and this method may miss important unintended outputs. The conclusion, with respect to this study, is that although the model is suited for curriculum evaluation, it does not take into account the context and processes which could have a great effect on the outcomes of the study. So the model cannot be used to attain the goals of this study.

2.9.7.2 Kirkpatrick's four level model *(Frye & Hemmer, 2012)*.

According to Frye and Hemmer (2012), Kirkpatrick's four level model has been widely used to evaluate training programmes. The evaluation model is based on four levels – *reaction,*

learning, behaviour and *results. Reaction* refers to the reaction of the trainees or workshop participants towards the training they have received. This mostly involves affective decisions about the training programme and may seek to know the trainees' feeling about the way the programme was carried out. *Learning* involves the degree to which the participants perceive that their knowledge or skills have increased as a result of the training. *Behaviour* focusses on the extent to which the performance of the trainees has changed as a result of the training received. In other words, behaviour is the evaluation of the degree to which the practice has actually changed as a result of the training received. Evaluation at the *results* level focuses on the overall impact that occurs in the organisation as a result of the training programme. This might involve the evaluation of the level of improvement in production, the increase in overall test scores, and so forth.

Kirkpatrick's model is widely used because it is easy to obtain participants' opinions of a programme or workshop just as it terminates; and their learning, especially when the interval between the training and the evaluation is small. However, the shortcomings associated with the model are that most evaluations are done at levels 1 and 2, which can be fine in the case of brief professional development initiatives as workshops which take place for a few days or weeks. But the SIKSP is a project that spanned ten years, so this model would not be very suitable. Also, the context, which plays a very important role in determining the outcomes of an evaluation, is left out in this model.

2.9.7.3 The Discrepancy Model (Steinmetz, 2002).

Stufflebeam and colleagues explain that in this model, evaluation begins with the setting up of objectives and a set of standards (S) which are the goals expected to be achieved. The next step is to make observations to determine the way the programme was practically implemented, and recording the actual performance. A comparison is then made between standards and the actual performance, to determine the difference discrepancy between set standards and the performance. After identifying the discrepancy, corrective measures are then taken to close the gap between the intended and achieved objectives.

This model is useful as a self-evaluation framework and a systematic approach to programme improvement. It is easy to see if the programme objectives have been attained or not, and remedial measures adopted to make the programme more efficient. However, setting baseline standards may be a formidable task in some cases, and in others, just impossible.

Moreover, the approach can be very limiting as it may not be possible to predict all outcomes of a programme, since there can be unintended outcomes.

2.9.7.4 The Explication model *(Koppelman, 1979)*

This model of evaluation employs an ethnographic, systematic observation to reduce the evaluator's observation bias. In this technique, the ethnographer establishes guidelines for doing observations that can be followed by other trained observers to obtain more objective data. Data gathering involves the teacher, students, evaluation coordinators. Conclusions are reached after discussions and understanding with teachers and administrators.

This approach to programme evaluation has the advantage that it is non-threatening since it is non-judgmental, but seeks to explain what is going on. In addition, the teacher is involved in the process from the beginning. Although the approach best suits monitoring and process evaluation, teachers may feel uncomfortable when their learners have to evaluate their teaching. This approach is not suitable for evaluating a project that has terminated as the SIKSP.

2.9.7.5 Goal-free evaluation *(Scriven, 1991)*.

Scriven is unique in taking a stance against basing evaluations on pre-determined goals. In his view, the evaluator should proceed in the process of making objective value judgements of the programme or any object and finally coming to a definite conclusion as to whether the programme is good or bad. The evaluator is expected to establish a list of potential causes to observed effects, and keeps on refining the list and eliminating all sources of evaluator bias. Scriven argues that by choosing to examine all outcomes in the absence of a priori objectives, the evaluator is in a better position to capture all the accomplishments of the programme without bias. Merit is determined not by comparing the programme accomplishments to programme goals, but to the expressed needs of programme stakeholders.

I agree with this model to an extent, if it is used as a supplement to other types of evaluation. The model when used in this way can become a valuable tool of uncovering intended as well as unintended programme outcomes. However, it is more suitable for use by external evaluators who have no knowledge of the programme's goals and objectives. Hence it is not a suitable model for this study.

2.9.7.6 Responsive evaluation *(Stake, 2002)*.

Robert Stake's (2002) approach to evaluation, known as *responsive evaluation*, focuses on the needs of the beneficiaries rather than on the achievement of pre-conceived objectives. According to him, the evaluator must keep communicating informally with the programme beneficiaries to assess their needs (which are assumed to be changing with time), and then plans the evaluation accordingly. The evaluator also uses a variety of sources to collect data. According to Stake (2002), an educationally responsive evaluation would focus more on the programme activities than on the objectives. It would also focus on the needs of participants, and seek to obtain evaluation information from them. There is no formal evaluation plan, but the themes come up as the evaluator focuses on the data to inductively discover patterns. Thus, responsive evaluation focuses on observations as the programme unfolds. Also, judgement of the programme is obtained from the participants rather than the evaluator.

Stake's model has the advantage that there is a higher chance of utilization of evaluation results as they would be more relevant to the programme participants. However, the approach may not be suitable for a retrospective evaluation with a priori defined objectives by which the success or failure had to be measured in order for the funders to continue spending tax payers' money. I agree with Stake's strategy of obtaining the necessary information for decision – making from the participants, and will make much use of it. However, the model as a whole would not meet the purpose of this study.

2.9.7.7 The Context, Input, Process, Product (CIPP) model (Stufflebeam, 2003a).

Stufflebeam's Context, Input, Process and Product (CIPP) model came into existence in the mid-1960s as a result of dissatisfaction with the existing evaluation approaches in use at the time. Stufflebeam argued that the purpose of evaluation as a means to determine whether or not the programme objectives were attained was too narrow and not so useful. In his view, evaluations ought to have broader scope and proactively help the managers take decisions that would lead to the improvement of such programmes. In his view, the main aim of evaluations was *to improve and not to prove*. Stufflebeam (2003a) saw evaluation from the perspective of the role it served in decision-making within a system of planned social change. The model was designed to carry out evaluations in real life conditions by proactively enabling and guiding comprehensive, systematic, informed decisions that could lead to improvement or accountability in the dynamic conditions of an unpredictable world.

Some of the advantages of the model are that: 1) It is can be used for formative evaluation to guide improvement decisions as well as summative evaluations for accountability purposes. 2) It is a holistic model, including improvement and accountability decision-making options. 3) The fundamental philosophy of the CIPP model that the main aim of an evaluation is 'to improve, not to prove' somehow attenuates the feeling by managers who may see evaluations as scary judgement that could result in sanctioning them for not performing well enough. 4) It is extremely flexible and can be used in conjunction with other models and methods. 5) It is stakeholder-centric, that is, it gives much room to the voice of stakeholders or project participants (McLemore, 2009; Sopha & Nanni, 2019; Zhang et al., 2011).

Critics of the CIPP model hold that it focuses more on the management. They argue that CIPP places too much power in the hands of managers; linking the evaluator to the manager and decision-makers and not to all stakeholders. Others hold that it has a rather idealistic view of the evaluation processes; ignoring the practical reality that evaluations are usually messy and could be time-consuming and costly.

As a way of avoiding a top-down approach to decision-making, the CIPP model makes room for consultation and opinion of all stakeholders. This means that the final decisions are arrived at by an audience of stakeholders rather than a single decision-maker. However, it is argued that achieving this goal with a wide range of stakeholders is difficult. Some of the reports obtained from stakeholders may not be useful for decision-making due to the way they were produced. For example, they may lack clarity or have contradictory conclusions (McLemore, 2009; Sopha & Nanni, 2019; Zhang et al., 2011). The model is supposed to be a decision-making model which makes use of the evaluation findings to take decisions aimed at improving the project or entity being evaluated. However, critics argue that decision-making in projects and organisations could be a complex issue. Decisions, they argue, could become very complex when they involve political or economic interests of people in power.

Despite all these drawbacks, the CIPP model still has many advantages over other alternatives. For this study, it had the greatest potential of helping me achieve the overall purpose of the evaluation; especially when used in conjunction with the constructivist model of Guba and Lincoln (1989).

2.9.7.8 Why I chose to use the CIPP – Constructivist hybridised model

There is no ideal evaluation model to use for all evaluation studies because every model has its strengths and weaknesses. Guerra-López and Thomas (2011) have given some important

guidelines for making decisions on the framework to use when doing evaluations. They suggest that before choosing an evaluation model to use, the evaluator should consider the evaluation task, the goals of the evaluation and the extent to which the evaluation model fits with the situation at hand. In this case, I considered the characteristics of the SIKSP, what I wanted to achieve in the evaluation, and was convinced that the CIPP model was going to be most useful. I chose to use the CIPP model because of its holistic approach, its philosophy of aiming to improve rather than to prove, and above all, its strong recommendation to involve the stakeholders in all steps of the evaluation and decision-making processes. The four components of the CIPP model made me get a structure to guide the study. However, I still needed to bring in the mechanism of getting the opinions of the participants through a constructivist approach of consensus-building. That is where I saw the constructivist evaluation model of Guba and Lincoln (1989) most suitable. So, I used a hybrid of the CIPP and the Constructivist evaluation models to cover what I wanted to get out of the evaluation study.

2.9.8 Evaluation criteria.

A number of criteria have been identified as crucial for every evaluation activity of projects and programmes. These include relevance, effectiveness, efficiency, sustainability and impact (Faúndez & Weinstein, 2014). In this study, I will limit myself to the evaluation of relevance, effectiveness and impact of the SIKSP.

2.9.8.1 Relevance of educational interventions.

Relevance refers to the extent to which an intervention's design and objectives are responsive to the needs of the beneficiaries (Kahan, 2008; OECD-DAC, 2002; Samset & Christensen, 2017). In the case of the SIKSP, relevance could be assessed by answering the question: To what extent did the courses, activities, and processes at SIKSP enable the in-service teachers to achieve their goals of integrating science and IKS? If the design and activities of a project did not meet the needs of the targeted beneficiaries, then the project was not useful to them. When evaluating a project therefore, it is necessary to give a chance for the project beneficiaries to assess whether the project's services were consistent with their needs.

In a more practical sense, Woolley, Rose, Orthner, Akos, and Jones-Sanpei (2013) offer a definition of relevance of educational objects from the perspective of the intended users. They view relevance as the extent to which the programme beneficiaries, such as students or in-

service teachers, perceive the course content to be meaningful and useful to solving practical problems in a real world; or the way they perceive it as having potentially useful applications in their lives in the future. In the context of the SIKSP, relevance was evaluated from the way the project beneficiaries, namely, the in-service teachers and postdoctoral fellows involved in the project, perceived the project as useful to their professional development and to the improvement of their pedagogic repertoires.

2.9.8.2 Effectiveness of educational interventions

Effectiveness refers to the degree to which the intended objectives are attained as a result of the intervention (Kahan, 2008; OECD-DAC, 2002). The question to answer is the following: To what extent did the intervention contribute to the achievement of the intended objectives? Determining the effectiveness of a project is thus very important because it can help policy makers and other decision-makers to abandon ineffective projects or continue with effective ones. However, it is not so easy to determine whether the attainment of intended objectives was solely due to the intervention alone (OECD-DAC, 2002; Samset & Christensen, 2017). In many interventions, such as the SIKSP, there are no control groups, and one cannot use experimental designs. The effectiveness of such projects is often determined from its design and implementation, as well as from the value judgements of the project beneficiaries and other stakeholders using case study designs.

2.9.8.3 Efficiency of educational interventions.

Efficiency is concerned with the degree to which an intervention is economical (Samset & Christensen, 2017). An efficient programme or project is one that uses the least quantity of resources to produce maximum results; other factors being constant. In other words, an efficient programme or project is one that is cost-effective.

2.9.8.4 Impact of educational interventions.

The impact of an intervention is much broader than effectiveness. It is a measure of all significant effects of the intervention on its beneficiaries and other stakeholders. Impact refers to the long-term effects of a programme or project. These may be positive or negative, direct (primary) or indirect (secondary), foreseen or unforeseen (Faúndez & Weinstein, 2014). To know if a programme has a high impact, one needs to answer questions such as the following:

Has the programme left lasting footprints in the lives of individuals or a group? It is much more difficult to estimate the impact of an intervention because there are too many variables involved. Even when there are positive outcomes that align with the project objectives, it is often difficult to attribute such positive gains to the intervention alone.

2.9.8.5 Sustainability of educational interventions

Sustainability refers to the continuation of the programme or project benefits after it has come to an end (Faúndez & Weinstein, 2014). It refers to the extent to which the programme activities and outcomes can be achieved without any further need of funding. Unlike the four preceding criteria which concern specific aspects of an intervention, sustainability is concerned with the life of the project itself – the probability that the project continues to exist long after funding had stopped. Sustainability is thus more difficult to achieve than the other criteria. Sustainability of instructional practices is greater if the beneficiaries of a professional development initiative are empowered enough to continue running with the vision after the project has ended (King, 2014). In the case of the SIKSP, funding ended in 2013. Since then, many in-service science teachers have continued to receive training in implementing a science-IKS curriculum. Also, research has continued in this domain. So, one might guess that there seems to be a measure of sustainability.

2.10 Conceptual Framework Used for the Evaluation

A conceptual framework is an important tool used to guide and direct the researcher towards the accomplishment of the research objectives. It may be made of more than one theory as the researcher sees fit. In this study, I first adopted the CIPP model of evaluation which is a systems model. However, I noticed that the CIPP model alone could not accomplish the evaluation as I intended, so I supplemented it with constructivist notions of evaluation from Guba and Lincoln's (1989) *Fourth Generation Evaluation*. In order to fully realise the constructivist notions inherent in the fourth-generation evaluation, I built reflectivity into the design.

2.10.1 The CIPP evaluation model.

According to (Stufflebeam, 1983), a full implementation of the CIPP model would provide information that can be used to answer questions such as the following:

1. What needs were addressed, how pervasive and important were they, and to what extent were the project's objectives reflective of assessed needs?

2. What procedural and budgeting plan was adopted to address the needs, what alternatives were considered, why was it chosen over them, and to what extent was it a reasonable, potentially successful, and cost-effective response to the assessed needs?

3. To what extent was the project plan implemented, and how and for what reasons did it have to be modified?

4. What results (positive and negative as well as intended and unintended) were observed? How did the various stakeholders judge the worth and merit of the outcomes, and to what extent were the needs of the target population met? (p.124).

The above questions typically address the various components of the CIPP framework. The first question addresses the context, the second addresses the input; the third the process, and the fourth the product evaluation. As mentioned earlier, the CIPP framework has been found to be very useful in carrying out formative evaluations, but also for carrying out summative evaluations. When the CIPP framework is used for accountability purposes or summative evaluations, the context evaluation provides information about the objectives and reasons for their choice as well as a needs assessment. The input evaluation provides information on the chosen strategies and design, as well as the the justification for such preferences over possible alternatives.

According to Stufflebeam (1983) if evaluation information is recorded and made available for public review, it would enable the public to judge whether decisions taken to end or implement a project were based on valid reasons. However 'while the CIPP model makes no special provision for formulating and testing hypostheses, it does, through its provision for context, input, and process information, provide a rich array of background data against which to interpret and understand outcomes' (p.128). In order to have a fuller understanding of the CIPP framework, I will attempt to explain its different facets – context, input, process and product evaluations- in the light of what the author of the model meant.

In the context of the present study, the CIPP model can be represented as in Fig. 2.1. Context evaluation assesses the needs of the participants, input evaluation assesses the design

of the programme theory that was designed to have an effect on the participants when applied. The process evaluation phase assesses the rolling out of the designed activities; whether they were carried out as planned and whether or not changes were made along the way. Product evaluation assesses the results of all that took place as a result of the workshops, seminars, lectures, etc. in the process evaluation stage. It also assesses any unintended outcomes such as the AASIKS and the South Africa- Mozambique joint IKS project that came up during the project.

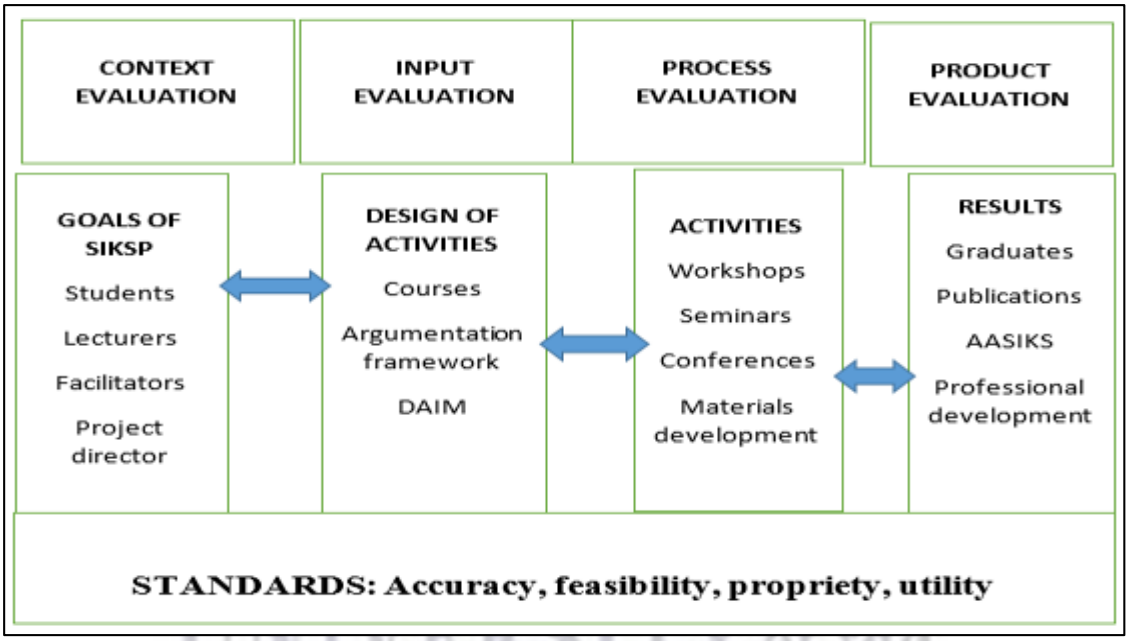

Fig. 2.1 The CIPP Evaluaton model (Stufflebeam, 2003) as applied to SIKSP

2.10.1.1 Context evaluation

The context evaluation is predominantly a needs assessment. According to Stufflebeam (2003), the main objectives of a context evaluation are to determine the needs and problems whose solutions would lead to the project's improvement, to identify the strengths and weaknesses of the project, and to assess the project's overall status. A context evaluation also examines whether the set goals and priorities are sufficiently responsive to the needs of the project beneficiaries (Stufflebeam & Coryn, 2014). Context evaluation provides information necessary for the readjustment of the project goals and priorities in order to meet stakeholder

needs in the case of ongoing projects. It also provides a basis for judging the project or programme outcomes.

Several methods have been used to carry out a context evaluation, employing a variety of instruments and methods of data analysis. According to Stufflebeam and Coryn (2014), some of the most common methods used to evaluate context include interviews of beneficiaries (to get their perceptions of the strengths, weaknesses and problems encountered) and to generate hypotheses. The evaluator can also examine existing project records to identify performance patterns and background information, use expert review panels and workshops to review and apply findings, and concensus-building techniques such as the Delphi technique to reach a concensus. While the methods are useful, it is also important to know the uses of the context evaluation.

Context evaluation is the means by which an institution or a project communicates with its public in order to have a shared understanding of its strengths and weaknesses, needs and opportunities, as well as priorities (Stufflebeam, 2003; Stufflebeam & Coryn, 2014). Context evaluation might be used to formulate objectives for improvements or curriculum revision, and to determine where an educational intervention is most needful in a geographical location such as a school district. It can also be used to help students and parents to re-direct their focus and efforts in certain priority areas and to aid in informed decision-making in order to make educational programmes more effective. Also, context evaluation is a means by which to evaluate the output of an intervention. The records of a context evaluation are excellent means of justification of an evaluator's goals and priorities. However, context evaluation is only part of the whole process of carrying out an educational evaluation. We also need to do an input evaluation.

2.10.1.2 Input evaluation.

Input evaluations involve the overall design chosen to accomplish the goals set during the context evaluation. They involve decisions about the means required to reach a given set of goals, or a given number of identified needs. These decisions may include those dealing with staffing, budgets, procedures and project plans, as well as the choice of one plan over other alternatives. According to Stufflebeam (2003), the main objective of an input evaluation is to prescribe a programme which would help to bring about the needed changes in an intervention most effectively and at a minimal cost. In the view of Rossi et al. (2004), input evaluation

involves what they refer to as programme design or programme theory. This is the hypothesised mechanism whose implementation would result in the solution of the identified problem that the project is intended to solve. In the case of the SIKSP, the program theory would be the DAIM instructional strategy, which in turn, is underpinned by the two argumentation theories (Toulmin Argumentation Pattern [TAP], and Ogunniyi's Contigity Argumentation Theory [CAT]). The effective application of this framework, according to the designers of the SIKSP, is supposed to enable teachers to be able to integrate science and IK in their classrooms.

According to Stufflebeam (2003), the methodology for carrying out an input evaluation depends on the state of the situation at hand. It may involve reviewing the literature , visiting exemplary programmes, doing a document review, a content analysis or using a checklist. The information gathered from these sources could then be used to make informed decisions about a possible solution to the identified problem, making a prediction of potential effectiveness and feasibility of the proposed method. A visit to a similar project helps the evaluators to make a realistic appraisal of the potential resources and barriers that may be involved, and to figure out a way of overcoming the obstacles. According to Stufflebeam (2003), an evaluator can use the advocacy team technique in which two groups of experts make claims and counter-claims about alternative strategies (with justifications) to convince a panel of experts in order to arrive at the best design. The main use of an input evaluation is in preparing project proposals to be presented to funding agencies. The records of an input evaluation can also be used to justify the choice of one procedure over other alternatives, and as a basis for judging the project implementation (Stufflebeam, 2003; Stufflebeam & Coryn, 2014).

2.10.1. 3 Process evaluation

A process evaluation is an ongoing monitoring of the implementation of an educational programme or project. In process evaluation, one may ask questions such as the following: Is the project being carried out as planned? Does any of the project components need any modification to make it more effective? According to Stufflebeam (2003), one of the main aims of a process evaluation is to provide feedback to programme and project managers about the extent to which an educational intervention is being carried out as planned–whether programme activities are being implemented on schedule, whether available resources are being used efficiently, and so on. Process evaluation provides a means of guiding and modifying the project's functioning, and also provides periodic assessment of how programme or project

participants accept and are able to carry on their roles. A process evaluation, according to Stufflebeam and Coryn, also provides a detailed record of the programme as implemented and how it compares with what was intended during the planning stage, the costs incurred in implementing the programme, and how the various stakeholders judge the quality of the programme as a whole (Stufflebeam, 2003; Stufflebeam & Coryn, 2014) .

In order to carry on a sound process evaluation, a process evaluator or team is needed to monitor how the programme is evolving. The process evaluator reviews the processes, project documents, and provides feedback on a regular basis. The process evaluator or monitoring team may achieve their obligation by carrying out unobtrusive observations, getting an overview of the programme operations by visiting and observing programme activities, studying programme documents, attending staff meetings, interviewing key participants, and so forth. According to Stufflebeam, the process evaluator should constantly reassure the project managers and staff that the main purpose of the process evaluation is to assist the staff to carry on their project. Through constant feedback and discussions between the process evaluator and the project staff, the original design can be modified where necessary in order to make the project more effective.

According to Stufflebeam (1983), 'the main use of process evaluation is to obtain feedback that can aid staff to carry out a program as it was planned, or, if the plan is found to be seriously flawed, to modify it as needed" p.133. Managers use process evaluation feedback sessions as a means of keeping their staff to be duty-conscious and informed about the functioning of the project. Process evaluation records are useful for accountability purposes and for use by external evaluators and project funders who want to know how the money was spent. They also help external audiences to learn about the project in case they want to conduct a similar one elsewhere. Process evaluation is an important source of information for interpreting product evaluation results because in order to explain why the product outcomes came out the way they did, one needs to know what was actually done during the project implementation in the first place. Thus process evaluation leads to improvement of the project or programme, supports accountability, and enables the understanding of why certain outcomes occurred.

2.10.1. 4 Product evaluation.

In the view of Stufflebeam (1983), 'the purpose of a product evaluation is to measure, interpret, and judge the attainments of a program…. to ascertain the extent to which the program has met the needs of the group it is intended to serve' (p.134). Knowledge of a project's achievements is important during the project implementation and also at the end of it. It is essential that the product evaluation takes a broad perspective by considering the effects of the project – including the positive as well as the negative effects, and also the intended and unintended outcomes. The evaluation should gather and analyse judgements of the project from a wide range of stakeholders and also compare the project outcomes with those of similar projects. An evaluation of the outcomes should be viewed from many vantage points such as viewing by groups and individuals, and evaluated in comparison with the intended objectives, and also examined for cost effectiveness.

There is no standard method for conducting a product evaluation. However, there are a number of techniques that can be employed. These methods often include the use of both quantitative and qualitative (mixed) methods, as well as the use of a variety of instruments such as in-depth interviews of participants, surveys, performance tests, and so on. For example, a survey could be used to gauge participants' views on the success or failures of the project. Also, in-depth interviews could be conducted with a smaller number of selected participants in order to get an in-depth understanding of the project. The designs could include case studies as well as experimental and quasi experimental designs.

The most important use of a product evaluation is to determine the worth of the project; and information gathered from such evaluations would serve decision making. For example, the information could help funding agencies to decide whether to continue funding the project or stop doing so if it proves to be a waste of resources. A product evaluation could also help an interested researcher to be able to answer questions on whether the project could be replicated in other settings. It could also provide information as to whether the project should be modified to make it more cost effective or to make it better serve the needs of all members of the target group of beneficiaries.

To sum it all, the information gathered from a product evaluation is very useful for accountability purposes and for justifying the continued funding of a project or its termination. Finally the records of the whole project could be of tremendous help to project developers who

might like to pursue similar projects in different settings. The question that arises may be how to apply these notions of the CIPP model to the SIKSP. In this study, the information needed for the evaluation was obtained from the participants of the project who provided it based on their lived experiences in the project. They were prompted to look back retrospectively in order to co-construct meaning as described in *fourth generation evaluation* by Guba and Lincoln (1989).

2.10.2 Constructivist (Fourth Generation) Evaluation (Guba & Lincoln, 1989)

The Constructivist or Fourth Generation evaluation approach as proposed by Guba and Lincoln (1989), came about as a result of their dissatisfaction with the previous approaches to evaluation. According to them, the first generation of evaluation which lay emphasis on measurement, was 'fraught with managerialism' where managers had too much power to the exclusion of other stakeholders. The second generation of evaluation which lay emphasis on description, in their view, was dominated by the positivistic worldview that ignored the contexts of the evaluations. Lastly, the third generation of evaluation approaches that emphasized judgement, in their view, was insensitive to value-pluralism (Guba & Lincoln, 1989; Huebner & Betts, 1999; van de Kerkhof et al., 2010). As a solution to all these perceived shortcomings, they proposed the *Constructitivist evaluation* approach which they called *fourth generation evaluation*. This approach is based on Stake's responsive evaluation model which emphasized that every evaluation should be responsive; that is, each evaluation should take into consideration the needs of the stakeholders.

The constructivist evaluation approach can be understood more easily by comparing it with the positivistic approaches. The two approaches differ ontologically in the sense that the positivistic approaches believe that there is a single reality which is neither affected by the researcher nor the context of the evaluation. On the other hand, the constructivist approach holds that there are multiple realities which are socially constructed, and that reality is what is arrived at by consensus. The two views are opposed to each other because the constructivist approach of reality is not defined a pririori and its nature cannot be determined beforehand either; whereas in the positivist view, reality is defined beforehand.

The positivistic approach to evaluation has an objectivist epistemology. That is, it believes that reality can be studied by an objective observer from a detached, value-free position. On the other hand, the constructivist epistemological position is that the researcher is

never completely objective. Also, the researcher is part of the researched and the product is the result of joint interactions. The final product is therefore the result of the intersubjectivities of the participants and the researcher involved in the study.

Whereas the preferred methodologies of positivistic approaches are randomised control trials (RCTs) and quasi experimental designs, the constructivist approach prefers qualitative methods involving continuous dilectic of interaction, analysis, and re-analysis, leading to constructions that are highly context-dependent.

The place of the constructivist approach to evaluation is justified by the fact that this would permit the views of the various participants involved the SIKSP to be the ones whose opinions matter the most in determining the value and usefulness of the project. That is, the merit and worth of the project is arrived at through the joint intersubjective value judgements of the various participants of the project and the evaluator. These value judgements are heavily dependent on individual perceptions and constructions of the project participants.

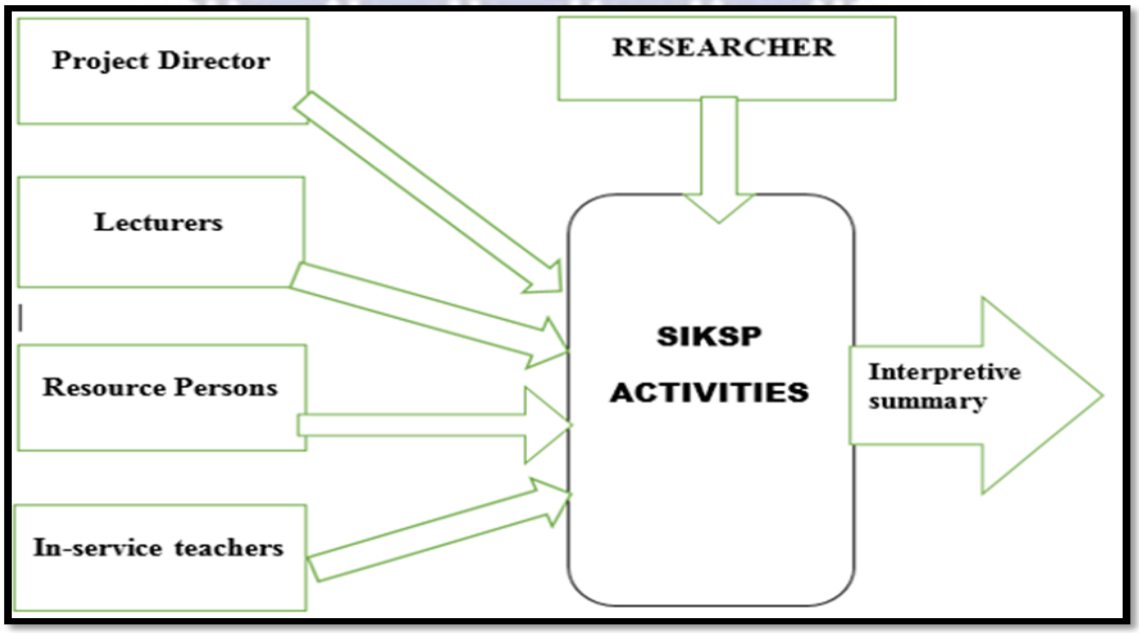

Fig 2.2 A constructivist evaluation of the SIKSP by project participants

Figure 2.2 shows how the Constructivist evaluation model was applied to the SIKSP by the project participants. The project participants who were made up of the project director, the lecturers, the post doctoral research fellows (or resource persons) and the in-service teachers expressed their perceptions about each activity of the project (as indicated by the arrows). The researcher also interacted with the activities and with the perspectives of all the other

participants. The main goal was to synthesise all the intersubjective views expressed by the different participants in order to possibly arrive at an interpretive summary of some sort or a consensus. This joint construction of the individual constructions of the participants is indicated as the interpretive summary (of the expressed views). In order to know if the participants agreed with the interpretive summary, the researcher sought the participants' input and comments after he had done his part. Any feedback was taken into account and the interpretive summary modified accordingly.

2.10.3 Reflectivity.

Reflectivity is often attributed to the work of John Dewey (1933) who believed that reflection was emancipatory and that one of the main aims of education should be the enablement of teachers to acquire it (Wlodarsky, 2010). According to Dewey (1933), reflective thought is any "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends." p.9. This implies that discursive-argumentative environments such as those that took place in the SIKSP workshops could be very supportive of reflective practice. Similarly, Quinn, Pultorak, Young, and Mccarthy (2010) regard reflexivity as a planned activity that takes place over a long duration, and requires individual awareness of self and self-perception. In their view reflexivity is developmental, takes place in stages, and is based on experience. Sellars (2014) defines it as "The deliberate, purposeful, metacognitive thinking and/or action in which educators engage in order to improve their professional practice" p.2.

Reflectivity thus involves an individual stepping back and thinking critically about past actions to determine at what point they were good or bad, and how to effect corrections. Reflective practice therefore could be a good vehicle to attain belief revision to the reflective practitioner. Reflexive teachers think critically about their practice, and take decisions as they review what they did, the decisions they took, and the effects of those decisions. In fact, some researchers believe that without critically reflecting on practice, the teacher would not learn much from past experience (Rog, 2015b). On the other hand, research shows that reflective practices are useful in enhancing the capacities of evaluators as well as participants in responsive, participatory enquiries (van Draanen, 2017) and also relevant and useful in professional development of teachers (Wlodarsky, 2010).

Teacher reflections can help teacher trainers to better evaluate the impact of coursework on in-service teachers' thinking. They can also equip the trainees to meet the challenges they would face in the field (Fox & White, 2010; Quinn et al., 2010). Quin and colleagues investigated the growth and development of the reflections of in-service teachers taking a graduate professional course using the in-service teachers' programme portfolios. An analysis of the in-service teachers' reflections enabled the course instructors to be able to determine much more insightful issues on how these in-service teachers changed over time, something that grades alone could not do.

One of the prominent theorists of reflexivity is Schön (1983). Schön distinguishes between two types of teacher reflection – reflection-in-action (which takes place at the spur of the moment in the classroom where the teacher has to take immediate decisions) and reflection-on-action (which refers to a teacher's retrospective reflection on actions or decisions of the past, and their effects).

In this study, reflectivity was built into the design as participants' perceptions were sought at all stages of the study. This was also achieved when participants' perceptions and value judgements were expressed through interviews and other avenues that helped make their voices shape the results. Thus, the conceptual framework constitutes of the CIPP model for its structure, while the constructivist worldview, together with reflectivity, shape the means of reaching meaningful conclusions. This was achieved through the multiple perspectives of the participants, and the interaction with the researcher's value judgements. Hence the complete conceptual framework resembles what I have depicted in Fig. 2.3 below.

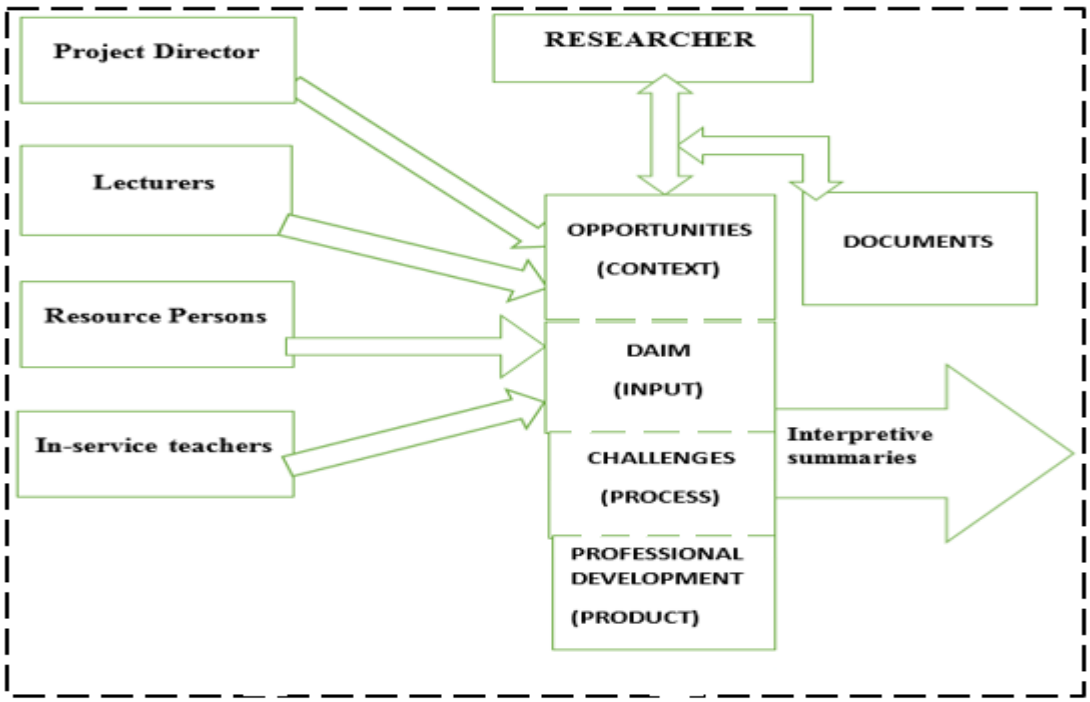

Fig 2.3 The conceptual framework used for the study

Figure 2.3 shows the full or complete conceptual framework. It follows the same pattern as in Figure 2.2 where the participants expressed their views about SIKSP activities. The main difference is that in the complete conceptual framework, the research questions (which were organised as much as possible, to align with the structure of the CIPP model), take the place of the project activities in Figure 2.2. (The boundaries between the types of evaluation in Fig. 2.3 are not rigid, but porus; meaning that a question can transcend these boundaries). The participants gave their input through the questionnaire, interviews and reflexive journals. In this research, I (the evaluator) was a participant researcher or an internal evaluator. For each research question, after gathering the views of the other participants, I interogated them reflectively, with my own opinions since I was in the project since 2009 as an in-service teacher and as a research assistant. I also interacted reflectively with the project documents in order to come up with a possible conclusion. I then interacted with all the data to find themes in order to arrive at conclusions which were interpretive summaries of my own value judegements and the data. After these theoretical concepts, I proceed to review some studies that have used the CIPP framework of evaluation in the next section.

2.11 Some studies that used the CIPP model

The CIPP model has been widely used in evaluating educational programmes and projects. Daniels (2010) used the CIPP model to evaluate the effectiveness of the Common Teaching Platform, a regional collaboration programme for training undergraduate nurses by three universities in the Western Cape, South Africa. She used interviews, focus group discussions and a document review to collect data. The data were collected from the Chief Executive Officers of programme, the administrative and health departmental heads, as well as nursing students of the participating universities. The results of the evaluation indicated that effective collaboration was hindered by the fact that the concept of collaboration was relatively new at the time and people needed enough time to accept the change. Secondly, the exclusion of some important stakeholders at the planning stage led to many challenges faced during the implementation phase of the programme. The study concluded that the participants felt the programme was only partially successful as the throughput rate was met, but some challenges such as inadequate resources, lack of willingness by the institutions to share resources and expertise, and lack of commitment to the programme remained unresolved.

Bachenheimer (2011) used the CIPP model to evaluate a Digital Backpack program in a Northern New Jersey School District. The Digital Backpack was a rolling computer bag given to K-12 classroom teachers. It contained portable digital tools that were part of the teacher's instructional practice, accompanied by other professional development activities. This evaluation used pre- post- surveys and a focus group interview. A sample of six teachers took part in the study, which was analysed using a mixed-methods approach. The evaluation addressed issues involving professional development, technology integration, and student engagement as related to the Digital Backpacks. The results showed that the teachers indicated overall positive attitudes and perceptions towards their professional development, integrated technology into the classroom in a variety of ways; many of which contributed to high levels of student engagement, and created opportunities for students to use technology with creativity, collaboration, and reflection.

Chen (2009) used the CIPP model to evaluative 20 English training courses offered in the Applied English Department (AED) of a tertiary Institute in southern Taiwan. The courses were designed for, and taken by, students who were preparing to teach English to children. It was an evaluative case study employing mainly qualitative methods e.g. questionnaires, interviews and document analysis to gather the data. The evaluation was done by using four

key components of the courses, namely: "course aims and objectives", "course contents and materials", "course conduct and teaching-learning process" and "assessment and student performance". The results suggested that there was some incongruence between student needs and the courses offered. Based on the findings key suggestions were proposed for the AED to improve courses.

Tunc (2010) employed the CIPP model to evaluate the effectiveness of an English language teaching program at Ankara University Preparatory School program through the perspectives of instructors and students. The study involved 406 students attending the preparatory school in the 2008-2009 academic year and 12 instructors teaching in the programme. The instruments used included document analysis, a student questionnaire and an interview schedule for the instructors. The data were analysed using both quantitative and qualitative methods. The results of the study indicated that the programme was partly successful in achieving the aims of the programme. The findings also provided evidence for recommendations that needed to be undertaken in order to make the programme more effective. These included improvements in the physical conditions, content, materials and assessment dimensions of the programme.

Mirzazadeh et al. (2016) used the CIPP model to guide conceptualization, planning, implementation and evaluation of a revised undergraduate medical education programme in Teheran. It was an eight-year longitudinal evaluation study divided into four phases compatible with the four components of the CIPP model. The stakeholders included medical students, lecturers, and others; and the study used a variety of instruments and mixed methods of data analysis. The CIPP model was found to be useful in helping policy makers to make informed decisions based on data gathered during the evaluation. The setback of the model was that the data was burdensome and that it failed to address some unanticipated evaluation outcomes.

2.12 Conclusion

The main aim of this study was to evaluate the Science and Indigenous Knowledge Systems Project from the perspective of the project participants. The task of carrying out a project such as the SIKSP is challenging since science and IK worldviews are much different, and the science teachers had only been schooled in the science worldview. This phenomenon of seeking to include indigenous perspectives in science classrooms has reached a worldwide status, and has the potential of motivating non-Western learners, who form the vast majority,

in the case of South Africa, to pursue sciences and science-related careers. An instructional approach that has been found useful in this endeavour is the Dialogical Argumentation Instructional Model, which is a major focus of this study. A constructivist approach to evaluation was deemed appropriate for use in this study, to supplement the CIPP evaluation model, making use of the participants' reflective practices. In the next chapter, I will describe the methodology that I used to carry out this study.

CHAPTER THREE: METHODOLOGY

In chapter two, I examined the literature relevant to the study in the light of the research focus and questions and also discussed the conceptual framework used in the study. In this chapter, I will present the research methodology that I used to gather, process, analyse, and interpret the data. The research methodology acts as a road map for every researcher and informs any reader on the procedures that the researcher followed to obtain and analyse the data (Burian et al., 2010). Thus, the research methodology lends credibility to the results of the study, and enables other interested researchers to replicate it or to be able to give an appraisal of the study in question (Creswell, 2014). I will begin the chapter by situating the research in a paradigm.

3.1 Research Paradigms or Worldviews

A paradigm is an overarching philosophical framework underpinning the researcher's ontological, epistemological and methodological beliefs or assumptions (Denzin & Lincoln, 2018; Lincoln et al., 2018). Guba and Lincoln (1989) view a paradigm as "a basic set of beliefs" or "assumptions" which could act as basic principles that guide one's activities (p.80). They further assert that a paradigm is abstract, and comprises four philosophical assumptions: the nature of reality (ontology), knowledge (epistemology), systematic inquiry (methodology) and ethics (axiology). These basic beliefs taken together, determine the overall framework or worldview that guides a study or a paradigm.

There is no consensus on the number of paradigms that guide researchers as there are many of them mentioned in literature (see Denzin & Lincoln, 2018; Lincoln, Lynham, & Guba, 2018). However, there seem to be just three or four basic ones mentioned by most authors. These are positivism, interpretivism or constructivism, critical theory, and pragmatism (see Lincoln & Guba, 1989; Lincoln, Lynham & Guba, 2018; Mertens & Wilson, 2019).

3.1.1 The positivist worldview

In the view of the positivist, there is a single reality which must be discovered by the researcher within a certain level of certainty (Lincoln, Lynham & Guba, 2018). In order to achieve that aim, the researcher must not permit anything extraneous to the specific variables to distort the process of inquiry. Thus, the experiment should be designed in such a way as to

control, as much as possible, the extraneous variables. Also, the evaluator or researcher is not supposed to influence the results by introducing any researcher values or effects. The methods best recommended to achieve these ideals are randomized controlled experiments, which must be analysed quantitatively. The results obtained under such controlled conditions, according to the positivists, would then be objective, value-free, context-independent, and hence generalizable to all contexts. This view is very much applicable in the natural sciences where the researcher deals with inanimate objects with no minds or wills to take decisions of their own. But research of projects such as the SIKSP concerns the social world, not the natural. This is more complex as one deals with humans who are intentional beings, and who cannot therefore be controlled as the positivist paradigm holds. For that reason, I concluded that this paradigm was not suitable for use in this study.

3.1.2 Interpretivist or constructivist worldview

Interpretivists oppose the positivist notion of a single reality external to the researcher. Instead, they hold that there are multiple realities jointly constructed by the researcher and the researched. The researcher's values, culture and background therefore have an influence on the results of the inquiry. While positivists try to control confounding variables in order to arrive at knowing a concept, interpretivists or constructivists seek to understand the complexities of phenomenon in its context and to interpret it. To the constructivist, the goal of research is to have a maximum number of views of the participants about the object under study (Creswell, 2014; Lincoln, Lynham & Guba, 2018). The researcher recognises that their interpretation is shaped by their background, the context, and the interaction with the study participants. The tenets of the constructivist worldview largely align with my research focus. Hence this was the main worldview that influenced my approach to the study.

3.1.3 Critical theory or transformative worldview.

Critical theorist drew inspiration from Karl Max. Some of the critical theorists include Immanuel Kant, Hegel, Max Weber, Jurgen Habermas, Paulo Freire, and many others. According to critical theorists, power relations dominate all social inquiry. Also, all inquiry is socially and historically constituted (Kincheloe et al., 2018) . Facts and values are intertwined and embedded in ideology. In many societies, some groups are privileged, and suppress others. This oppression is reproduced when the oppressed fail to rise against it. The work of the

researcher is to raise awareness to the social injustices and stand to defend the oppressed in the society. Thus, critical theory advocates for a change of the status quo.

The critical theory paradigm is therefore emancipatory in approach and seeks to address inequalities through advocacy and activism. The researcher and the researched are regarded as co-researchers; hence the participants' voice plays a significant part in the results of the study. This paradigm, though different from the positivist tradition, is more suited for advocacy and change. It is not used in this research, but included for completeness.

3.1.4 Pragmatic worldview.

This worldview is often attributed to the ideas of William James and John Dewey, among others. In this worldview, the emphasis is not on the abstract meaning of words and philosophical positions. Rather, those who use this worldview focus on what works well; or how they can achieve practical goals using the most appropriate methods possible (Creswell, 2014). To a pragmatist, the use of evaluation results is a key concern. Pragmatism believes that there is a single reality but different interpretations of it by different individuals. The evaluator determines what is important in an evaluation and uses eclectic methods as deemed appropriate, depending on the research or evaluation questions, the purpose of the study, and the context – social, cultural, political, etc. The research is affected by the evaluator's values. Although I disagreed with the ontological stance of a single reality, I found the methodological position of this paradigm appropriate, and in many ways, aligned with my study.

3.1.5 Worldview guiding this study

The aim of this study was to find out the extent to which the SIKSP achieved its goals, using the views of the participants as the main source of data. The conclusions are therefore determined by their views and perceptions of the project, together with my own subjective interpretations and analysis. In addition, data from the document analysis needed more than the interpretive worldview to analyse since some of it was quantitative. Hence, I also used the pragmatic worldview. This blend of two paradigms or worldviews is common with studies that use mixed methods (Creswell, 2014). A summary of the main ideas of these philosophical worldviews or paradigms is shown in Table 3.1.

Table 3.1 Summary of paradigms and assumptions affecting inquiry processes

Assumptions	Positivism	**Interpretivism (Constructivism)**	Critical theory	**Pragmatism**
Ontology (The nature of reality)	Single reality, unaffected by observer	Relativism; multiple, socially constructed realities	Historical realism; virtual reality	Single reality; Individual interpretations of reality
Epistemology (Nature of knowledge and the relationship between the knower and that which can be known)	A dualist, objectivist epistemology; Observer studies from a detached, value-free position [subject-object dualism]	Monistic, subjectivist epistemology. The researcher is part of the researched and the interaction produces the results.	Subjective, emancipatory, value mediated results	Evaluator determines what is important in the study and relationships with stakeholders
Methodology (Systematic approaches to gathering information about what would be known)	Interventionist, experimental; uncontaminated by context; leads to universal, context-free conclusions	A hermeneutic/ dialectical, leading to a jointly constructed result	Dialogic/ dialectical	Methods depend on questions and purpose of evaluation; Mixed methods common
Axiology (The nature of ethics)	Value-free; values contaminate findings	Value laden, leading to informed action	More than value laden, leading to social change	Evaluator's values and politics determine actions

(Adapted from Lincoln & Guba, 1989; Mertens &Wilson, 2019)

3.2 Research Design

The research design can be compared to the architect's building plan or blueprint that the researcher intends to use in order to carry out the study. In view of the research aims and questions, I deemed a case study design as the most appropriate design for this study. Case studies are often characterised by a small sample size, and multiple instruments of data collection. They are generally suitable where an in-depth investigation of a phenomenon or event is required (Creswell, 1998; Martinson & O'Brien, 2015; Silverman, 2010; Yin, 2009). Martinson and O'Brien (2015) posit that 'a core feature of the case study approach is a reliance on systematic and detailed data collection from multiple sources, particularly first-hand observations' p.178. The multiple sources of data collection lead to the question of how to combine the data collected from these sources. This often calls for triangulation (to be elaborated upon later).

Creswell (1998) points out that the case study must be a "bounded system" involving a single case or multiple cases, usually employing in-depth data collection techniques and multiple sources of information. Yin (2009) considers two pertinent aspects of a case study – the scope and the context. He asserts that:

> A case study investigates a contemporary phenomenon in depth and within its real-life context … copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result, relies on multiple sources of evidence, with data needing to converge in a triangulating fashion (p.18).

Yin (2009) recommends mixed methods designs for such complex studies. In line with his recommendation, this study took the form of an evaluative case study making use of the explanatory case study approach of using mixed methods (Creswell, 2009; Yin, 2009)

Yin (2009) is also of the view that case studies are particularly useful in evaluation research for various reasons. For example, they can be used to: 1) explain the causal links in real-life interventions that are too complex for other strategies, 2) describe the intervention in the real-life context in which it occurred, 3) illustrate certain topics within an evaluation, and 4) clarify situations when there is no clear outcome (p. 19-20). The explanatory case study is very useful when an evaluator is seeking to explain causal links in educational or other interventions that are too complex for the survey or experimental strategies to explain. In other

words, an explanatory case study enables one to establish and justify the link between programme implementation and the programme effects (Yin, 2003).

Case studies are well known for their use of multiple instruments and rich, in-depth qualitative data obtained through interviews, focus group discussions, and similar instruments (Martinson & O'Brien, 2015; Yin, 2003, 2009). By using open-ended questions in the questionnaire and interviews, the researcher is able to gain some insight into the feelings and perceptions of the different participants involved in the study. The use of the data collected from various sources, when combined together using both qualitative and quantitative methods, enables the researcher to obtain a more holistic and credible picture of the case.

3.3 Research sample

It is generally almost impossible for the researcher to obtain data from every member of the target or accessible population. Hindrances such as the high cost involved, time constraints, and geographical diversity, just to mention a few, may prohibit the use of the whole population to gather data (Cohen et al., 2007). To obtain the required information, the researcher often resorts to a sample or a smaller group of participants that are representative of the target population, for the collection of relevant data. In this study, sources of data collection included the project designers and implementers, in-service teachers, and alumni.

As indicated above, this research was an evaluative case study of a Science-IKS Project which took place in a university in Cape Town. Individuals who had taken part in the project provided the data needed to carry out the evaluation. These included the project director, lecturers, post-doctoral students who were mentors in the programme, as well as in-service teachers and teacher-trainers who undertook the training to implement a science-IKS curriculum in their classrooms.

In quantitative research, the population of the study consists of the group to which the researcher hopes to generalise the results (Fraenkel & Wallen, 2008). Similarly, Babbie and Mouton (2001) consider the population of a study as the group of people about whom we want to draw conclusions. However, in an evaluative case study research like this one which is largely qualitative, the main aim of the researcher is not to generalise the findings to a target population. On the contrary, it is to understand and interpret the case, and to provide information that is useful for decision-making. This research is an evaluative case study that

aims at producing credible information to aid informed decision-making about the Science and Indigenous Knowledge Project. The study has as a main goal, to determine the project's merit and worth in training teachers to integrate science and IKS in the South African context.

The sample was made of: 1) project designers and implementers on the one hand, and 2) project beneficiaries on the other. The first group includes the project director, the facilitators (postdoctoral fellows who acted as support staff and resource persons), the lecturers involved in training the teachers. The second group consists of postgraduate in-service science teachers and teacher trainers who had been part of the project, as well as alumni of the School of Science and Mathematics Education who had participated in the project at some stage. However, there was an overlap of many functions as some participants (the facilitators and lecturers) were both project implementers and beneficiaries concurrently. More detailed descriptions of the sample will follow in section 3.4 (Context of the study).

3.3.1 Sampling technique used

Most researchers of quantitative research (e.g. Cohen et al., 2007; Fraenkel & Wallen, 2008) agree that representativeness of a sample is best obtained by using random sampling techniques to eliminate researcher bias. However, there are many instances in the social sciences where random sampling is not possible (in qualitative research, randomization is not necessary) and other techniques have to be employed. Hence, in this study, the purposive sampling technique was deemed most appropriate. According Fraenkel and Wallen (2008), purposive sampling is a non-random technique whereby the researchers use their prior judgement to select a representative sample because they believe from their prior experience that the individuals they select can provide the right information needed for the study.

After deciding to go in for the research, I introduced the issue during our bi-weekly SIKSP seminars where we usually met for research, collaboration and discussions. I also spoke with colleagues at a personal level, asking them to take part in the evaluation study. Since most of them were colleagues with whom we had been working on the project for over five years, it was not difficult to get their consent to participate in the evaluation study. I also sent emails to some of the former colleagues and postdoctoral fellows (some of whom were in different African countries) soliciting their participation in the study. Out of the 25 people contacted, 22 of them accepted to participate in the study while three of the teachers opted not to participate. Of these three, one colleague who had completed his doctoral studies explained that he did not

have much knowledge of the project because he used to come to the university campus and seminars only occasionally. Two others (one lady who dropped out of her master's programme and a male colleague who also abandoned his doctoral programme) did not give any reasons.

3.4 Context of the study

In this section, I will describe the background of the project and its participants. This is important for the understanding of the interactions that took place and the intersubjective joint constructions of the conclusions that arise from the evaluation of the project activities by the participants.

3.4.1 The Science and Indigenous Knowledge Systems Project (SIKSP)

As mentioned in chapter one in section 1.2, the SIKSP was established in 2004 to train science teachers to implement the new science and indigenous knowledge systems (IKS) curriculum as demanded by the new government policy. While the introduction in section 1.2 focused on the historical origins of the project, this section will focus more on the structure and processes of the SIKSP. A flowchart of the SIKSP's procedure of training in-service teachers is shown in Figure 3.1. The in-service teachers came to the SIKSP as novices in IK. As they continuously interacted with the project staff, facilitators, as well as the IKS materials during the lectures, seminars, workshops and conferences, they gained knowledge and skills in IK. After a number of years, they were then deemed knowledgeable enough to implement the science-IKS curriculum. In addition, they were awarded higher degrees.

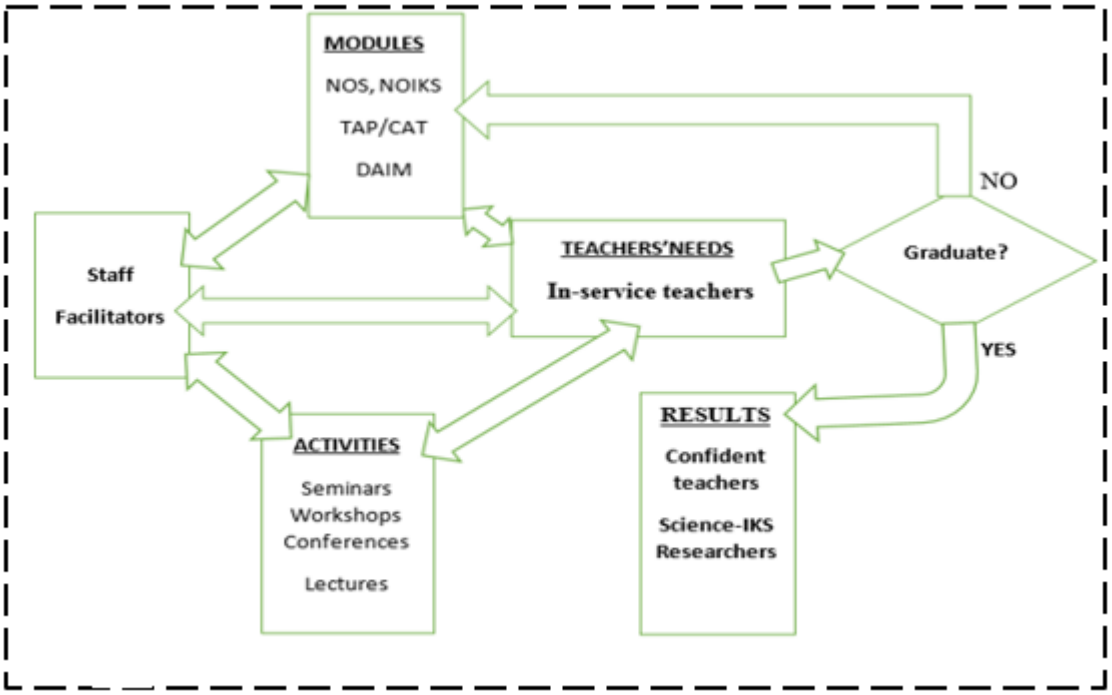

Fig 3.1 A flowchart of the SIKSP training programme for in-service teachers

The project was headed by an experienced science education professor, assisted by a group of dedicated science teacher-trainers as lecturers, and postdoctoral research fellows acting as facilitators of learning and research. Initially, the training process of the in-service teachers included special academic courses specifically designed to equip the in-service teachers intellectually, and also to challenge their prevalent worldviews concerning the nature of science (NOS), the nature of IKS (NOIKS), the nature of science and IKS (NOSIKS) and the integration of IK in science classrooms. The Practical Argumentation Course (PAC) which involved the use of dialogical argumentation (Ogunniyi, 2007a) was very instrumental in influencing many of the science teachers to adopt different views. Also, many instruments were designed to challenge incoming in-service teachers' predominantly mechanistic worldviews as they began the training. One of these instruments was on the nature of science (NOS) (Ogunniyi, 2005, 2006; Ogunniyi & Hewson, 2008) [see Appendix D3]. Another instrument used was the nature of IKS (NOIKS) [see Appendix D4] and the third was on the Nature of Science and IKS (NOSIKS) (Ogunniyi, 2007a).

Apart from the taught courses, the project ran bi-weekly workshops where the in-service teachers and other researchers met for three hours on Friday afternoons (Fridays were for seminars but Saturdays were used for the SIKSP workshops) to practically carry out the

practice of integration of science and IKS using the proposed strategy of dialogical argumentation instructional model (DAIM) (which will be elaborated upon later). Specifically, the three-hour Saturday workshops focused on the development of IKS teaching materials. With the change of policy by the university to focus on master's degree programmes by theses rather than by coursework and mini-theses the courses were then dropped. However, the electronic versions of the PAC and Psycho-socio-cultural Issues in Science and Mathematics Education (PISME) (Ogunniyi, 2004) were still made available to in-coming students so that they could read on their own. Following the suppression of the courses, the project team intensified the seminars and workshops. The aim of the advanced seminar lectures was to increase the research capacities of the in-service teachers and to an extent, fill the gap created by the absence of the course work. In addition to these bi-weekly seminars and workshops, the project organized four periodic science-IKS national/international workshops and conferences in 2007, 2009, 2011 and 2013, respectively. During these workshops and conferences, science educators and resource persons in the field of science-IKS integration were invited to speak and the in-service teachers also had an opportunity to present their research.

According to Ogunniyi (2004), in-service science teachers enrolled for the Master's course took a module known as *Psycho-socio-cultural Issues in Science and Mathematics Education (PISME)*, which was an attempt to train practising teachers to help their learners to integrate science and IK. The PISME module tried as much as possible, to use pedagogies similar to what indigenous people learners use back in their communities. The module also gave equal recognition to science and IKS; not treating one as the standard and the other as subordinate. In the view of Ogunniyi (2004), the pedagogical and methodological approaches characterised by discussions, debates, explanations, giving priority to group related rather than individual tasks, continuous assessment and essays rather than end of year examinations, and seeking group consensus rather than individual viewpoints, was a way of making the SIKSP approach to resemble the indigenous learning environment context.

The adoption of dialogical argumentation as a pedagogical tool and the DAIM approach enabled the in-service teachers to discuss and actively participate in debates involving scientific and indigenous issues. They also engaged in debates about many other controversial issues, thus, engaging in a practice that scientists and indigenous people do in practice. In my view dialogical argumentation was a good tool as it is an approach that breaches the gap between the two epistemologically distinct science and IKS worldviews. The use of TAP and CAT as

the underpinning argumentation theories takes care of a greater number of argumentation types than when using TAP alone. Many researchers have identified various ways of learning common among indigenous people (Brayboy & Maughan, 2009; Chinn, 2007; Mpofu, Mushayikwa, et al., 2014; Ogunniyi, 2004). A review of the literature characterises indigenous learning as holistic, informal, participatory, verbal, practical, and mostly uses unstructured settings, imitation with real rather than prototypes or laboratories, oral traditions, song and dance, drama, shared experience, discursive interactive; learning through social activities, play, etc. The SIKSP method of instruction underpinned by dialogical argumentation where participants get involved in dialogues and discussions is quite consistent with many of these methods.

The SIKSP is underpinned by an argumentation framework aimed at helping science teachers integrate science and indigenous knowledge in their classrooms (Ogunniyi, 2004, 2007a, 2007b). The argumentation framework is based on a socio-constructivist approach to teaching and learning which draws on two argumentation theories namely, Toulmin's (1958/2003) Argumentation Theory (TAP) and Ogunniyi's (2007a) Contiguity Argumentation Theory (CAT). While the TAP is very useful in engaging learners in informal, inductive-deductive arguments, it does not include non-logical or metaphysical discourses which are typical in indigenous knowledge discourses that are normal in IK contexts (Ogunniyi, 2007a; Ogunniyi & Hewson, 2008). CAT is more applicable in more complex contexts such as in the context of non-logical or metaphysical discourses.

As mentioned above, the instructional strategy developed at SIKSP, and which is being used for the integrating science and IKS, is the Dialogical Argumentation Instructional Model (DAIM). In this teaching approach, learning begins with individual learners (or in-service teachers in the case of SIKSP) reflecting on the argumentation tasks individually. The second phase involves small group discussions during which individual learners (in-service teachers) present their views and defend them while their peers examine the various claims and supporting arguments. At a later stage, the group conclusions are presented to the whole class. The final phase is that of cognitive harmonisation during which the various views are examined in order to reach consensus if possible. Many studies have already been published on this (e.g. Hewson & Ogunniyi, 2011; Moyo & Kizito,2014; Ogunniyi (2007a, 2007b, 2011; Ogunniyi & Hewson,2008).

3.4.2 Researcher's Background

In qualitative research, the researcher is part of the research and any findings of the research are the joint constructions of the researcher and the research participants. Social enquiry is thus affected by the researcher's beliefs and worldviews, as they form an inseparable part of the enquiry process (Creswell & Miller, 2000). Therefore, as a means of establishing validity (credibility) in social inquiry, many researchers recommend researcher reflexivity, or the researcher disclosing their socio-cultural and historical background, as well as their values and biases since they affect the manner in which the researcher interprets experience (Cope, 2009; Krefting, 1990; Patton, 2002a, 2002b; Popay & Mallinson, 2015; Whittemore, Chase, & Mandle, 2001). The argument is that a reader who has a knowledge of the researcher's background would be able to guess the underlying influences that might have affected the data collection, analysis and interpretation. Thus, such disclosure might help to increase the credibility of the results of the inquiry. In line with the recommendations of these researchers, I will proceed to give a brief summary of my background in order to anticipate what could have possibly influenced my constructions of reality.

I was born in a small village in the rural regions of North-West Region of Cameroon. Growing up in the cultural milieu was quite different from the urban life to which I was introduced later on. In the rural areas, every child belonged to the community; family bonds were strong, and everyone would join to rejoice with the success of an individual or join to express solidarity with a calamity suffered by an individual in the community. The spirit of *Ubuntu* was the norm. Most people who were regarded as successful in the community were those who were endowed with physical, intellectual, social and cultural skills – people who were proactive and multi-talented; for instance, those good at farming, hunting, public speaking, wrestling, playing traditional music, dancing, etc. Unfortunately, I lacked most of these qualities since I was rather timid and docile. By the community's standards, I did not do very well. When I started going to school at an early age, I found an area where my talents were more suited. I did well at school according to my teachers, although most people in the family originally thought that the teachers were possibly assessing wrongly. After changing schools and still 'passing well' in the different schools, they had to accept the judgement of the schoolteachers, though reluctantly.

My school experience made me gain some degree of self-confidence. The more I travelled the journey of schooling, the more distant I was from traditional beliefs and values.

Firstly, the Mission School education taught me Christian norms and values and I was made to understand that many cultural ways were at odds with Christianity. Secondly, when I started studying science subjects at secondary/high school, our teachers taught us that cultural practices were unscientific and full of superstition, so we had to completely forget about them because they could not be verified. On the other hand, we were taught that scientific laws and theories follow a rigorous process of verification and validation before the scientific community accepts them, and that once accepted, they are universally true. To teach us the processes of science, we performed some experiments such as oxidation, burning things in air and finding the masses of the oxidised states, etc. Through these simple experiments I was convinced that all scientific experiments follow the Scientific Method; that all scientific laws and theories are proved true and universally valid because they had been verified at the stage of 'hypotheses' by scientists all over the world and confirmed using unimpeachable scientific techniques before passing the test as theories or laws. Since traditional practices and beliefs did not follow the rigorous, systematic, steps of the scientific method, they were dismissed by me, inter alia, as unscientific and superstitious.

When I started teaching science, I followed what my science teachers had taught me. As a science teacher, one of the first things to do to the learners just beginning to learn science was to 'inculcate' into them the 'fact' that science was the only trustworthy way of knowing the truth. This was done by teaching about the empirical nature of science and the set of procedures that had to be followed, typified in *The Scientific Method*, to arrive at 'scientifically proved and universally true' conclusions. The next step was to emphasize the 'rigorous steps' through which a hypothesis had to pass in order to become a theory or law. Finally, one had to compare 'science' with 'tradition' – an exercise that was aimed at glorifying science (and technology) and condemning cultural beliefs and practices as rubbish. We praised the discoveries of Isaac Newton, Albert Einstein, and so forth; and the advances that science had brought to humanity. This was the mind-set that I had for over the twenty-five years of teaching science at secondary/high school level.

My coming in contact with indigenous knowledge was quite unexpected. I left for South Africa with the intension of studying educational technology (which was new in my country at that time). However, at my university, science education had a project of working on the integration of science and indigenous knowledge. At first, it did not make any sense to me; it actually sounded ridiculous. One of the first encounters I had in the School of Science and

Mathematics Education was the filling of the NOS Questionnaire. The questionnaire really made me tremble. Everything that had made me believe in the infallibility of science was put to question. I was almost confused when even the infallibility of the 'Scientific Method' was challenged. After my honours programme in science education, I became a teaching assistant in the physics department. There, the scientific method was still reigning supreme. That is where I really had a cognitive conflict. I was expected to help first year students to understand concepts in a general physics course. The course approach was heavily derived from the Scientific Method. How could I point out the new perspectives I had heard about the prevalent beliefs about it? Finally, I resolved to use the two perspectives; the old view in the physics department and the new in the School of Science and Mathematics Education.

As I engaged in the process of studying for my master's degree in science education, I started attending the bi-weekly workshops organised by the SIKSP. It is through these workshops and the argumentation-based activities that I began to reflect back at the cultural practices that I had been taught to condemn, devalue, ridicule, and which I actively taught my learners to do the same for over two decades. The more I looked back, the more I discovered sense in some of the cultural practices. I gradually began to see that there was much scientific value in cultural practices. Afterwards I began to experience a sense of guilt for what I had been doing as a science teacher against cultural values, although I was not alone in doing so.

From 2010 to 2013, I was a research assistant in the SIKSP and had many opportunities to interact with the project director of the SIKSP from whom I had to ask so many questions concerning science, and sometimes, IK. During this period, I acquired much knowledge and many skills about indigenous knowledge. I worked with the project director, and learned transcription of audio documents, quantitative and qualitative techniques of data analysis and so on. My increased understanding of indigenous knowledge and science deepened my interest in IK. At the end, I began longing for the day that I would eventually go back home and influence a change in the way science is taught in my country.

That was some information about my background which could be used to guess from what position I view and interpret experience. Next I will describe the sample used in the study to collect the data.

3.4.3 The project director

The project director was a committed Christian in his mid-70s, who in his words, was 'retired but not tired'. His experience, dedication, and research in science education span four decades; taking him through several countries, including Nigeria, Botswana and South Africa. He had supervised or co-supervised over a hundred master's and doctoral students of science education. He had produced over 150 articles in peer reviewed journals and conferences, spanning four decades. Since the 1980s, his research interest has consistently focused on making science more relevant to African learners by taking their cultural backgrounds into consideration when the teaching of science. He had also been editor of some of the most prestigious journals in science education, including the International Journal of Science Education, Science Education and the Journal of Research in Science Teaching. He is at the originator of the Contiguity Argumentation Theory used as one of two argumentation frameworks in integrating science and IK.

As UNESCO chair of the Centre of Excellence for science education in Africa, he has been involved in building capacity in several universities in Southern Africa, and played a major role in the forming and running of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE). Recently he was given two awards in recognition of his contributions to the improvement of science education regionally and globally. In January 2014, the SAARMSTE bestowed on him the Life Time Achievement Award for his meritorious services to the association. In 2015 he was awarded a distinguished researcher award for his lifetime contributions to science education by America's National Association for Research in Science Teaching (NARST), one of the world's most renowned research conferences in science education. In the email addressed to him, NARST writes: "This award recognizes an individual who, through research over an extended period of time, has made outstanding and continuing contributions, provided notable leadership, and made a substantial impact in the area of science education.*"*

3.4.4 The lecturers [All names are pseudonyms]

Kenneth: He is a devoted Christian in his late 60s with a background of English Language and Natural Science. Prior to 2004 when he joined the SIKSP, he was involved in another project – the Relevance of Science Education (ROSE). He has been very instrumental in the organisation of the bi-weekly workshops and seminars as well as all the national/international

workshops and conferences organised by SIKSP since 2004. Through the SIKSP, he studied for his doctoral degree.

Salman: Salman is a devoted Muslim in his mid-50s with a background in the natural sciences, and like Kenneth, has been in the project since its inception. He is very gifted in ICTs and witty. He is the one of those who always make the atmosphere light when there is tension with witty jokes. He also enrolled for the PhD under the project.

3.4.5 The facilitators [All names are pseudonyms]

The facilitators were all experienced science teacher trainers, most of whom were postdoctoral fellows involved in mentoring the in-service teachers, coordinating the seminars and workshops, leading materials development sessions, and assisting in organising and executing other activities of the project. They had different experiences and backgrounds.

Emma: Emma was a female postdoctoral fellow and teacher-trainer in her mid-50s. She was from a SADC country and joined the project in 2009. She has a PhD in science education and had been a science teacher for 30 years. Starting as a secondary school teacher in 1987 she proceeded to teach at the university level in 1995. Her research interests are mainly in contextualising science teaching and integrating indigenous knowledge in the science curriculum.

Edmund: Edmund was a qualified male science teacher-trainer and researcher in his mid-50s. He was from one of the SADC countries in Southern Africa, who served as a postdoctoral fellow in the project from July 2009 to September 2011. He obtained a Secondary Teacher's Certificate in 1986, a Bachelor of Education (Physics and Chemistry Education) in 1990, an M. Phil in 1996, and a PhD in 2006 from a renowned British university. His areas of research interest are Teachers' Self-directed professional development and Contextualized Science, with an emphasis on the integration of Science and Indigenous Knowledge Systems.

Yemie: Yemie was in her mid-60s and had a double major in zoology-botany and education at the bachelor's level and a Master's degree in instructional technology from a Nigerian university before moving to South Africa in the mid-1990s, where she obtained her PhD in Education from one UCT. She taught life sciences and education courses at a Cape Town university for five years. Her particular interests are in inter-culturally relevant instructional practices. She joined the project in 2011 as part of her postdoctoral fellowship

programme. At the moment, she is an executive member of AASIKS. Although she ended her fellowship programme some years back, she still volunteers her services to the members of the project.

Corrine: Corrine was a retired teacher-trainer in her mid-70s. She was the only White member of the group, and the only person with English as home language. She taught for over forty years (12 years as a science teacher and 30 as a science teacher-trainer) before going on retirement in 2008. Although she thought that it was too late for her to be studying towards a degree, she never the less kept coming to the seminars and workshops. She had been a great source of inspiration in the group, and had contributed cultural artefacts such as indigenous musical instruments and other materials for teaching in multicultural classrooms. She had a keen interest in using indigenous story telling in teaching.

3.4.6 The in-service teachers

For lack of space, I will not write about the in-service teachers (which includes teachers and teacher-trainers) individually but will give the description in more global terms. Besides the project director, the two lecturers, and four facilitators already mentioned, 16 other teachers and teacher trainers took part in the study. The in-service teachers whose ages ranged from 30 to over 55 years taught at various levels – primary, high school, and tertiary. Although most of the teachers were South Africans, some came from other parts of Africa – East, West and Southern Africa. There were 5 males (of whom 2 were teacher-trainers) and 11 females (of whom 3 were teacher trainers). All the 16 in-service teachers responded to the questionnaire while I interviewed 8 of them. I chose the interviewees was purposive, and based on their availability and their longevity in the project. The teaching experience ranged from 0 to 34 years, with a mean of 15.3 years.

3.5 Instrument Development and Validation

As mentioned earlier, it is characteristic of a case study to use multiple instruments or sources of data collection. These data sources are largely influenced by the nature of the research questions (Creswell, 1998; Stake, 1995; Yin, 2009). The instruments used in this study included a questionnaire, interviews and document analyses. SIKSP documents such as articles in SAARMSTE publications, journal articles, theses, SIKSP-organised workshop and conference publications, teachers' reflective diaries, video clips, and the AASIKS website were

valuable sources of information. In this section I will describe the process of developing and validating the instruments used to collect the data for this study.

3.5.1 The SIKSQ Questionnaire

The use of questionnaires is very common in social science research. Questionnaires vary in content and design, depending on the context and purpose of the research. In this study I used the SIKSP evaluation questionnaire which also elicited biographical as well as academic and professional data. The questionnaire was developed and validated through a rigorous process. I presented the first draft of the questionnaire to 15 members of the SIKSP research group in their bi-weekly seminar for critical comments and suggestions. The group comprised two professors, four doctors of science education, and nine students who had completed their master's studies and were already pursuing or about to commence their doctoral studies, and one student about to complete the master's. (Another master's student present was not considered because she was relatively new and did not have much knowledge and experience about the project).

Following the critical comments and suggestions of the research group members, the questionnaire was very much restructured. The Likert-type questions were reduced in number and the open questions completely scrapped. After several revisions, the revised version was given to eight science education researchers for rating. The items were rated on a scale of 1-5 for relevance, clarity and unambiguity; where 1 meant the item was very poor and 5 meant it was excellent. Any item rated less than 3 was immediately eliminated. For the rest of the items, the raters provided comments on how to modify the items that scored 3 or 4. After another correction, the final version of the questionnaire comprising 36 items was rated by four experienced science education researchers. A pairwise correlation coefficient using a modified Spearman Rank Difference formula stood between .96 and .99. The final form of the questionnaire is shown in Appendix C.

It is characteristic of qualitative studies to use open-ended as well as semi-structured questions. While structured questionnaires are easy and good in large-scale surveys, open-ended questions are more useful in case studies because they elicit deeper and richer responses from participants. However, since interviews permit deeper probing with the participants, I use semi-structured questions but probed for further details and clarifications during the interviews.

3.5.2 Interview schedules

Interviews are very useful means of data collection in qualitative research. They are used to find the feelings of respondents in-depth. There are basically three types of interviews – structured interviews which have the same questions asked to each respondent in the same order, open interview where the researcher asks dissimilar questions, and semi-structured interviews where the researcher uses a mixture of structured and unstructured questions. I used structured interviews for this study. To get the perceptions of various stakeholders involved in the study, I constructed different interview questions, depending on the role played by such stakeholders and the research questions. I constructed four sets of interview questions; one for the project director, one for the lecturers, another for the resource persons (who for most part, were postdoctoral fellows), and a final one for the in-service teachers and teacher trainers.

The interview questions were given to six science education researchers for rating, critical comments and suggestions. They were to rate the questions for clarity and relevance on a scale of 1-5. A very good and relevant item was rated 4 or 5 while a bad one was rated 1 or 2. For each item rate 3, they provided suggestions on how to improve on it. After their ratings and comments, I made some adjustments as necessary. Any item rated 1 or 2 by one or more of the researchers was automatically removed. After making corrections in line with their ratings and recommendations, the number of items in the director's interview reduced from 22 to 16; that in the lecturers' interview from 17 to 12; that in the resource person's interview from 10 to 6; and that in the in-service teachers' interview from 18 to 12. Finally, the revised version of the interview items was given to four science educators for rating. They rated each item on a scale of 1-5; a very poor item rated 1 and a very good one 5. A pair-wise inter rater reliability by the four science education researchers using a modified version of Spearman-Brown formula gave the following values: the project director's interview was between .95 and .96; the lecturer's interview between .96 and .97; the in-service teachers' interview between .97 and .99 and the resource person's interview between .92 and .94. The interview schedules are found in Appendices B1 to B4.

3.5.3 Documents

Document analysis in qualitative research is a method whereby a researcher reviews documents, coding the content to get identified themes (Bowen, 2009). Document analyses in this study included many documents from the project such as proposals, project reports,

graduation lists, publications, theses, workshop attendance and minutes, IKS workshop and conferences, audio visual materials, and others. I reviewed the archived documents keeping in mind the CIPP framework that structure the study, as well as the research questions. Any information which could help to answer the research questions was recorded in a notebook kept for the purpose.

3.5.3.1 The Reflective Diaries

At the end of the project, the project director gave some questions to all participants present at the time to express their feelings about the project, and its impact in their practices. This evaluation was done by responding to the questions of the Reflective Diaries (see Appendix D2). Since this study was in the same line, I found the responses of the reflective diaries very useful, and used them in some of questions in this study.

3.5.3.2 Observation of DAIM lessons

I originally thought that it was good to observe some of the teachers applying DAIM in their classrooms. To that effect, I developed a DAIM lesson observation instrument and had it validated by three SIKSP science education researchers. Their rating and comments were used to refine it to the DAIM lesson rating scale shown in Appendix E. A pairwise inter rater reliability using Spearman-Brown formula gave values between .91 and .93. There were complications in going to carry out direct observations of DAIM lessons in the schools. Hence, I decided to use archived video and audio DAIM lessons of former master's students which I had helped to transcribe during my time as a research assistant in the SIKSP. There were four video and audio materials available. Three of the lessons were carried out as part of the in-service teachers' teaching practice, and one as an exemplar to showcase what is done at SIKSP during the visit of the Deputy Minister for Science and Technology, one of the funders of the SIKSP. I chose three of the lessons, watched them again, and reviewed the transcriptions.

I also gave the rating DAIM rating scale with the lessons to three of my colleagues to do a rating for the purpose of comparison. The percentage agreement was between 60 and 70%. It was not possible to review the perspectives and do another set of observations. So I used the rating scale and my prior experience to evaluate the DAIM lessons. After my analysis, I presented the result to one of the in-service teachers who could be reached for critiquing and validation. (One of the teachers could not be reached, and one had died a few years back).

3.6 Trustworthiness (rigour)

Terminology can sometimes be confusing, for example, some researchers use trustworthiness and credibility interchangeably in qualitative research as the equivalent of validity in quantitative research. Trustworthiness in this research is taken as the equivalent of rigour in quantitative research (Houghton et al., 2013). Validity is a very important but complex concept in research, and any research that lacks it is worthless. Many researchers define validity as 'the extent to which a measure accurately represents the concept it claims to measure' (Collingridge, & Gantt, 2008; Drost, 2011; Roberts, Priest, & Traynor, 2006). As such, the validity of data collected depends on the accuracy and appropriateness of the instruments, the research design and procedures, among many other factors. While the term *validity* is more common in quantitative research, qualitative researchers prefer to use in its place terms such as t*rustworthiness*, *dependability*, *credibility*, *meaningfulness*, and so on.

There are many types of validity; some of the most important types being content validity, internal validity, construct validity, and face validity. Content validity measures whether test items are representative of the content it is supposed to cover. This is usually evaluated through expert opinion. Internal validity concerns the viability of a causal link between an independent and the dependent variable (Bryman & Cramer, 2004; Hakan & Seval, 2011; Kimberlin & Winterstein, 2008).

Construct validity is a measure of the extent to which the measured variables actually represent the targeted construct the researcher wants to measure. It is a measure of the degree to which the operationalised construct is close to what was intended to be measured. Face validity on the other hand, is a subjective judgement of how a construct is operationalised.

In a largely qualitative certain terminology is more appropriate. Guba and Lincoln (1981, 1989) have provided some terminology as alternative terms to quantitative terminology used to determine the rigour of an inquiry. These are represented in the Table 3.2 below.

Table 3.2: Criteria for judging the quality of research

Quantitative research (rigour)	Qualitative research (trustworthiness)	Strategy employed
Internal validity	Credibility	Triangulation Member checks Prolonged engagement Use of peer debriefing
External validity	Transferability	Thick description Purposive sampling
Reliability	Dependability	Audit trail Code-recode strategy Triangulation Peer examination
Objectivity (free from bias, value)	Confirmability	Triangulation Practice reflexivity

Adapted from Anfara, Brown, & Mangione (2002)

3.6.1 Credibility (internal validity)

As shown in the table above, credibility is the equivalent of internal validity in quantitative research. Credibility is achieved in qualitative research by adopting certain techniques. Adopting these techniques increases the likelihood that the conclusions drawn by the researcher, and attributed to the various participants, match the constructed realities of these participants. The credibility of a qualitative inquiry can be increased by using techniques such as prolonged engagement, persistent observation, peer debriefing, negative case analysis, progressive subjectivity and member checks (Guba & Lincoln, 1989).

3.6.1.1 Prolonged engagement

Prolonged engagement means that the researcher stays a long time at the research site in order to understand the context of the study, and to build trust and establish rapport with the participants (Guba & Lincoln, 1989). As far as this study is concerned, I had been in the project attending workshops and seminars with all the other participants of the study for at least a year by the time I commenced this study. With some of the participants we had been interacting for

close to seven years in the workshops, seminars, conferences and even off campus. So there was much trust and interaction between the participants and me as we were almost like members of the same family.

3.6.1.2 Peer debriefing

The process of engaging with disinterested peers on discussions about the research process and findings in order to obtain searching, critical input to challenge the researcher to refine his methods or analyses. In this study, I was interacting and obtaining critical input from two postdoctoral students with whom we were sharing the office as well as the lecturers and the project director. This input helped me to rethink many times and either refine my methods or to change completely.

3.6.1.3 Negative case analysis

This is a process whereby the researcher searches for and discusses the data that do not support the patterns or explanations in place in order to arrive at a more refined explanation that takes the deviant case into consideration. After the interview transcriptions, I noticed one incident where one of the respondents expressed a view contrary to what most of the rest were holding. In a further interrogation, I got more insight which was very useful and has enabled me to bring the thought in by way of recommendations at the end of this thesis.

3.6.1.4 Progressive subjectivity

Progressive subjectivity is the process of monitoring the researcher's evolving constructions about the inquiry (Guba & Lincoln, 1989). This can be achieved by keeping a reflective diary where the researcher records his/ her constructions about what to expect from the period before the commencement of the inquiry till the end. I kept a record of the research in reflective diaries and from the time I started in 2016. What I am doing now has very little resemblance to the ideas which I had when I just started, from a highly positivist position to an interpretive constructivist paradigm.

3.6.1.5 Member checks

Member checks involves cross-checking preliminary data, preliminary categories, and interpretations with respondents or stakeholders. This may be formal or informal, and with one

or more participants. The formal member check is usually done just prior to the submission of the final research report. After transcription of the interviews, I sent the transcribed copy together with the audio file to each of the interviewees who were off-campus via email to edit and make any corrections and adjustments before I could use the corrected copies for analysis. Surprisingly, none of them sent back any corrections, so I assumed they had no problem with it. We shared offices with the project director and the lecturer whom I had interviewed. Since they were on campus regularly, very approachable, and we were meeting and interacting almost daily, I preferred meeting with them face-to-face for clarifications concerning the interviews in their offices.

3.6.1.6 Triangulation in this study

Triangulation is the use of multiple methods, sources or researchers to enhance the credibility or validity of research findings (Archibald, 2016; Goodrick & Rogers, 2015; Martinson & O'Brien, 2015). The underlying assumption giving credence to triangulation as a possible method of eliminating research bias is that since every source of data collection by itself has an inherent source of bias or error, the bias of one source is eliminated by using several sources. Triangulation can involve the use of several data sources (data triangulation), the use of more than one person in the collection of data (investigator triangulation), or the use of multiple methods (methodological triangulation), among others (Hussein, 2009; Krefting, 1990; Mathison, 1988; Torrance, 2012).

While triangulation provides evidence for the researcher to a make sense of the situation under study, it may result in more complex situations that the researcher must analyse before drawing any conclusion. Triangulation may result in three outcomes: convergence where the different sources of data point to one conclusion; inconsistency where the data from different sources does not point to any single conclusion; and contradiction where the data suggests contradictory conclusions about the object or phenomenon under study. Whatever the outcome, the researcher is supposed to apply reflexivity to make meaning of the situation in order to construct plausible explanations of the social phenomenon. This may warrant further investigation by the researcher in order to get a better understanding of the phenomenon before drawing any conclusion.

This study made use of data triangulation and methodological triangulation. The quantitative data from document analysis and questionnaire used with qualitative data from

interviews concurrently to provide a more comprehensive picture. In the study, each research question was answered using a combination of data sources, research instruments and the researcher's own subjective knowledge and interpretations. The table below shows a short summary of the research questions and the sources of data collection**.**

Table 3.3 Evaluation questions and data sources used in the study

Question	Data sources	Instruments	Alignment with CIPP model
What opportunities and challenges emerged for the SIKSP participants as they were being trained to implement a science-IK curriculum?	Project director, lecturers; in-service teachers	Interviews, Questionnaire, published articles	**Context/Input** evaluation
What were the participants' perceptions of the effectiveness and challenges of using DAIM as an instructional tool for implementing a science-IK curriculum?	In-service teachers; facilitators; lecturers; project director	Questionnaire Interviews; Reflective diaries;	**Input/Process** evaluation
How did the teachers apply DAIM in their classrooms?	SIKSP archives	Video/audio/ text analysis	**Process/ Product** evaluation
To what extent did SIKSP enhance the participants' professional development and ability to carry out science-IKS research?	Publications; Graduation rates; Case studies	Interviews; Documents; Questionnaire	**Product** evaluation

3.6.2 Transferability (external validity)

Transferability is the counterpart of external validity in quantitative research. Transferability depends on the degree of fit between the two contexts. It is achieved through thick description of the context. Since qualitative research is context-dependent, a description of the context enables a reader to compare his/her context with the one in which the research

was carried out in order to determine to what extent findings in the study could be expected to be similar to those in his/her own context.

3.6.3 Dependability and confirmability (reliability & objectivity)

Dependability or consistency is the equivalent of reliability in quantitative research. It is accomplished through a dependability audit. Confirmability, on the other hand, is the equivalent of objectivity. Confirmability in qualitative research is achieved by making sure that data can be traced to their sources and the logic used to interpret and synthesis the results into a coherent report is made explicit in the case study. Confirmability is usually achieved through the confirmability audit. In this study, confirmability was achieved by keeping the original data such as interviews and transcripts safe and using direct words of the interviewees in the findings before giving my own interpretive construction of the conclusions drawn from the data.

3.7 Data Collection, Preparation and Analysis

3.7.1 Data collection

As mentioned earlier, three instruments – a questionnaire, interviews, and document analysis were used to collect data for this study. I will next describe how I used these instruments to collect, process and analyse the data. The interview data was collected between June 2017 and May 2018, the questionnaire data between September 2017 and March 2018, and the document analysis between October 2017 and May 2018.

3.7.1.1 Data collection from the SIKSQ Questionnaire

The data from the questionnaire was collected in from September to November 2017. I sent the questionnaire to individual participants in the SIKSP group via the group email, appealing for individuals to complete it and email back their responses. After one month with no response, I sent a reminder to the group and also resolved to send the questionnaire to the participants individually. I made printed copies of the questionnaire for some participants who could not send the electronic versions to fill during our workshops. This paid off. Eventually, five of the participants used the printed versions. By November 2017, most of the members (18) had done so. The rest of the participants completed theirs by March 2018.

3.7.1.2 Data collection from interviews schedules

The interviews took place between June 2017 and May 2018. It was not easy to schedule an interview with some of the interviewees, so I used different approaches, depending on the situation. Four of the in-service teachers did face-to-face interviews but since many of the teachers and alumni were working in different areas of Cape Town, and some in other countries of Africa, I had to make some adjustments. During our seminars, I met and discussed with some participants and we agreed that I should send each of them the interview questions for them to answer at home and email the results to me later. I could then make a follow up interview so that the participants could clarify an issue which I did not understand, or to probe further.

I commenced the interviews on June 6th 2017 with the project director. This interview took place in his office and took 40 minutes. We agreed to continue on June 8th. I used an audio device – a *genx digital voice recorder* (with an inbuilt memory of 8 gigabytes) to record the interview. The second part of the interview took place on June 8th as planned and took 24 minutes, giving a total time of 1 hour and 4 minutes. We also agreed that I could come in whenever it was possible to ask for clarifications and follow up on anything I did not fully understand in the interview. The interview of one of the lecturers also took place in his office, which is just adjacent to that of the project director, on the 29th of June 2017 and took 59 minutes. The other lecturer was not on campus for some time, but we agreed with him that he would do a written interview and send me the responses by email, which he did.

I interviewed one other resource person in her office and also interviewed three participants in the conference room where we usually hold our workshops because it was quiet and separated and very conducive. During each interview I obtained the participant's permission to record our interview. I always recorded the interviews using at least two recording devices for extra security. It was not possible for some of the participants to come to campus, so I made arrangements to meet two of them off campus – one at her workplace, and the other at her home.

One of the respondents was in a South African city two hours by air from Cape Town, so we agreed to have telephonic interviews via Skype. We tried three times, and failed. Finally, he proposed, to my relief, that I should structure the questions and send to him to answer in

written form; and that I could follow up where I needed further clarification. This I did, and the problem was solved. After a few days, he emailed the responses to me.

The last interviewee was a professor in a neighbouring country to South Africa. We agreed to proceed with the interview via Skype. After several failed attempts, the interview finally took place May 4th 2018. We tried using the video option, but it did not work. So, we did the audio. As we started the interview, I asked and obtained her permission to record our interview, which she granted. I used two recording devises for extra security, in case something went wrong with one of the recording devices. One was a *genx* digital voice recorder which I had been using during the earlier interviews and the other was a tablet. The interview took approximately 34 minutes.

3.7.1.3 Data collection from documents

Document analysis took place over a period over a period of eight months, from October 2017 to May 2018. I examined the project records such as funding proposals, meeting attendances records, conference proceedings, IKS materials, graduation records, and end-o-year reports, etc. as mentioned in section 3.5.3 above. Each time, I jotted down any information that I deemed relevant to my study in a notebook. Whenever I needed any clarification of some information which I did not understand from the documents, I asked the lecturer or the project director, who were very ready to help. I also gave the DAIM lesson observation scale to three science education researchers to rate the archived lessons that were video- and audio-taped, with their transcriptions to rate the three DAIM lessons found in the archived documents. Then, I also went through each DAIM lesson using a priori coding (Saldaña, 2013).

3.7.2 Data preparation

3.7.2.1 Data preparation from the SIKSP Questionnaire

The data from the questionnaire were coded and then captured on two excel spreadsheet. The first sheet contained the participants' personal data such as biodata which was found on the first page of the questionnaire. The second spreadsheet contained the responses to the questionnaire items. All the codes were written in a notebook for future reference. The data were next transferred to SPSS for analysis.

3.7.2.2 Data preparation from interview schedules

After each interview, I immediately stored copies of the audio files in different storage devices, for example, my laptop, my office desktop computer, and two portable flash drives in order to avoid any embarrassment of data loss. Immediately after each interview, I would listen it many times with the help of headphones, in order to get familiar with the content of the interview even before I carried out the next one. I transcribed the project director's interview and that of the lecturer verbatim. Since the transcriptions were taking much time (more than five hours for an hour long audio file), I recruited someone to help me transcribe the rest of the interviews verbatim. In the next phase of the transcripts, I went over the verbatim transcriptions and deleted most filler words such as '*uhm, err, ummm'*, and repetitions in order to make coherent reading of the interviews. I also changed any names which could lead to the identification of a participant or the institution to a pseudonym or 'the university'. Also, I made corrections of some grammatical errors highlighted by the computer. The final transcript of the interview was then stored with the pseudonym of the interviewee and date of interview indicated on the file.

3.7.2.3 Data preparation from documents

The qualitative data from documents was mostly arranged into themes and sections in line with the research questions while the numerical data was extracted and recorded in form of tables, graphs. The aim was to arrange the data from these documents into forms that made it easy for triangulation with data from other sources to obtain a more holistic view of the case. The codes and themes from the observed DAIM lessons were arranged in tables and graphs.

3.7.3 Data analysis

The data analysis was influenced by the interpretive/pragmatic paradigm blend adopted for the study. The data were therefore analysed using qualitative and quantitative methods, with the qualitative largely dominating. In line with the conceptual framework and the research questions both descriptive and evaluative data were analysed from an insider position, and from the perspective of the participants. Reflexivity was built into the design of the research questions so that participants could carry out a reflect on practice (Schön, 1983) in the SIKSP.

3.7.3.1 Data analysis from the SIKSP Questionnaire

I used SPSS software to analyse the questionnaire data. The data from the excel spreadsheet were imported into SPSS and the analysis done using descriptive statistics option. Other descriptive statistical data were analysed using the Microsoft Excel programme.

3.7.3.2 Data analysis from interview schedules

As a first step in the analysis of the transcribed data, I printed it using double spacing of the Microsoft Word, landscape orientation and leaving a very wide margin on the right side of the paper so that I could use it to write words or short phrases when coding. Secondly, I read the transcript several times and began coding manually using a pencil at the beginning, then with pens of different colours later on. Thirdly, as more interviews were transcribed, I began to combine those of the in-service according to the interview questions and not according to participant. Thus for the in-service teachers' interviews, I combined all the responses to item one for all the teachers while maintaining the pseudonym of each participant alongside his or her response. I continued similarly for the all the items, and also for the interview transcripts of the two lecturers and the four facilitators. Fourthly, I identified the items whose responses would answer the respective research questions. Having done that, I proceeded to critically analyse the data in line with the research questions to do the coding.

I used thematic analysis (Braun & Clarke, 2006; Haven & Van Grootel, 2019) to come out with categories and themes. Thematic analysis involves identifying, interpreting and arranging sections of the coded data into patterns, and themes. In particular, the approach used to form themes was inductive analysis as suggested by Thomas (2006). According to him, in this approach the evaluator or researcher uses "detailed readings of raw data to derive concepts, themes, or a model through interpretations made from the raw data" p.238. My choice of the general inductive approach was because it is specifically tailored to answer evaluation questions. Although other methods of qualitative data analysis, for example, the constant comparative method, are more frequently used in most qualitative data analyses they are more general in nature. In the general inductive method, the evaluator looks in the text for core meanings relevant to the evaluation questions to identify the most relevant categories and themes that emerge from the raw data.

During the coding process, I used mostly *In Vivo* coding and descriptive coding. In Vivo coding is when the researcher or evaluator uses the interviewee's exact words as codes while in descriptive coding, the researcher uses a word or phrase to describe a chunk of data (Saldaña, 2013). I then combined the codes in accordance with identified patterns or categories and sub-categories to form themes using axial coding methods (Saldaña, 2013).

3.7.3.3 Data analysis from documents

As mentioned earlier, (see section 3.8.2.3), qualitative data from the documents were arranged into themes. The quantitative data were organised into tables, graphs or frequencies ready for triangulating with data from other sources to gain a more holistic picture.

3.8 Ethical considerations

Research ethics plays a very important role as it helps to curb the excesses of inhumane cruelty meted on vulnerable groups and animals in the name of research. The horrendous experiments carried out on human subjects such as those in the Tuskegee Syphilis Experiment (Johnson & Christensen, 2016; Lombardo & Dorr, 2006) and the Nazis clinical experiments (Schüklenk, 2000) point to the importance of ethical standards to guide research that involves human beings and animals. Ethical considerations form a very important aspect of this research, just as any other investigation in the social sciences, since human beings are involved. Adherence to ethical standards ensures that the research does not infringe upon human rights of the research participants nor results in physical or psychological harm. To ensure adherence to ethical standards throughout this research, I took a number of steps. These include:

- fulfilling the standards of the university ethics committee
- seeking prior informed consent of respondents;
- avoiding deception of respondents
- ensuring anonymity and confidentiality; and
- assuring respondents of their right to participate in the study voluntarily, and to withdraw at any time they so wished to.

3.8.1 Institutional research committee standards

Every institution of research has research and ethical standards by which researchers has to abide. This research, which is part of a larger body that has been going on in the School of

Science and Mathematics Education of the university, was approved by the Senate Research Committee after examining the methodology and ethical commitments (See Appendix A).

3.8.2 Informed Consent

I was privileged to work with colleagues in a research group of which I have been part since 2010. Since most of the participants were postgraduate students or researchers who had been involved with the project being evaluated, it was easy to seek their consent, although I had to do the written request to fulfill the demands of the University Research Ethics Committee (see Appendix A). The consent letter to the research participants explained the aims of the research, and explicitly acknowledged their rights to free, voluntary participation and withdrawal in case they wanted to do so.

3.8.3 Freedom from harm

Harm can be caused to research participants unintentionally; and could be physical, emotional, psychological or otherwise (Babbie & Mouton, 2001; R. B. Johnson & Christensen, 2016; Krefting, 1990; Ritchie & Lewis, 2003). It is required of every researcher to make known to research participants any harm that can possibly occur because of participation in the research. However, it is difficult to list all possible harm since some is psychological and personal, such as stress in filling a questionnaire or in responding to questions that involve some painful past experiences. In this research, I made known to the participants any possible form of harm that I knew about in the informed consent letter. Besides, all the participants were part of the project that was to be evaluated.

Some researchers (e.g. Johnson & Christensen, 2016) are of the view that deception of participants might be permitted in some instances when the benefit of the study outweigh the harm or deception. However, in this study there was no need for deception or compromise of ethical standards. The purpose of the research was clearly put on the informed consent for the participants to decide whether to take part or not.

3.8.4 Confidentiality and anonymity

Anonymity and confidentiality are very important in research. Without the guarantee of anonymity and confidentiality, participants could be reticent to express their feelings objectively for fear that they might suffer some form of punishment, if they express negative

comments in the study. Anonymity ensures that responses cannot be clearly attributed to the particular participant who gave the information and is often achieved by asking the participants to use codes or false names instead of their real names. However, in certain situations such as was the case in this study that involved a small sample and interviews, it is difficult to apply this principle strictly because the researcher or someone else has to interview the participants. Also, I needed to use the responses of the questionnaire to triangulate with interviews and the data provided in the self-reflective Questionnaire that had been used earlier. So it was necessary for participants to put their real names. However, in reporting, I used pseudonyms to conceal the identity of the respondents.

As a result, much emphasis was then placed on confidentiality or the non-disclosure of information provided by research participants. This means that the information provided by a participant could not be divulged to a third person, except my supervisor, without the permission of the one who provided it. The manuscripts of questionnaires, the audio tapes of interviews and video tapes were also securely kept in a safe cabinet. To ensure anonymity, the names of participants were replaced with pseudonyms to hide their real identities in the transcribed data.

3.9 Conclusion

This aim of this study was to evaluate the Science and Indigenous Knowledge Systems Project whose principal objective was to train science teachers on the integration of science and indigenous knowledge in their classrooms as required by government policy. The study was an evaluative case study situated within a blend of constructivist-pragmatic worldviews as a guiding, overarching framework. The evaluation study is largely from the perspective of the participants – project implementers as well as beneficiaries – some of whom have been part of the project since 2004. These perspectives were expressed through a questionnaire, semi-structured interviews and reflective diaries.

The study used mostly qualitative methods to analyse the data, although quantitative methods were also employed. I described the process of developing and validating the instruments, and of analysing the data collected to ensure trustworthiness criteria were met. As is the case with most largely qualitative inquiry, I made my background known in order to let the reader have an idea of the inherent influences that might have shaped my perceptions as I did interact with the data and research participants.

The research took place in four phases. First, I developed the instruments and validated them through formal and informal discussions, rating, and refinement. In the second phase I administered the instruments to collect the data. During the third phase, I analysed the data obtained from instruments and critically compared the results obtained from different sources as a means of triangulation. The final phase involved putting down the findings, discussing them, drawing conclusions, and making recommendations based on the findings.

Having described how I collected and analysed the data from the participants and documents, I will present the findings in the next chapter (chapter four).

CHAPTER FOUR: RESULTS AND DISCUSSION

In this chapter, I will proceed to answer the research questions posed in chapter one. The research is a retrospective assessment of the SIKSP by the project participants. For the sake of brevity, context evaluation is not a main focus of the study. However, I attempted to describe the context of the project in some detail in the previous chapters to enable the reader understand how it could possibly influence the rest of the results. The main focus of the study is on the input, process and product evaluation phases. For each research question, I will present the results from various data sources, using the participants' words as much as necessary, then followed by a brief discussion. For ease of reference, the research questions were follows:

1. What opportunities and challenges emerged for the SIKSP participants as they were being trained to implement a science-IK curriculum?
2. What were the participants' perceptions of the effectiveness and challenges of using DAIM as an instructional tool for implementing a science-IK curriculum?
3. How did the teachers apply DAIM in their classrooms?
4. To what extent did DAIM enhance the participants' professional development and ability to carry out science-IKS research?

4.1 Research Question 1. Opportunities and challenges for participants

Research Question 1: What opportunities and challenges emerged for the SIKSP participants as they were being trained to implement a science-IK curriculum?

This question is largely a context evaluation and to an extent, involves input evaluation under the CIPP evaluation framework. An assessment of the challenges faced by the in-service teachers defines their needs while the assessment of opportunities at the SIKSP enables us to understand the extent to which the participants believed that these opportunities were useful in solving their identified needs. A basic need of the in-service teachers was that they lacked the knowledge and skills to implement the science-IKS curriculum as demanded by the new curriculum. The SIKSP was to enable them to acquire the necessary skills to do so.

The first questions of the questionnaire (Appendix C, 1.1 -1.10) sought to know the perceptions of the participants about the usefulness of some SIKSP programmes and activities. The results are shown in Table 4.1. For the sake of brevity, I have reduced the rating scale from

four to two categories as follows: *not useful* (replaced *Not at all*, and *Very little)* and *useful (*replaced the last two categories – *Much* and *Very much*).

Table 4.1 Perceptions of the usefulness of the various SIKSP components

Perceptions of the usefulness of the various SIKSP components (**N=21)**			
Q1). To what extent were each of the following useful?	**Not useful f (%)**	**Useful f (%)**	**Null f (%)**
Q1.1 The Practical Argumentation Course	0	19 (90.5)	2 (9.5)
Q1.2 Bi-weekly workshops and seminars	0	21 (100)	0
Q1.3 IKS materials development sessions	0	20 (95.2)	1 (4.8)
Q1.4 National and International IKS workshops	1 (4.8)	18 (85.7)	2 (9.5)
Q1.5 SAARMSTE conferences	1 (4.8)	19 90.5	1 (4.8)
Q1.6 TAP	1 (4.8)	19 (90.5)	1(4.8)
Q1.7 CAT	0	20 (95.2)	1 (4.8)
Q1.8 DAIM	0	20 (95.2)	1 (4.8)
Q1.9 S. Africa-Mozambique IKS reviews	0	20 (95.2)	1 (4.8)
Q1.10. Advanced seminar lectures	0	21 (100)	0

During the training, the participants were exposed to many programmes and activities in order to help them acquire the necessary knowledge and skills to implement the science-IK curriculum in their classrooms. The taught courses or modules, and the advanced seminar lectures helped to provide the participants with the needed theoretical concepts such as the argumentation theories of TAP and CAT, the NOS, etc. The seminars and workshops were also platforms for the practical application of the theories and DAIM. The IKS materials development sessions, as well as the South Africa – Mozambique IKS Reviews Project provided opportunities for hands-on activities by the SIKSP participants.

The participants rated all the programmes and activities from 85.7% or higher. Taught courses at SIKSP such as the Practical Argumentation Course (PAC), were specifically designed to equip in-service teachers with the necessary knowledge and skills to implement a science-IKS curriculum. After the university's decision to stop course work, the seminars became the main platform for SIKSP members to meet, learn, and interact with one another. Every teacher rated the advanced seminar lectures as well as the bi-weekly seminars and workshops as particularly useful, each rated at 100%. Of the 21 participants, 19, that is, 90.5% found the PAC useful in helping them to achieve their purpose of learning to integrate science and IKS. From the rating, one can deduce that the programmes and activities were largely achieving the purpose for which they were designed.

In order to explore the experiences and perceptions of the in-service teachers further, I asked the following questions during an interview to eight of the in-service teachers:

In Learning Outcome 3 (LO3) of the new science curriculum, science teachers were required to integrate science and indigenous knowledge in their classrooms in order to make science more relevant to their learners. How prepared were you to implement this policy before joining SIKSP? What programmes and activities particularly helped you to know how to integrate science with IK in your classroom? What are some of the difficulties that you faced during your training? (See Appendix B4: Questions 1, 3, 4 ,5 and 6)

The responses of the eight participants interviewed revealed that all of them had used the DAIM in their classrooms. The analysis of the responses to the above questions resulted in the identification of some themes which are summarised in Table 4.1.2 below.

Table 4.2: Opportunities and challenges of participants (N=8)

OPPORTUNITIES	FREQ	%
Interactive classes through Seminars and workshops	8	100
Practical teaching approach through DAIM activities and discussions	7	87.5
Exposure through academic conferences and international IKS workshops	5	62.5
Practical hands-on activities through IKS materials development sessions	4	50
Exposure to new knowledge through taught modules, and IKS reviews	3	37.5
CHALLENGES	FREQ	
Managing work, family and in-service training	3	37.5
Difficulty grasping DAIM approach	3	37.5
Other personal issues e.g. health, finding sample, time factor	3	37.5
Financial difficulties	2	25

4.1.1 Learning opportunities of participants

4.1.1.1 Learning new, interactive approaches to teaching/learning

The area of IKS was very new in science education in the South African context, especially. Most teachers knew little or nothing about what IKS was, and to think of integrating it with science was almost unthinkable to them. Hence being involved in the SIKSP was a big

privilege to learn about this new area of knowledge and how to bring it to the science classroom through the DAIM as the teaching method. Before arriving at the DAIM, the Project Director had considered other approaches based on conceptual change. However, from his knowledge of IK since the 1980s, he settled on the argumentation-based strategy as the teaching model to integrate science and IK. One of the advantages of DAIM was its resemblance of the methodologies employed by many indigenous people where learning is communal rather than individualistic, and mostly involves dialoguing rather than written work. Modelling the teaching approach to include individual, small group, and whole class much resembles indigenous ways of problem-solving. Blending it with dialogical argumentation also makes DAIM resonate well with the ways scientists work. When I asked the Project Director why he chose the argumentation-based approach rather than some other, he said:

> **Prof**: *I had to articulate gradually the specifics of the Dialogical Argumentation Instructional Model. …through a lot of reading and thinking, … I have always been thinking about myself. I said yes, I do argue a lot in my mind in making decisions before I even consult somebody to talk; and then I can correct my views, and then modify it. And then, I can go to a larger group. It's also similar to how you work in indigenous places. You solve your personal problem, then you take it to the family, then you take it to the community, and then there is consensus. So, whether it's science or IKS, both systems are similar* [Prof, Interview]

Kenneth, the lecturer, also confirms how the method adopted at the SIKSP was novel, unconventional, requiring that the teachers should learn new ways of preparing lessons. He said:

> **Kenneth:** *The intervention also consisted with novel ideas of lesson design, and lesson implementation and practical work, where science and indigenous knowledge systems were integrated…. Yah! Well, I think looking at the project it was the workshops, seminars and conferences, and the establishing of writing of papers [that] was very, very significant in this engagement. Err… if I recall we… hum… we went through a series of two booklets of readings initially. The one was* ***The Nature of Science*** *booklet and the second one was* ***The Nature of Indigenous Knowledge Systems*** *booklet. And then, based on these, we had hum…. we had a number of conferences*

Yemie, a former teacher trainer in her late 50s, who was a postdoctoral student and mentor to many in-service postgraduate participants at the SIKSP, also deeply appreciated the DAIM as a method of integrating science and IK. She particularly appreciated the collaborative, unconventional ways of teaching people with widely diverse backgrounds.

> **Yemie**: *We had many different students, they had different needs, different abilities in SIKSP. And what we did was, we worked with them individually. We paired` off the …*

I can say the staff with student in writing papers for journals that helped the students. We paired off student and student and told them to collaborate and corporate and come up with papers which they would present at the conference….. so the students themselves even before they finished their masters had presented papers; a lot of papers in accredited conference proceedings …. That is one thing I learned; that you know, it is possible to work with somebody in order to impart skills than to teach those skills… So I learned that from SIKSP … SIKSP project is a very intimate group; has a very intimate group of people. They learned to work together, and they learned new things [Yemie, Interview]

Emma was also very positive about the contribution of the workshops and seminars to the learning process at SIKSP. These unconventional methods, in her view, made participants feel that they could contribute something during group discussions, and also learn from others collaboratively. She also saw the collaboration of the SIKSP and another project working on IKS as a profitable learning opportunity for the participants involved:

Emma: *I think they [the workshops] were very, very useful. And the fact that we named it 'workshops' not just normal classes, really helped because everyone, I think, felt that he could contribute something…. And because we extended SIKS Project with the* ***Mozambique and South African Documentation Project*** *– review of IKS and documentation, I could see even from the participants from Mozambique… Some of them are really applying what we learned from the workshops. …They are still applying skills, maybe, not the content, the themes, but the skills they gained from the workshops. They are still applying for presentation in conferences, writing papers, etc. So from my perspective, [the] workshops were very, very useful in terms of capacity building* [Emma, Interview]

4.1.1.2 Learning through hands-on science IKS activities

One of the activities that enabled teachers to gain practical experience on science-IK integration was the Saturday IKS materials development sessions beginning at 9 am and terminating at 1pm, with a break and a meal in-between these times. During these practical sessions the in-service teachers were involved with hands-on activities to develop IKS-embedded science lessons, write out strategies of teaching science-IK lessons, develop IKS materials for the different strands in the curriculum, write out exemplars of science-IK lesson plans, and so on. The purpose of these materials was to produce IKS materials in the form of resource books to support science teachers with examples of how to practically integrate IK in their classrooms. Although the materials were not yet published due to other reasons, they helped the in-service teachers to gain confidence in integrating science and IK.

An unplanned project, the South African-Mozambican Collaborative Research Programme, that involved researchers on IKS from two the two countries. This project involved documenting IKS publications in the two countries and was also very useful in enabling the SIKSP participants who took part in it to acquire skills of searching, summarizing and documenting IKS articles and other publications. The skills from this project could easily be transferred to other areas of research besides IKS.

4.1.1.3 Learning s through research conferences and workshops

Some of the things that had the greatest impact in the lives of the participants were the experiences gathered as they worked on research in the science-IK domain. Most of the participants, who were mostly primary or secondary school teachers at the time they joined the project, developed over time to reputable researchers. The participants were introduced to research in science and IK, and as they progressed to postgraduate level, they began to present research papers. First, they presented at the bi-weekly seminars, then, at workshops with collaborating institutions, and finally at peer-reviewed national and international conferences. In the interview, the Project Director disclosed:

> **Prof**: *When some of them attended the SAARMSTE conferences, they now saw me and my team members, who also were their colleagues, presenting papers. And that motivated quite a number of people, including those in the Department of Education* [Prof, Interview]

Kenneth also believed that the SIKSP project took research and development seriously. During his interview he said:

> **Kenneth:** *The other significant point of the SIKS Project was … to source funding so that we could equip students to accompany us, you know, to the to the conferences. And during the seminar time we managed to get them to collaborate on the writing of the papers, specifically in the area of the integration of science and indigenous knowledge system. Hum… and present the work, and get critiqued on the work so one could see how one contributed to the growth and professional growth* [Kenneth, Interview]

4.1.1.4 Learning new knowledge about science and IK.

Most of the participants who came to SIKSP were holding positivist, Eurocentric worldviews about the world and little or false notions about the nature of scientific knowledge

and of IK at the beginning of their studies. The SIKSP offered great opportunities for new knowledge about science and IK.

> **Prof**: *Well, at first I started thinking to integrate science and indigenous knowledge. You need to understand each of them, what they are. So I began to develop materials on nature of science on one side, and the nature of indigenous knowledge on the other. This is not my first experience in indigenous knowledge. I've been writing about indigenous knowledge since the 1980s. …So I started writing on indigenous knowledge; how to bring it in relationship to science. So if you read my articles in the '80s I started writing about IK. It wasn't popular at all anywhere in the world at that time. …. Very few people were interested; not to talk of South Africa here. So the organisation of it [SIKSP] was just based on teaching them the nature of science, and teaching them the nature of IKS* [Prof, Interview]

Teachers' beliefs are very important because they affect what the teacher does and how he/she does it. The SIKSP staff particularly targeted the in-coming participants' beliefs about science and IKS. These beliefs were questioned through two questionnaires which welcomed all new in-service teachers to gauge their conceptions of science and IKS before the SIKSP intervention. During his interview, Kenneth narrated how the in-service teachers were first introduced to the integration of science and IKS in the project.

> **Kenneth**. *Well, I think that the approach that was adopted by the project leaders and assistants was one of firstly, testing; … testing the initial stance in terms of indigenous knowledge systems. Then there was an intervention process of lectures, of introduction of theories, of socio-cultural approaches. So there was an intervention and then there was a post, uhm… a series of post intervention questionnaires. One thinks specifically of the questionnaires, … a questionnaire called The Nature of Science. So that was a pre-post kind of questionnaire. Then there was another questionnaire called* ***The Nature of Indigenous Knowledge Systems*** *which was also a pre-post kind of questionnaire. The third questionnaire was …* ***The Nature of Integrated Science and IKS Questionnaire*** *which looked specifically at the characteristics of indigenous knowledge systems and how they compare to the modern science characteristics. Yah! Then to answer the question more directly, there was a definite change because of additional evidence and information and a wider understanding. A definite change between the pre- ideas and then, of course, the post ideas. … So yes, it was interesting to work through these questionnaires. It was interesting to hear the discussions and debates around these questionnaires. And there was a gradual buy-in; into the concept of integrating science and indigenous knowledge systems* [Kenneth, Interview]

4.1.1.5 Learning through a community of practice

Meeting regularly every fortnight as a research group at the workshops had become the tradition of SIKSP members for many years. Although funding of the project ended in 2013/2014, most of the members continued meeting at workshops or during conferences. Many of them feel as if SIKSP is a family. The creation of the African Association for the Study of Indigenous Knowledge Systems (AASIKS) during the last SIKSP-organised IKS Conference in 2013 was an unexpected gift. AASIKS has continued to keep SIKSP members and alumni closer together through AASIKS-organised conferences which take place annually.

4.1.2 Challenges of participants

4.1.2.1 Challenge of teachers' beliefs about science and IKS

Most of the teachers and teacher trainers had false beliefs about the nature of science and IKS at the time they enrolled in the project. Due to their past training which followed the Eurocentric approach, school science was taken as what was in the textbooks and no other worldview could be deemed as being scientific. Science was also largely taken to be the truth, and not tentative or dubitable. On the other hand, most of the teachers had very little or no idea what IK was. In the interview, I asked them how prepared they were to integrate science and IK before joining the project. Some of the teachers viewed it as superstition or some kind of black magic, witchcraft, or similar things that could never be associated with science. The excerpts of the interviews may help to buttress the point.

> **Amanda**: *My knowledge of IKS and its integration was minimal before joining SIKSP. My whole world opened when I was introduced to IK and its relevance to our world and specifically my teaching.* ***Knowledge which my mother/elders had taught me was always only applicable at home as teachers never connected my two worlds****…* [Amanda, Interview; emphasis mine]
>
> **Zameka**: *Before I joined the SIKSP team I used to teach only what is in the textbook. I did not integrate IKS as I also didn't know how to; as there are not even examples in the textbooks that we use and there was never training provided on how to implement IKS. ...* ***I did not see the link between science and IKS*** *and always treated them as two separate entities* [Zameka, Interview]
>
> **Laura:** *I was not prepared at all [to integrate IKS]. [I] Had no idea what it was all about. I thought that indigenous knowledge was some kind of witchcraft. Also thought why do they want to add witchcraft in the curriculum? The terminology was totally strange to me. Never heard of it before* [Laura, Interview]

The interview with Ayanda, a physical science teacher in her mid-thirties, is typical of what other teachers experienced.

RES*:* *How prepared were you to implement the new science-IK curriculum?*

***Ayanda**: I was not prepared at all; as I did not even know the meaning of indigenous knowledge …Not at all*

***RES**: Ok, what were you doing?*

***Ayanda**: I mean you do nothing! If you don't even know what indigenous knowledge means, (laughter) then you'll do nothing as far as that is concerned and…*

***RES**: …Yah, … it means you just ignored the….*

***Ayanda**: (Interjecting) There was nothing to ignore because …. I did not know the meaning itself; and how crucial it was to integrate it with the science subject.*

***RES**: OK… so you just let it lie…*

***Ayanda**: Not to let it lie. It's that …when you're not aware of something then you won't bother with it …. Yah, yah…even the meaning of **indigenous knowledge** itself; I only learned about it when I was at SIKSP. … If you were talking **local knowledge** maybe it would be different…yah …The word itself, 'indigenous knowledge' was actually, … it was strange. It was foreign for me. …*

***RES**: When you heard that word 'indigenous knowledge', what came to mind, possibly?*

***Ayanda**: Nothing*

***RES**: Nothing?*

***Ayanda**: Nothing, nothing…nothing, much honestly, I'll be lying if I said something came.*

The challenging situation having to train science teachers schooled in the Western view of science and their partial or total ignorance of IK is succinctly painted by one of the lecturers, Kenneth, during the interview.

RES: *How* was the approach received by the incoming teachers, …when they came and heard about IKS?

Kenneth: *Well, first [there was a] mixed reaction. It was something new, it was something fresh. If one takes into account the teachers up till that stage were very much familiar and trained within the positivist science view, whereby science was learned and taught in order to get students through examinations and through the grades; with the intention of following more the modern science approach to understanding the different phenomena of science. Certainly, there was a lot of tension in the beginning because many of the teachers also were not necessarily from a rural area; and not necessarily taking into account or quite understanding what indigenous knowledge was all about. And so some saw it as a superstition; some saw it as witchcraft; some viewed it as something that shouldn't be in textbooks. They had never really seen it in textbooks*

before. And so the socio-cultural kind of background that many of them had was either a mythical kind of home background or it was from a religious believe system; religious background. So yah! I think that there was that skepticism. … And so it was quite difficult to engage. There were one or two of the attendees who participated, who were quite familiar with this aspect of work. [Kenneth, Interview]

4.1.2.2 Challenge of teachers' previous approaches to teaching

The teaching approach prevalent in South Africa before the socio-political changes of the mid-nineties was teacher-dominated rote learning. Following the reforms brought about in the new post-apartheid curricula, the teacher's role was expected to change to a learner-centred one where the teacher was to act as a facilitator of learning rather than an authoritative dispenser of knowledge. As teachers were still struggling to play such a rather supportive role instead of the dominant one they had known all along, it became difficult to adjust to the method adopted in integrating science and IK at SIKSP. During the interviews, the director pointed out that this was a big challenge faced by the in-coming teachers.

Similarly, Kenneth also confirmed during his interview:

> **Kenneth**: *In my case I did my studies to see how effective this integration was or how what Bandura says the efficacy of this integration by looking at some case studies of students and … it is probably a fifty-fifty kind of success rate. Mainly because at the workplace the environment is not clued in enough to this integration aspect and so schools are geared towards teaching for exams. Secondly there's always the syllabus that needs to be gone through and all the admin work needs to be done. So you'll find that where they, where they do, they need to press it in but it's not consistent and not part and parcel of the pedagogy. Thirdly there's new pedagogies and I think teachers are reluctant to actually go the argumentation route, the teaching and learning spaces that one creates in the classroom, because it's easier to give them the textbook route to talk and chalk. And the planning of these lessons I think is what teachers would grapple with. So our teachers come out of the pedagogy of engagement and looking at ways of integrating these authentic knowledges with science knowledge. But because they are junior in most cases, they fall into the same format that the schools have and that clearly is a is a challenge* [Kenneth, Interview]

In response to the interview question on the difficulties encountered when using DAIM, Fielding, a High School physical science teacher by then, had this to say:

> **Fielding:** *Very challenging… yah, in order to try to implement IKS in the classroom, it is, it is very challenging because, uhm,… people are very resistant to change, right? And especially teachers, err… myself being teaching using…. teaching the old method or making use of western science knowledge only is very comfortable, were comfortable*

because you're exposed to it and to incorporate IKS you had to read up a lot. You have to prepare; you have to be properly prepared…. The students, the students find it very interesting … colleagues on the other hand see it as extra work and some of them even view it as controversial because of the beliefs…. dominant belief systems or beliefs they have. And in terms of the principal and the superiors, they were more concerned about covering the curriculum content in the class. So that's what made it very challenging [Fielding, Interview]

4.1.2.3 Challenge of DAIM approach being more demanding on the teacher

4.1.2.3.1 Cognitive challenges of DAIM

The new teaching approach using DAIM is intellectually more demanding on teachers. First, they need to learn theoretical concepts of argumentation such as the underlying theories of TAP and CAT on which DAIM depends. It takes much time (approximately two years) to master these concepts and to be able to use them with a fair degree of confidence and to be able to apply them in the classroom. The Project Director confirmed during the interview:

> **Prof:** *Well, as I said, the first one is even to master what it entails; what DAIM entails. To really know what it is all about; since it is not the normal instructional approach… Yah, then of course the problems …Yes the challenges… Err… first of all it's using the theoretical framework of which students are not familiar. So it takes an average of two years for them to become comfortable with the theory, the underpinning theory, say, for example, Toulmin's Argumentation Pattern and the Contiguity Argumentation Theory which are the foundation, or foundational to the Dialogical Argumentation Instructional Model which drives the project. So it takes them… first of all, it's abstract…We are talking about constructs; and it takes a while before students get familiar with the arguments. What are the elements of arguments? And then you talk about perceptions, perceptual shifts, cognitive shifts, all these terms are pretty uhm,… abstract; especially in the absence of rigorous courses that we used to run before* [Prof, Interview]

4.1.2.3.2 Teachers' pedagogical challenges of becoming facilitators

Besides learning the new concepts associated with DAIM, the in-service teachers also had to learn the new approach of being a facilitator while the learners construct knowledge rather than being the dispenser of knowledge as was the case in the former teacher-centred methods. This meant a paradigm shift for the in-service teachers too. Transitioning from the teacher-centred to learner-centred approach was a challenge that the in-service teachers also had to deal with. Gwendoline, a Mathematics and Physical Science teacher and manager the

mathematics courses in a group of tertiary institutions at the time, narrates her experience as she started in the project and how much time she took to understand some of the concepts:

> **Gwendoline:** *So, only when I joined the SIKSP group, you know, I got to learn more about what indigenous knowledge is and how to do it. So it took me about a year to be honest it took me a year to understand what indigenous knowledge actually entails, … So right at the beginning I wasn't prepared at all; I just went about with the traditional. I was actually very against it. I was very resistant to change but as I said, after a year in the SIKSP group, I got to almost like fall in love (laughter) with indigenous knowledge and with the integration of it with science… whatever I'm, I'm, doing now, if I teach any topic even within my, my, own studies… I integrate it to what was known to the students, you know?* [Gwendoline, Interview]

4.1.2.4 Challenges of in-service teachers' school environments

The typical school environment is not really designed to support teachers using DAIM which is a learner-centred approach. Many schools are very much concerned with covering the official syllabuses rather than paying attention to inquiry processes that probably take more time, even if the learners gain more conceptual understanding of the concepts through such methods.

Fielding had a challenge adapting DAIM as studied at SIKSP to the real situation in schools. To him, the disparity between the university environment where he learned the DAIM method and the high school environment was so different that it required a lot of re-adjustments to cope in the actual classroom contexts in which the teachers work.

> **Fielding**: *I think one thing ... maybe the lack of trying to recreate the school set-up or the classroom set-up. Because during the workshops and during the meetings, we sometimes are not quite representing the situation well. Because when you go to the school environment then you are faced with different challenges ... So basically what I'm saying is [that] one of the great problems or challenge is that we didn't focus that much on trying [to] reproduce the classroom situation in order to see how effective the DAIM will work...* [Fielding, Interview]

4.1.2.5 Challenge of a change of university policy

The policy adopted by the faculty of education to require master's students to go in for full theses instead of coursework and a mini-thesis was seen as a very major challenge to surmount.

Prof: *In the absence of rigorous courses that we used to run before. Err that one stopped when the university now wants theses that will only be based on full theses, … and not those that are based on courses as well as mini theses. So mini thesis are funded but not much funding is made available for it. So the faculty will want research so these students can actually have full thesis. Now you don't do full thesis when you come to a field with very little understanding of that field. So that's a major, major problem* [Prof, Interview]

The same sentiment is echoed by Kenneth who claims that the change of policy was done for purely financial reasons:

Kenneth: *A mini thesis carries less financial support than a full thesis; so that was kind of the rational." Kenneth continues to lament the fact that although there were remedial measures put in place to sort of compensate for the loss of the course work, they were not so effective. The main remedial structures put up were the intensification of the seminars and teaching research methodology through the advanced seminar lectures. However, even though these measures helped to fill the gap left by the lack of course work, there were many drawbacks. Firstly, the workshops were not compulsory, so some teachers who needed them the most did not attend them as they were supposed to. Secondly, the duration of the bi-weekly workshops was much shorter than that allocated for modules. Thirdly, what the in-service teachers learned during these workshops were neither tested nor rewarded as was the case for the modules. Arguably, this led to the loss of the motivation that the examinations contribute to one's effort to study* [Kenneth, Interview]

4.1.2.6 Challenges involving in-service teachers' personal issues

In a typical situation where one has adults with families going in for professional development courses, there are many intervening variables that affect the lives and studies of the in-service teachers and teacher-trainers involved. Some of these factors include the issue of sharing time and resources between family, work and training, health, finances, just to name a few.

For Ayanda, funding, family and health were challenges she had to grapple with.

Ayanda: *Oh yah! The finance was a bit of a problem, uhm… although there was in the beginning there was err… a big problem with the finances but then obviously there was some support, financial support …the bursary, yes. NRF … Yes, yes, there was bursary and although there were times when we were in need, but it was not terribly financially but it was also time consuming because I had to also manage the family and the kids, you know? So it was not that easy; and also, it happened when my health was err… a bit weak. So that was also another, another uhm… challenge… yes, that I experienced. Otherwise, the study itself I enjoyed it a lot* [Ayanda, Interview]

Gwendoline had her own challenges of a different nature. At one time during her master's programme, she had to change her research focus and the research sample resulting in many personal challenges.

> **Gwendoline:** *Ok in my case, my difficulties…at first it was my .. situation. My personal situation changed, so I had to change my, err…, sample group, so I worked with different samples. Actually I exposed DAIM to a much bigger group of people; but that was one of my difficulties, … when I had to change my sample group. Uhm …and also to get into the schools, you know? That was also very difficult. You know after I've been out of the curriculum advisor, you know, [it] was quite, difficult to get into the school. But eventually uhm… you know, I got into the school …* [Gwendoline, Interview]
>
> **RES:** *So when you say one of the difficulties was to get into the system, what do you really mean*
>
> **Gwendoline**: *You know, to find schools or teachers to work with you. Because, you know, they didn't know what it [DAIM] was all about. And some teachers, they resist to change you understand? They don't want to … (I mean this is what I experienced) they don't want to learn new methods or maybe they don't have time or whatsoever. For the teachers just to commit themselves to my project, do you understand? That was one difficulty* [Gwendoline, Interview].

The duties surrounding in-service teachers can be overwhelming. These teachers are full-time teachers as well as parents with families. Studying at postgraduate level, doing research, attending seminars and workshops was a challenge expressed by several in-service teachers. Amanda, for example, said one of her main challenges was: "*Difficulties related to work commitments versus attending seminars and Saturday SIKSP meetings*" [Amanda, Interview].

The project director on his part, made mention of some of the challenges he had witnessed over the years in the project. Some of these challenges include attrition caused by mobility as well as financial and social problems

> **Prof**: *Many would start enthusiastically, then soon fade due to other demands because these are also teachers, so apart from personal and social problems they face funding at times even though they get bursaries it's not sufficient for their needs; and so many drop out because the other principals,… or they have more personal demands …though many of them are enthusiastic, not only the academic challenge for them but also the social challenges they face individually and …some of them are transferred from place to place. Sometimes they're transferred quite far from the place where they should be doing their research projects* [Prof, Interview].

4.1.3 Interpretive summary and comments

The focus of this question was the opportunities and challenges experienced by the in-service teachers during their training at SIKSP. The findings suggest that the designed courses, seminars, workshops, national and international conferences, research opportunities were very relevant to the in-service teachers' needs and provided them with many learning experiences. Through these experiences, the in-service teachers became more knowledgeable in the nature of science and IKS. They also gained skills to teach the more inclusive science-IK curriculum as demanded by the post-apartheid curriculum in South Africa. This suggests that the multiple strategies adopted at SIKSP, underpinned by the argumentation theories, were effective in bringing about the needed changes in the teachers' views about science and IK, subsequently leading to a change in their instructional practices.

The experiences at SIKSP offered unique opportunities through the use of argumentation theory using TAP, and CAT (Ogunniyi, 2007a, 2007b, 2011a). Dialogical argumentation has been well attested as a fruitful means of approaching scientific inquiry in science education as it permits learners to express their views or refine them on the basis of more convincing evidence, and to challenge opposing views (Grooms, Enderle, & Sampson, 2015; Macagno, 2016; Newton et al., 1999; Zohar & Nemet, 2002). Exposing in-service teachers to discursive, argumentation-based sessions during the seminars and workshops enabled them to engage in fruitful argumentation discourses, and knowledge construction similar to what scientists do (Mercer et al., 2004). One shortcoming of TAP has been that it is applicable to inductive-deductive informal logic. So CAT compensates for this shortcoming as it is applicable to a wider spectrum of situations, including the non-logical metaphysical discourses, which are possible in argumentation that involves IKS (Ogunniyi, 2007a; Ogunniyi & Hewson, 2008).

It took quite some time for the in-service teachers to begin changing their views and to adopt the new instructional approach of DAIM used at SIKSP. Exposing the in-service science teachers to new instructional practices and pedagogic tools did not change their previously held beliefs and instructional practices easily. In fact, studies have shown that teachers tend to teach the same way they were taught (Oleson & Hora, 2014). Other studies also show that changing a teacher's instructional approaches, especially those that had been used for many years, is very difficult (Davis, 2003; Martin & Hand, 2009). Since the in-service teachers had been using teacher-centred methods acquired since the apartheid era, they could not just abandon these methods so easily because they have relied on them over the years. Hence one of the challenges

was to enable a change of teachers' beliefs about science and IK. Research has consistently shown that teachers' beliefs do influence classroom practice (Bryan & Atwater, 2002; Fang, 1996; Pajares, 1992; Rubie-Davies et al., 2012). Furthermore, the change in teachers' beliefs is not just that simple, but is complex. It may need reflexivity where the teacher critically questions past actions, and collaboration with colleagues (Thornton, 2017)). In the case of the in-service teachers in this study, they needed to change from a Euro-centric, dominantly scientific worldview to a dualistic one that recognised IK as valid knowledge in the science classroom (Biesta et al., 2015; Gay, 2010; Hewson & Ogunniyi, 2011). For teachers who had known no other view other than the Euro-centric, positivist approach of teaching science, such a change was a major paradigm shift. This is where dialogical argumentation-based strategies became very useful. Many empirical studies have shown that argumentation-based instructional strategies were able to help in-service teachers change their views about the inclusion of IK in science classrooms, and to alter their classroom practices as a result (Hewson & Ogunniyi, 2011; Ogunniyi, 2007a, 2007b, 2013; Ogunniyi & Hewson, 2008).

4.2 Research Question 2. Participants' Perceptions of DAIM

> *Research Question 2: What were the participants' perceptions of the effectiveness and challenges of using DAIM as an instructional tool for implementing a science-IK curriculum?*

In the CIPP framework, this question is input evaluation where the participants express their value judgements about the main approach used by SIKSP to implement the science-IKS integration. In this question, I examine the perceptions that participating SIKSP members had about the effectiveness of DAIM as an instructional tool to implement a science-IK curriculum in science classrooms, as well as the challenges they encountered when implementing DAIM in their schools. For the purpose of triangulation, these perceptions of the in-service teachers, teacher trainers and post-doctoral fellows were captured using interviews, a questionnaire, and reflective journals. I will begin with the results of the questionnaire, followed by the interviews, and finally the reflective journals.

4.2.1 Participants' perceptions of DAIM from SIKSP Questionnaire results.

The training of in-service teachers to integrate science and IK involved many different activities (See Table 4.1). Question 1.8 of the questionnaire asked the participants to indicate how useful they believed the DAIM was. For the sake of simplicity, I will collapse the *agree* and *strongly agree* to *agree*; similarly, d*isagree* and *strongly disagree* will be collapsed to *disagree.*

Out of the 21 participants, one left this question blank while all the rest of the 20 participants were of the opinion that DAIM was useful in equipping them to integrate science and IK. Some items in the second section of the questionnaire that sought the participants' perceptions about DAIM (or argumentation that underpins DAIM) are shown in Table 4.2 below.

Table 4.3 Participants' perceptions of DAIM-related items (N=21)

Statement (D=Disagree; A=Agree)	D (%)	A (%)	Null
q2_13 DAIM could help learners know when to use science or IK	1 (4.8)	20 (95.2)	0
q2_14 DAIM draws from IK and scientific methodologies	1 (4.8)	20 (95.2)	0
q2_15 Argumentation enables learners to express their views	2 (4.8)	19 (90.5)	0
q2_16 Argumentation enables learners to construct knowledge	0	21 (100)	0
q2_17 Argumentation leads to acquisition of interpersonal skills	0	21 (100)	0
q2_24 Participation in DAIM practical activities helped me see science in IK practices	1 (4.8)	19 (90.5)	1 (4.8)

Table 4.2.1 shows the participants' perceptions of DAIM-related items. (It should be recalled that DAIM is the instructional model used at SIKSP, underpinned by the argumentation framework of TAP and CAT). A total of 19 or 20 out of the 21 chose Agree or Strongly Agree for all the items in the table. This means that they see DAIM as a useful tool to enable learners know in what context to use science or IK worldviews, to construct

knowledge, and to acquire interpersonal skills. Also, 19 out of the 21 participants (that is 90.5%) are of the view that their participation in the DAIM activities in the workshops and seminars helped them to better integrate science and IK.

4.2.2 Participants' perceptions of DAIM from interview schedules

The DAIM is the flagship of the SIKSP as far as integrating science and IK is concerned and everyone involved in the project views it in his or her own way. The participants' perceptions of DAIM were captured through the interviews and also through documents of the project; in particular, the reflective diaries of participants in 2012.

4.2.2.1 Perceptions of DAIM by the Project Director

The project director was of the view that DAIM was effective in enabling the participants change their perceptions of IK and science. In his view, many participants come for training with a largely positivist worldview of science and little or no knowledge of IK. After a few years in the project, they would have gained better knowledge of IK, recognising it as a source of valid knowledge. They would also move away from the dominant science worldview to a dualistic worldview that recognises school science and IK as valid sources of knowledge in the classroom. However, he admits that the change does not come quickly.

> **Prof:** *It took them an average of 18 months to 2 years to understand the argumentation processes underlying the DAIM. Toulmin's Argumentation Pattern (TAP) and the Contiguity Argumentation Theory took them an average of 15 months to 2 years to really have some confidence on what it is really all about.* [Prof, Interview]

The multi-pronged approach of using workshops, seminars, conferences, IKS materials development, etc. seemed to have paid off. The participants gradually learned new skills and adopted new instructional strategies in the process. However, the project director points out some challenges with respect to the in-service teachers' backgrounds and the working environment:

> **Prof:** *The first one [challenge] is even to master what it entails; what DAIM entails. To really know what it is all about; since it is not the normal instructional approach. For them to change from their old habits (from a teacher-centred approach) to a learner-centred approach; that's one big challenge. The second challenge is relating to their school environment. The administrative support is generally weak.* [Prof, Interview]

The Project Director further revealed that after surmounting the initial huddles of mastering argumentation and the DAIM, the participants were greatly transformed. They gain skills to integrate science and IK in their classrooms and also research skills in the area of science-IK integration. As he went on, many of the teachers had proceeded from honours degrees to master's and PhD's. In his words,

> **Prof:** *They have grown astronomically professionally. Academically, they are not the same type of people. Apart from promotion to other positions …. Headmaster, headmistress, …They are no longer the same people who came here a few years ago.* [Prof, Interview]

The Project Director disclosed that although DAIM was effective in enabling in-service teachers and teacher-trainers to gain knowledge and skills in integrating science and IK, the new university policy of changing from course work and mini theses to full theses with no supporting courses posed many challenges. As a result of the new policy, he said, the time taken for the in-service teachers to graduate increased because the in-service teachers did not have the necessary research background which the courses had been providing.

> **Prof**: *The only let down is that even the time to complete the thesis is now much longer than it would have been the case, because they did not have those opportunities to be exposed to the fields of maths and science education. They have to learn everything by reading, and as full time teachers, this is a great challenge for them. In order to compensate for the gap created by the elimination of course work, the project team devised some strategies to at least fill that gap. The bi-weekly seminars also included sessions of advanced seminars to teach research methods. However, the seminars do compensate at least, to some degree, to help them reinforce the things they are learning. Then of course, many of them go to conferences, and that also helps them to develop confidence, to develop stability in their understanding, and they are greatly enhanced, and so on, and so forth.* [Prof, Interview]

4.2.2.2 Perceptions of DAIM by the lecturers

The lecturers were of the view that the DAIM was effective in helping the in-service teachers and teacher trainers to acquire the attitudes, knowledge and skills to implement a science-IK curriculum. Salman put it this way:

> **Salman**: *The DAIM especially was useful to demonstrate to new audiences the inherent nature of IK – that it comes from within. Then during the sharing phase is when things fall into place with others that you are interacting with. …. The workshops and seminars served to concretise the conceptions of IK with practical examples and for*

participants to have a common idea of what this integration entailed and how to take it forward. [Salman, Interview]

Kenneth adds that the project helped to source funding for their training and research, train them to become researchers in IK and to develop resource materials to support science-IK integration, and also fostered collaboration with other researchers and institutions. By so doing, the project helped the participants to make progress in different dimensions - academic, professional and social.

> **Kenneth**: *And during the seminar time we managed to get them to collaborate on the writing of the papers, specifically in the area of the integration of science and indigenous knowledge system. Hum… and present the work, and get critiqued on the work so one could see how one contributed to the growth and professional growth- Professional growth and academic growth and social growth. The project helped this group of students as they went on their journey from very basic degrees right up through to the professional PhD's.* [Kenneth, Interview]

4.2.2.3 Perceptions of DAIM by the facilitators

Corrine, a retired teacher trainer shares her opinion of the project. She testifies:

> **Corrine**: *The most enriching aspect of my association with the SIKSP was to observe and participate in the development of young researchers and experience first-hand their transformation as confidant individuals and competent scholars. The association with students from other countries including Cameroon, Kenya, Ghana, Eritrea, Namibia and Mozambique generated a spirit of positive inclusivity and respect for the way different cultures solve their problems and yet highlighted the universality of the human condition and the importance of acknowledging and incorporating indigenous solutions when solving local or regional problems.* [Corrine, Interview]

Some of the facilitators also testify that they learned a lot from the SIKSP. The facilitators, just as the in-service teachers and other teacher-trainers had been trained in the conventional methods of teacher-training which did not explicitly recognise IK as valid knowledge, not to talk of integrating the two. Some of them had some ideas of valuing IK, but not putting IK at par with school science. Some of them acknowledged the gains they had made at the project. For example, Emma says that she had had interest in IK in the curriculum, and that coming to know about the Contiguity Argumentation Theory was very helpful to her. During the interview, she said:

> **Emma:** *I think they [TAP & CAT] both had their usefulness and their limitations as well. And in my understanding that's why we moved to a more sophisticated theory like, I would say, the Contiguity one. I would say they were very relevant. For example,*

Toulmin, I would say, was the basis for all other kinds of theories and ways we were trying to integrate indigenous knowledge in science classrooms. They are both useful but they both have their own limitations, and I guess even the Contiguity Theory might have its own limitations as well. Yah! They were useful. They were useful as a base to start this issue of integrating different types of knowledge. Of course, one of the limitations with Toulmin is …. It is either this or that. Like one argument will win, the other one will lose. While when we talk about contiguity, we are taking into consideration the context …. It's not a kind of war situation where one wins and the other loses. Yah. [Emma, Interview]

Furthermore, Emma acknowledges that the preparation of in-service teachers to write conference papers helped her to improve on her own academic writing skills, as she said in the excerpt below:

Emma: *We participated in so many conferences during the time in the project. I think (I am assuming), I have improved my own skills in writing papers to conferences and presenting papers because we did a lot in conference participation, in writing papers, co-writing papers. So that's one area in which I can say I learned a lot and improved my skills - writing and presenting at international conferences.* [Emma, Interview]

4.2.2.4 Perceptions of DAIM by the in-service teachers and teacher trainers

The participants recognized the role played by DAIM and the underlying argumentation theories of CAT and TAP in helping them understand IK and its integration with science. Here are some excerpts to serve as examples:

Gwendoline: *What also assisted me is the fact that I also got to learn about this theoretical framework, the CAT and the TAP. The argumentation Pattern, the argumentation pattern and uhm … Ogunniyi's CAT framework, when I first understand that as well. That also assisted me in, you know, in integrating my science with the IKS*. [Gwendoline, Interview]

Laura: *What I enjoyed most was the DAIM activities. It assisted me to integrate science and IK in the classroom through language. It made me more aware of the different cultures and how I can learn from them.* [Laura, Interview]

Albert: *I would say the dialogical argumentation [instructional] model was ,uhm,… the argumentation model that was presented to us how to argue and how to extract, that was actually, uhm,… even also a lightbulb moment. How to extract knowledge in a classroom environment, in a group environment, in group dynamics to get to a point where you can say, err, we've reached now a cognitive organisation, we've reached an area where we all agree. Whether we agree to disagree, or whether we agree to agree,*

we now on the same level. You would say yes I do understand your background of how you process or came to that conclusion, scientific conclusion because your thinking pattern is like that and my thinking pattern or background is like that, but we've come to a conclusion, you see. .... So we put everything together in one pot and we brew it and out came something new. So, it's not on the one side that you, you would say you love or like IKS, and you supress the western kind of science. The two work together… Yah. [Albert, Interview]

4.2.3 Perceptual shifts experienced by in-service teachers and teacher trainers

To gauge how the in-service teachers' perceptions might have changed (or not), I asked them the following questions during the interviews: 1) *How prepared were you to implement the science-IK policy before coming to SIKSP? 2) How prepared are you now?* After being exposed to the DAIM and related activities, many teachers changed their perceptions of science, IK, and the integrated science-IK curriculum. Whereas many of the teachers coming into the project with dominant positivist views did not see any relation between science and IK, all of them changed to a more liberal view of knowledge that acknowledged IK as valid knowledge that could be used alongside school science in the classroom. A few examples are given below to illustrate the point.

Amanda

Before: *My knowledge of IKS and its integration was minimal before joining SIKSP… I thus had no idea of content or methodology to implement IKS.*

After: *I feel so much more equipped to manage IK integration in my lessons as I have a more adept view of content and methodology to implement. I also integrate my new learning into all subjects I teach … as the IK and methodology is applicable across subjects.* [Amanda, Interview]

Zameka

Before*: Before I joined the SIKSP team I used to teach only what is in the textbook. I did not integrate IKS as I also didn't know how to as there are not even examples in the textbooks … I did not see the link between science and IKS and always treated them as two separate entities.*

After*: After being part of SIKSP I am now confident in teaching a science-IK lesson. I am able to come up with ideas to make IK part of my science lessons. I have learned that lessons are enjoyable for the learners when you bring in aspects that they are used to in lessons.* [Zameka, Interview]

Laura

Before: *I was not prepared at all [to teach IK]. Had no idea what it was all about. I thought that indigenous knowledge was some kind of witchcraft.*

After: *The workshops totally changed my mind-set and enlightened my worldview. I started to appreciate my heritage from where I come much more. The workshops inspired me to read up more about IK from the Zulu culture as well as other cultures. [Laura, Interview]*

Ayanda

Before: *I was not prepared at all as I did not even know the meaning of indigenous knowledge.*

After: *At least now I have been exposed to enormous information that I can use in class and I am able to integrate now these two epistemologies in order to make science a meaningful subject. So it's better, it's much better than before because the learner can take something that they learned at home or that they bring from home and they can always use it to learn the concept of science in the classroom.* [Ayanda, Interview]

Fielding

Before: *Yah…Initially, before I was exposed to the SIKS Project, I had limited knowledge of IKS…In fact, I barely knew about indigenous knowledge systems.*

After: *Yah, now after... about seven years. [After] seven years' involvement in the project, I believe that I am quite confident in trying or explaining indigenous knowledge concepts to students. Yah! Uhm… so to reflect basically, … there was quite a growth from when I started the project; when I started being involved in the project and where I am now.* [Fielding, Interview]

Gwendoline

Before: *To be honest when I first started the science and indigenous knowledge I didn't have a clue what was meant by indigenous knowledge until I actually joined the SIKSP group. I wasn't prepared at all... I was actually very against it [IK]. I was very resistant to change.*

After: *As I said, after a year in the SIKSP group, I got to almost like fall in love (laughter) with indigenous knowledge and with the integration of it with science… I think I'm very prepared [now]. I'm still open for any learning but I think I've got now a much better understanding of what science and indigenous knowledge is. So, I don't go into a class without relating that specific topic to the real life situation of the students…I try to always relate it to their situation. So I think I'm very prepared now.* [Gwendoline, Interview]

Sarah

Before: *When I came in, to be frank, the first time I did not have much knowledge about what indigenous knowledge was. So the first one month or two months I was a bit confused.*

After*: But through time, the lectures Prof was providing and the discussions amongst the members of SIKSP helped me to know, at least to have a basic understanding of what indigenous knowledge and indigenous practice is…. So at least I have realised that there are some similarities between IK and science; although there are also differences. … Yah,… now I know that it [IK] has value.* [Sarah, Interview]

From the foregoing excerpts, one can conclude that the DAIM activities that took place in the SIKSP had a very positive effect on the teachers' knowledge of IK, and their abilities to implement a science-IK curriculum.

4.2.4 Teachers' experiences of using DAIM in the classroom

To gain insight into the experiences of the in-service teachers and teacher-trainers (henceforth participants) as they tried to implement the new teaching approach (DAIM) practically, I interviewed eight of them who had taken part in the project. The questions I asked were the following (see Appendix B4, Questions 4&5):

> **RES:** *Have you ever tried to implement the SIKSP method in your classroom or school practically? [Yes/no].* ***If yes,*** *what were the* ***reactions*** *of your learners, colleagues, or principals when you used DAIM as a teaching approach in your classroom? What are the practical difficulties encountered when implementing the DAIM?*

All eight in-service teachers interviewed admitted that they had used DAIM in teaching. In the interviews, they shared their experiences of using DAIM to teach in the classroom, including the challenges they encountered. The various themes from the interviews are indicated in Table 4.4

Table 4.4 Teachers' experiences with DAIM in the classroom (N=8)

Positive experiences	FREQ	%
More active and excited learners	8	100
Interest in DAIM by other teachers	6	75
More complex learning with DAIM	5	62.5
Administrators interested the interactive classes	3	37.5
Challenges	FREQ	
Time factor	7	87.5
Lesson planning	7	87.5
Classroom management	6	75
Pressure to complete syllabuses	3	37.5
Initiating learners to start participating	3	37.5
Large class sizes	2	25
Unpredictable outcome of argumentation lessons	2	25

4.2.4.1 Teachers' experiences of using DAIM in science classrooms.

The most prominent experiences reported by all participants as they tried to use DAIM to implement the science-IK curriculum in the classroom were excitement, increased interest and active involvement of the learners. The DAIM approach, it should be recalled, gives time for the learners to start by reflecting on the question or whatever matter is to be discussed alone (intra-argumentation). Then the next step is to move to small group discussions where each learner expresses his or her viewpoint as a claim and defends it by giving the reasons to justify the claim. This is so different from the normal classroom where the teacher talks most of the time in an attempt to pass on scientific facts to the learners. The reports suggest that the participants experienced many types of encounters as they implemented DAIM. Some examples may help to buttress the point.

Amanda, a grade 6 teacher, is in her mid-40s and has been teaching for over 25 years. When she used the DAIM in her classroom, the learners were first sceptical as it was very unusual for learners to be talking and arguing in class in the teacher-centred methods that are prevalent in the schools. She admits that they soon got used to the new approach, and since

then, "*they simply loved the fact that their views and opinions are valued.*" [Amanda, Interview]

Zameka is a physical science teacher in a predominantly black school in Cape Town. Having enrolled in the SIKSP since 2009, she has been using DAIM to teach her learners. She said, "

> **Zameka:** *I did [use DAIM] and also as part of my master's data collection process. I am still using it as part of my teaching strategies. The learners reacted very positively and are performing much better. They now look forward to lessons as they say they are more interesting and they get to be part of the lesson than just listening to the teacher.* [Zameka, Interview]

Laura is a 59-year-old lady with over 36 years of teaching experience who was teaching grade 3 learners (8- or 9-year-olds). She was very sceptical about using argumentation with learners of her grade, believing that they would not be able to apply the method meaningfully. However, she wanted to try it as part of her master's programme. When she used the DAIM, she reported that:

> **Laura**: *The learners were extremely excited and their language improved tremendously. They were able to express themselves more easily and were not afraid to make any mistakes. They learned to listen attentively and they became more focussed in their school work. They enjoyed the fact they were not passive learners but were actively involved.* [Laura, Interview]

Another teacher, Ayanda, was teaching grade 9. She said her learners were also very excited and active when she introduced DAIM.

> **Ayanda**: *Oh! They will be excited; they will debate and argue a lot, it will be a long debate. Why this? Why that?... because most of my learners were coming from different backgrounds, so it did create a lot of arguments which were good arguments. Some would obviously come with criticism, good criticisms but it was part of learning; especially if you were talking about traditional medicines and how they cure, how they do this and the others will be like ooh a-a that is* ***muti [black magic].*** *That is when I had to intervene and say "not all herbs are* ***muti,****" you understand? So it was not easy but it was worth it, because at least it would create that… ability for learners to argue and debate.* [Ayanda, Interview]

Gwendoline has also recently got involved in the use of DAIM in teaching. She used it with teachers and learners as well. In either group, she says there was excitement.

> **Gwendoline**: *The teachers were very excited especially when I did my master's thesis, my research. I've done it with a group of teachers. They were so excited about the way I just compared that simple component of a capacitor, so they enjoyed it as well as the*

students and it made … I must say that I got very good feedback, excellent feedback from both the learners and teachers. [Gwendoline, Interview]

From the excerpts cited above, one can conclude that the application of the DAIM to integrate science and IK in the classroom led to many experiences as the method was new and full of active learning, requiring personal and collective participation by learners. However, after they get over the initial fear and reservation, they would want to talk and talk. They found the new method of instruction more exciting as they could freely express their views and opinions about any topic being discussed.

Teachers and school authorities expressed mixed reactions to in DAIM. While some of them admired the interactive nature of the student-centred approach, others disapproved of the DAIM approach. The most common reasons given by those who rejected it were that it took too much time and also, the noise levels during the classes were too high.

Amanda reports that:

Amanda*: My colleagues are also enthused by this new approach which fosters constructive discussions and critical thinking amongst learners. Some have taken to investigating IK which they can integrate in their lessons and they are attempting regularly to employ argumentation as a method of teaching and learning*. [Amanda, Interview]

On the other hand, Fielding sees the implementation of the DAIM approach "*very challenging*". According to him, the challenge is due to the fact that many teachers are resistant to change. They are comfortable with the methods which they had been using for many years and would not like to change them. He further explains that many teachers do not like to read a lot, so they would not like to go through the readings they went through in order to feel comfortable with DAIM. They see DAIM as extra work, which to them, is unnecessary. The principals and other administrators also have their own misgivings about DAIM. As Fielding reports,

Fielding: *The principals and their superiors were more concerned about covering the curriculum content in the class. So that's what made it very challenging*." [Fielding, Interview]

Fielding also said that when he mentioned to them the alternative, or the DAIM approach of teaching and bringing IKS in, initially their reaction would be quite positive. They would see it as a good idea. But when they got the experience or a deeper explanation of how DAIM works, how the instruction within the classroom had to change, they would become a bit

resistant because their main concern was to cover the curriculum content which would be assessed in official examinations.

A similar experience was reported by Sarah who taught the argumentation-based approach to a group of pre-service science teachers in Eritrea. She faced this problem when the pre-service teachers went for teaching practice in the schools. They were taught to use the argumentation-based instructional approach instead of the traditional teacher-centred methods prevalent in the schools.

> **Sarah:** *In terms of schools there were some problems in some schools. I mean the school directors ask like "Why are you taking a lot of time? Why are you using this method? Why not use this [different] method? They were like asking the pre-service teachers during the teaching practice time in schools. Some of the directors and department heads were supportive. Few of them were not really supportive and they were saying, "Why are you spending much of our time? Why not focus on the exam orientated thing? Why are you focusing on discussion only?" Things like that. But …majority accepted it positively.* [Sarah, Interview]

Laura reported that when she used DAIM, the learners were able to construct more complex learning experiences and developed more critical thinking attitudes.

> **Laura**: *The fact that they were able to ask me questions and agree or disagree with any of my claims by providing valid reasons made every minute in the class worthwhile for them. They started to read more often and came to class with topics which they wanted to discuss in groups in the class. They became more confident and also started to use the DAIM terminology during breaks while playing.* [Laura, Interview]

When Laura used DAIM, the reactions of here headmaster and colleagues were first, a surprise. They were surprised at the level of interaction and argumentation that the grade 3 learners were capable of.

> **Laura**: *The principal and other teachers were surprised that young learners were able to argue to such an extent. They thought it was never possible but realised that it can be done. They wanted me to do such a lesson in their own class, to compare their own class reaction with mine. However, the results were more or less the same. They came to the conclusion that this approach is the way forward. Some teacher's felt that they don't have the time to use this approach as it is too time-consuming.* [Laura, Interview]

Fielding also reported that when he used DAIM, the students found it very interesting because it was like you opened their minds – their worldviews in terms of things that they knew existed but they didn't know how it relates to what they were studying in the class. So they found it interesting.

The experiences of the in-service teachers as they used DAIM in the classroom were very positive, with the learners becoming more active rather than passively waiting for the teacher to deposit knowledge into their empty minds. However, the teachers also reported some challenges encountered when they were using DAIM.

4.2.4.2 Teachers' challenges of teaching using DAIM

4.2.4.2.1 Challenge of DAIM lesson planning

An aspect that demanded much time, creativity and skill to accomplish was how to make a good lesson plan to teach both science and IK in the same lesson. Many teachers testified during the interviews that this was a real challenge during their attempt to implement DAIM. Some excerpts illustrate what they said. For example, Laura said, "*Planning the lesson and activities were very time consuming"*

Albert, a teacher who had been in the project for over seven years at the time, stressed on the necessity of good content knowledge, good lesson planning, and an openness to surprises by the teacher who wants to successfully use DAIM as a teaching approach.

> **Albert:** *DAIM? You need to be prepared …You need to know your subject…Content … Yah. You need to. You can't just pick something from the air, then start talking about it and don't have err… back up or, information that you can back up, you know? Because dialogical argumentation is based on Toulmin's, uhm … argumentation. And Toulmin is saying you need to have, … to give evidence, you need [to know] if there's a rebuttal, uh … you need to back it up. If there's certain warrants coming you need to back it up with evidence. So from a teacher's perspective, there's a lot of … I would say planning that goes into it. You must know your subject content. You must know your way forward; how to argue. And you must be able to have an open ear to listen to others. You mustn't be the one track kind of … I would say, teacher or educator; where the teacher is the only source of information. Your learners, your students or whoever it might be in front of you; they come with vast amount of knowledge which we call home knowledge to the school, to the classroom. And if those are some of the practical implications, you need to plan ahead… Lots of planning and sometimes you don't always get the outcome, [the] required outcome. …What you've planned. But that's the reality.* [Albert, Interview]

4.2.4.2.2 Challenge of DAIM classroom management

The task of classroom management was reported to be more demanding on the teachers since DAIM permits learners to express their opinions during classroom discussions, and to argue in support of one view or against it. This process makes the class rather noisy compared

to the commonly practiced teacher-centred methods of teaching. Some of the teachers disclosed during the interviews as follows:

> **Zameka:** *The learners get really excited during the lessons and don't want to stop talking. The teacher has to make sure that everyone gets a chance to say something. DAIM makes lessons take a bit longer than normal chalk and talk lesson and that makes teachers to be a bit behind with the syllabus*. [Zameka, Interview]

> **Ayanda:** *Yah, yah! The noise and it was also time-consuming cause you have to prepare on time, it needs a proper… uhm … a lot of preparation. Yah! And the noise levels obviously would be increased… I never had much of a problem, honestly. Although when we would talk about it in the staff room some would say, yah the problem is uhm the noise (laughter) not that they were complaining against me but they would say it … causes noise. When they try it there would be some noise in the class, then … I think it needs you to be in control as a teacher, when things go out of hand you need to be in control …yah.* [Ayanda, Interview]

4.2.4.2.3 Initiating participation in DAIM classes

For some of the teachers, it was challenging to initiate discussions as the learners are not used to this state of affairs in their schools where the transmission of information dominates. Some teachers reported that as they started to implement the argumentation-based strategy of integrating science and IK, the learners were first sceptical or shy to express themselves since this is not the usual mode of instruction they experience.

Amanda said in her interview:

> **Amanda:** *At first they were sceptical, as is any person faced with new methodologies, but they soon warmed up to implementing argumentation and group work into their modus operandi in class.* [Amanda, Interview]

Gwendoline one of the teachers who had a similar an encounter said:

> **Gwendoline:** *The difficulties were…. first, to get them [learners] talking. …. because our students or our learners aren't used to having discussions in science and maths classes, …. so just to get them start talking… I think that was my biggest challenge, you know. Even with the teachers as well, just to get them to start talking about a specific topic or argue in a good way. But as soon as those discussions, you know, started it went very well. But that was the challenge, just to get them start going, you know, just to get them to start talking about whatever they are learning*. [Gwendoline, Interview]

Sarah, a science education teacher trainer also had a similar experience as Gwendoline when she used DAIM with her preservice students in an East African country where she taught for some time during her doctoral studies.

Sarah: *As I told you in the beginning it was not easy. It was not easy because they know what learner centre approach is because they have been taught in other education process, but this DAIM approach is new because they have never heard about it even, they have never heard of it… for the first two-three days that we were contacting, but through examples, through modelling things start to they became very interested to know more about it. So it was not easy to adapt it, but through the mmm …. through what you call it? Micro teaching. The micro-teaching, the reflection sessions, and the discussions [which] we had` after each classroom observation helped a lot.* [Sarah, Interview]

In some of the schools, the number of learners in one class is very high. In such cases, the teacher might find it more challenging to use DAIM. Amanda who was teaching grade six learners at the time, had such a problem. She said in her interview:

Amanda*: Class sizes does equal a fair amount of 'noise' and classroom space to move is always a challenge because we have 40 plus learners in a classroom".* [Amanda, Interview]

4.2.4.2.4 Challenge of time constraints and pressure to cover syllabuses

A typical DAIM lesson takes more time to prepare and to carry out as all the participants revealed during the interviews. For example, Zameka said:

Zameka: *The learners get really excited during the lessons and don't want to stop talking.…. DAIM makes lessons take a bit longer than normal chalk and talk lesson and that makes teachers to be a bit behind with the syllabus*. [Zameka, Interview]

Laura confirmed the issue of time when she said, "*Planning the lesson and activities were very time consuming"*

Teachers and the school system in general, are under enormous pressure to complete syllabuses paced out to them by education authorities. There is therefore the constant dilemma to choose between teaching for good conceptual understanding or completing the syllabus as stipulated by the highly placed education authorities. In such instances, most administrators would prefer that teachers cover the syllabus.

Fielding pointed out this challenge in his interview:

Fielding: *The main obstacle or the main problem is the time constraint. Time constraint because it's the first time; especially when is the first time I try to implement it. You first have to induct the students in terms of this type... the dialogical argumentation instructional model. You first have to explain to them what is it all about, and they have to buy into it to understand basically what it is. So that was time-consuming; and then*

you also have to basically kind of redesign the content to make it more, to include the dialogical argumentation aspects within the lesson. So preparation was, is also the other challenging factor. You have to prepare beforehand, which takes up time. And then, because it's more learner-centred or student-centred, it also requires a teacher to be a facilitator; to facilitate effectively, to make sure that the different elements of DAIM are addressed. [Fielding, Interview]

4.2.5 Participants' perceptions of DAIM from reflective diaries

The reflective diaries were a series of questions to which the project participants responded towards the end of the final phase of the project, in 2012. Every participant responded, except the project director. DAIM, which is the teaching approach used at the project, is used here rather loosely, to include everything that involved the argumentation-based activities such as workshops, seminars, etc. and the underlying theories of TAP and CAT.

4.2.5.1 Perceptions of lecturers from reflective diaries

To the lecturers, DAIM was a means of bringing together different knowledge systems which could not have been done without it. For example, Kenneth said "*The frames have helped to define more clearly the interconnectedness of dichotomized knowledges and worldviews*". Salman agrees with this view, but adds the critical role played by the lectures and practical experiences during the workshops in enabling him to more comfortably use argumentation as a teaching strategy: *The lectures and experiences have indeed played a role in making me more comfortable and at ease in using argumentation as a teaching strategy*." Kenneth particularly appreciates the value of CAT in the integration of science and IK: "*The CAT framework contributed … to understand the flexible state of the mind of people as they navigate through belief, culture and religion.* [Kenneth, Refl. Diaries]

While acknowledging the usefulness of DAIM, Salman cautions that each teacher ought to arm himself or herself with other teaching strategies besides argumentation because there are instances where the argumentation-based instructional approach might not work. "*Argumentation might not work in every kind of lesson and we need to use multiple strategies within the same lesson to keep learners interested and stimulated*." [Salman, Refl. Diaries]

4.2.5.2 Perceptions of facilitators and teacher-trainers from reflective diaries

Some of the facilitators and teacher trainers in the group who came in with a largely positivist notion of science and almost total ignorance of IK perceived DAIM as the means of their changing perceptions. Donga, a 50-year-old mathematics education teacher-trainer from a collaborating Cape Town university admitted that before joining the SIKSP, he doubted if IKS had any role to play in contemporary life and the science curriculum. After attending the workshops and seminars he now said:

> **Donga:** *I have grown to understand that knowledge from both IKS and modern science are all the same. … [the] two knowledge systems can actually co-exist." Sarah, a 45-year-old teacher-trainer who was pursuing her doctoral degree indicated that she was totally ignorant about what IK was when she came to SIKSP in 2012, but admitted "The exposure I got in the seminars helped me to appreciate the efforts and creativity of our ancestors and their practices.* [Donga, Refl. Diaries]

Some of the participants who had been exposed to DAIM and had seen it practically applied in the classroom were convinced that DAIM was a viable approach to integrate science and IK. Yemie, a postdoctoral fellow, in her mid-60s, after observing a number of in-service teachers apply DAIM during their teaching practice, and grade 8 learners involved in argumentation lessons, said:

> **Yemie**: *I have come to the conclusion that the use of dialogical argumentation in the classroom is very effective method for teaching any subject, especially science, in contiguity with IK…. discovering in practical ways, the way contiguity argumentation can be used in the classroom opened my eyes to the fact that argumentation is the most appropriate vehicle for the achieving the mandate to integrate science and indigenous knowledge*. [Yemie, Refl. Diaries]

Corrine, the retired teacher trainer who admitted that she had barely treated IK as an anecdote, revealed that her experience with DAIM changed her perception of how to integrate IK and science.

> **Corrine:** *The IK information that emerged from argumentation exercises during workshops gave quite a different perspective. .. Argumentation as a teaching strategy to initiate discussion and reveal participants' cultural perspectives, common sense knowledge or alternative ideas about science has been very illuminating and a way forward for implementing meaningful science and acknowledging indigenous knowledge.* [Corrine, Refl. Diaries]

To those who already valued IK before joining the project, DAIM helped to clarify things further. For example, Emma said "*No doubt the CAT theory I came to familiarize my self has grandly helped me to bring coherence to the idea of teach IKS…. I feel encouraged to think critically about CAT, and I am satisfied.*" Edmund added, "*When I joined the SIKSP project, I was already familiar with some of the issues. …. What I found new and intriguing, was the inclusion of argumentation as a vehicle towards Science –IKS integration. …. As a result, I have bought wholly into the use of argumentation as a vehicle for integration, and looking back, I cannot imagine successful integration without it*."

4.2.5.3 Perceptions of in-service teachers from reflective diaries

Albert who did not know IK at the beginning thinks that DAIM has enabled him to understand IK and to gain skills to integrate it with science. "I now understand how to use the DAIM model in the classroom with the learners. It also has empowered me to tap into IK-knowledge, because I know now what to look for and how to use IKS to explain science concepts to the learners." Alberts goes further than integrating science and IK. He now helps his colleagues to implement a science –IK curriculum. "I not only support an integration of science-IK curriculum in the classroom but also help (fellow SIKSP members) to develop resource materials for teachers so that they can use it in their classroom to ease the implementation phase of a science-IK curriculum at schools."

Fielding perceives DAIM as a means of effecting inquiry-based science teaching where learners co-construct knowledge, with the teacher as a facilitator. "The argumentation instruction method, however give learners the opportunity to enquire and discover scientific facts and values for themselves through intra- and inter-argumentation. The argumentation instruction has an added advantage, because it can give understanding to cultural values and beliefs which western science fails to do." He further expresses confidence in the method after being the project: "*Now being involved with IKS training for more than three years, I feel comfortable in teaching IKS topics and know how to move between the western science and IK-science worldviews."* [Fielding, Refl. Diaries]

> **Gwendoline:** *The seminars and workshops contributed a great deal in me understanding the theoretical framework of argumentation … Students engaged in discussions and argumentation where applicable and came up with loads of their own constructed ideas. I believe that this method will really enhance the understanding of the student pertaining a particular concept in Sciences.* [Gwendoline, Refl. Diaries]

Some in-service teachers view DAIM as a tool that enables them to regain their lost IK knowledge and hence, their dignity. Laura said: "After attending the workshops I realized that IKS is not something new to me… These workshops are so valuable to me because they made me realize once again how precious IKS is and how I nearly lost my valuable experience of learning Indigenous knowledge from two cultures at a young age. Science deprived IKS of its value." Thando expresses similar views that DAIM had enabled her to view her IKS differently: "I think for the time I have been exposed to argumentation, I have learnt to look at things differently; especially the traditional ways that I grew up in… Science and modern ways made sense to me but only recently, did I realise the values and richness in traditional practices. The exposure to argumentation has changed in me ways I look at everything around me"

DAIM was also seen as a tool of critical thinking, knowledge construction, and accommodation of different viewpoints for both teachers and learners. For instance, Thando said:

> **Thando**: *I think using argumentation to integrate science and indigenous knowledge can in a broader sense bring harmony in societies and bring about acceptance without being judgmental. If learners are aware of other ways of interpreting the natural phenomena, they will grow up to be more tolerant of people who are different from them… For me as an individual, argumentation has opened a new person in me; one who can think of how to say or argue my viewpoints without being offensive to others. I also consider other people's ways of viewing things and do not criticize them* [Thando, Refl. Diaries]

Ayanda on her part said: *"The exposure has instilled and increased confidence in me personally; when I make claims I always support them with evidence, in my academic work and professionally."* [Ayanda, Refl. Diaries]

Some of the teachers perceived problems faced when using DAIM as an instructional tool. Fielding, for example, argued that even though DAIM was a good method to integrate science and IK, the curriculum was an exam-driven curriculum, where IKS is basically not examined. This situation in according to him, was a challenge because teachers would prefer to teach what would be examined instead of IK. Another issue was time constraints. Teachers are always under enormous pressure to cover the syllabuses before the official examinations. Hence spending time to teach IK would be a problem for the school administrators who are usually judged on the results of the official examinations. Another challenge was the fact that argumentation and IK are concepts that are intellectually demanding for the teachers to master. So combining these two concepts was seen as potentially problematic.

> **Thando:** *The main challenge is the introduction of the argumentation instruction model accompanying the integration of indigenous knowledge into science, which is too much for teachers. …The two, indigenous knowledge and argumentation are unknown to teaching hence the negative hype*. [Thando, Refl. Diaries]

DAIM was seen as a means of skills to integrate science and IK in the classroom by many in-service teachers. Zameka intimates that she had been struggling with science-IK integration unsuccessfully, until after the experiences with DAIM, she found a solution.

> **Zameka:** *When I attended the seminars and got involved in the discussions and activities as well as sharing experiences with others I got ideas on how to integrate science with IK and that has made it easier for me to construct my lessons... Using argumentation as an instructional tool has helped a lot in integrating personal experiences with science and it has given learners the confidence to argue facts and their beliefs with others.* [Zameka, Refl. Diaries]

Ayanda expresses similar views about DAIM. She thinks that her experiences in the DAIM activities and workshops have reformed her way of thinking about IK completely. In her view, she has moved from a complete ignorant person about IK at the beginning to a confident teachers capable of integrating science and IK.

> **Ayanda:** *When I started I did not appreciate indigenous knowledge nor did I realize its richness until I matured in these workshops. I have now reached a level where I am confident of integrating these two worldviews harmoniously. The activities have instilled enthusiasm in me that teaching science using IK is inevitable. Initially, I did not understand how these two could work together, but now I have seen it possible through experience*. [Ayanda, Refl. Diaries]

Maurine, a 55-year-old teacher has a high esteem for DAIM as an instructional approach to integrate science and IK. Before joining the project, she had been struggling to integrate science and IK but could not do it well. Two years after her involvement at SIKSP, she says "*I have gained lots of knowledge and experience during the lectures, seminars and workshops. The exposure of lesson demonstrations done by educators and myself made it easy for me to teach IK*." Not only has she gained knowledge and skills to integrate IK and science, but she has gained much confidence in doing so. She says, "*I now have the confidence to teach, plan and develop materials. … The DA [dialogical argumentation] is a useful methodology to engage learners in arguments/discussions."* Moreover, she is now actively helping her colleagues to apply DAIM to integrate science and IK in their school as she intimated: "*At this stage I am now confident to teach, plan and design materials for IK. I am guiding and supporting my colleagues at my school on how to teach, integrate and plan their lessons."* Siya

adds: *"My experiences in workshops have also shown that preparation in terms of worksheet preparation, lesson plans and notes with introductory case studies were important in making the integration of science and IK possible."*

4.2.6 Interpretive summary and comments

The aim of the second research question was to find out the participants' perceptions of the effectiveness as well as the challenges of using DAIM as an instructional tool for implementing a science-IK curriculum. The results above suggest that DAIM was effective in diverse respects, such as changing perceptions with respect to IKS in science, resulting in more interactive and interesting science classes, acquiring inter-personal skills, and building collaborative, respectful, relationships across cultures, among others. These results corroborate several others that have found argumentation-based instructional strategies effective in integrating science and IK in South African classrooms (e.g. Diwu & Ogunniyi, 2012; Moyo & Kizito, 2014; Ramorogo & Ogunniyi, 2010).

DAIM is a learner-centred teaching model that enables the teachers to implement a science-IK curriculum. The DAIM approach fits the enquiry-oriented approaches of teaching that are believed to be more advantageous than traditional lecture-demonstration methods in science classrooms (Lin, 2014; Lubben et al., 2010; Opfer & Pedder, 2010; Wee et al., 2007). Although this sounds good, DAIM classes introduce many challenges for the practicing teachers because the DAIM approach is a direct contrast to the traditional teacher-centred approaches which they had been using for many years.

Among the challenges faced when using DAIM were the following: DAIM needed greater teacher preparation and facilitation, more time to effect the lesson, greater administrative support, and was hindered by an examination-driven curriculum that could negatively affect its implementation if teachers chose to 'teach to the test' (Hochberg & Desimone, 2010; Johnson et al., 2010; Shizha, 2007).

4.3 Research Question 3: Teachers' practical application of DAIM

Research Question 3: How did the teachers apply DAIM in their classrooms?

In order to understand the manner in which the in-service teachers applied DAIM in their classrooms, I analysed the audio- and video-clips of three teachers who had taught using the approach (found in SIKSP archives). I watched the video-tapes, listened to the audio- tapes, and used the transcribed texts of each lesson to do a content analysis (Elo & Kyngäs, 2008; Seuring & Gold, 2012; Vaismoradi et al., 2013). A brief description of each lesson is presented, followed by my analysis and comments. For each lesson, I will look at: 1) the teacher's techniques of scaffolding argumentation, 2) the learners' response patterns, and 3) the alignment of the lesson with DAIM.

4.3.1 SIYA'S LESSON: Subject: Physical science

Topic: Fluid Dynamics

Siya was a 51-year-old Black physical science teacher. He was formerly a chemical engineer, and decided to join teaching some seven years back. He was teaching in a school in a predominantly Black neighbourhood with poorly resourced facilities. His lesson was on fluid dynamics to grade 10 learners (16- to 17-year-old). All the learners spoke isiXhosa, the predominant language in Black townships in Cape Town.

4.3.1.1 Siya's DAIM lesson techniques

Siya made much use of questioning, explaining, making demonstrations, and giving instructions to the learners. His explanations were mainly about science concepts as well as the elements of Toulmin's argumentation pattern (TAP). His main purpose seemed to be a focus on making his learners understand the concepts by using a combination of questioning and explaining as scaffolding techniques. The excerpt below is to a large extent, representative of a typical scene in Siya's classroom.

Teacher: Can I get another try?

Learner: Something that is liquid or solid…[inaudible]

Teacher: Um… OK. Not quite there. I'm looking for a specific something. More precise. Of what a fluid is. [pauses]. Think of the word flow.

Learner: [Inaudible]

Teacher: OK. The word fluid comes from the word flow. Does anyone know of what is to flow?

Learners: Yes!

Teacher: Give an example of something that can flow.

Learner: Water

Teacher: Yes, water can flow. Another one?

Learner: [Inaudible]

Another prominent method used by Siya is explaining concepts and demonstrating whenever possible. His explanations involved the concept of a fluid and the different elements of an argumentation lesson.

> *Teacher: When air flows we call it….wind. So when we talk of a fluid mechanics, we talk of everything that can flow. So what happens when something flows? What happens in the environment? ….. I want you to look at this paper. This is an argumentation schedule, right? Something that shows what is an argument. An argument has got many elements. If you look a statement or a belief or an assertion, we call that a claim.*

4.3.1.2 Siya's learners' response patterns to questions

The learners' responses to the Siya's questions were mostly single words such as *'water', 'yes', 'inside'* or inaudible. They only responded to questions posed by the teacher. When trying to discuss, the learners often switched to *isiXhosa*, the local language of the learners, rather than using English, the language of instruction.

4.3.1.3 Siya's lesson alignment with DAIM as taught at SIKSP

In the DAIM approach to teaching, the lesson begins with individual learners, followed by group discussions and presentations, and finally whole class discussions. The individual level of argumentation seemed to be absent. And the learners were asked by the teacher to work in groups. The stage of whole class mediation was not so evident

Siya's learners seemed to have had an acute language problem that affected the implementation of an exciting DAIM lesson. They had much difficulty communicating using the English language, which is the medium of instruction. The terminology of TAP such as claims, evidence, warrants, qualifier, etc. as explained by the teacher, seemed to have added to the learners' language challenges. Hence the lesson did not align well with the expectations of a typical DAIM lesson.

The main challenge in this lesson was a serious language problem that mitigated against a good DAIM lesson. This language challenge was at three levels – English was a second

language to the learners; science terminology differs from ordinary language; and argumentation terminology requires a mastery of the terms and meanings. Hence they could not discuss in small groups as required by DAIM method.

4.3.2 PRIESTLEY'S LESSON: Subject: Mathematics

Topic: Reflection in the X-Y Plane

Priestley was of mixed-race, and 63 years old. He taught mathematics and physical science. Just as Siya, he was former chemical engineer by training, and joined the teaching profession some 7 years back. In his DAIM lesson, he taught grade 9 learners (15-16 year-old) geometry. His lesson was 45minutes long, on the topic *Reflection in the X-Y Plane*. His learners were predominantly of the mixed-race community and bilingual (Afrikaans-English).

4.3.2.1 Priestley's DAIM lesson techniques

Priestley used mostly Socratic style questioning and giving instructions to learners. He made the lesson interesting by often giving compliments to learners, and encouraging them to give their views or to explain why they gave the response they did. Most often, he would ask questions which required just one word, and the learners would all answer in a chorus. In other instances, he would call one learner to the board and ask specific questions.

4.3.2.2 Priestley's Learners' response patterns

The learners on their part, gave mostly short answers to the teacher's questions. In a few cases, they discussed among themselves. Hardly did the learners ask the teacher or each other questions. A typical scene in Priestley's class is shown in this excerpt:

Teacher: We have 4 areas on the board, some of those areas will be negative and some will be…

Learners: Positive

Teacher:[Writes on the board]. If you look at the coordinates what do you have there? Positive or negative numbers?

Learners: Positive

Teacher: Which number is positive?

Learners: [In a chorus] All.

Teacher: Is 4 positive?

Learners: Yes, sir.

Teacher: And the 3?

Learners: Yes, sir.

Teacher: Is it negative or positive?

Learners: Positive.

Teacher: She wants to know in which quadrant it is going to lie. Yes, come. [Points to a learner]. And another, come and help her. Come to the board. You can sit down. Take a piece of chalk and mark the point. Take a piece of chalk. Where is the point (4,3)? What did we say yesterday? Which one comes first? [Pauses]. When we talk of coordinates, which one comes first?

Learner: X.

Teacher: [To the whole class] Is that correct?

Learners: [In a chorus] Yes!

Teacher: The x-coordinate and then….

Learners: [In a chorus] The Y ….

Teacher: Right. … Now, how did you get the points? What did you do? Count the…You must have a reason why the point is there 4 units on the X and …

Learners: 3 units on the Y.

Teacher: And where they cross, that will be their point. Yes, thank you.

The learners only responded to the teacher's questions or followed his instructions. Although they were more active than those of Siya's class, they did not ask each other questions.

4.3.2.3 Priestley's DAIM lesson alignment with DAIM as taught at SIKSP

As with Siya's class, all interactions were initiated and sustained by the teacher. There was no evidence of following from individual through small group and finally, to whole class discussions, as the DAIM approach teaches. The teacher did not give time for the learners to present their answers to the rest of their peers, even though they did some work in groups.

The lesson was largely dominated and driven by the teacher, who showed much experience. However, he was the key player and determined nearly everything happening in

the class. Although there was interaction, it was a teacher-centred class in contrast to what a DAIM lesson is supposed to be.

4.3.3 Laura's lesson: Water Pollution

Laura was a 51-year-old-teacher with 34 years of teaching experience. She was of the mixed-race and taught grade 3 (8-9 year-olds). Her learners were divided into 5 groups, about 5-6 learners per group, and could express themselves very well in English. There were five groups I all. Her topic was *Water pollution*.

4.3.3.1 Laura's DAIM lesson techniques

Laura's approach was much different from the approaches by Siya and Priestley. Although she used questioning as a main technique, she also gave instructions to learners working in groups. She moved from group to group, assisting those who needed help. The argumentation tasks seemed to have been very well structured in advance, with each group doing a slightly different task. For example, one group discussed on the uses of water; another on saving water; another on water pollution; and another on sources of water. At the end of the discussions, each group chose one learner to present their conclusions to the whole class using its own method of presentation – mind maps, concept maps, lists, etc. while their peers asked them questions.

Laura also had the practice of making the learners seek evidence to justify claims. A typical example was the case where one learner gave the definition of a word, and she asked every learner to look up the meaning of the word in the dictionary in order to confirm or refute the answer that was given. The excerpt below shows what happened.

Teacher: Right! Is there any question that you want to ask this group? Right! Three questions will be enough because we need to give every group a chance. OK! Let's see. OK! John!

John: What is transparent?

Caro: Transparent means when you can see through.

Teacher: Right! Now, take up your dictionaries! We want to make sure if we can agree with Caro. Take up your dictionaries! … The word is tr..a..n..s..p..a..r..ent. John can you write it? Write it quite big on the board for us, please….[To another learner] Collette, if you don't have a dictionary then you can share with other people….

Teacher: Can you listen to Joy? She's going to read the meaning of the word out of the dictionary.

Joy: Transparent means we can see through.

Teacher: Okay. Do we agree or disagree with Caro? [Pauses]. Jessie?

Jessie: We agree with Caro because it is transparent.

Another component of Laura's lesson was the presence of IKS. She purposefully chose a comprehension text which contained science and IKS components, and made copies available to all learners. After giving the learners some time to read the text, she opened the floor for discussions. The excerpt below shows part of the scenario.

Teacher: Now, … how can you purify polluted water? …

Learner 1: We can clean the water by … first filter and then we boil it.

Teacher: Filter and boil it. Yes, anybody else? … Now if we throw bleach in the water, if we throw bleach in the water, what do you think? Is bleach a dangerous chemical or what? What do you think? What can it do to the body? What can it do to the body? … Janine.

Learner 2: If you throw it in the pool and you get into the pool, it can destroy your skin.

Teacher: OK. It can harm your skin. Anybody else? …

Yes, you can (get) sick. Karin is the last person!

Learner 3: It can cause rashes on your body.

Teacher: OK that tells us that bleach is not so safe after all, although the water that comes from the taps in our houses, they also use a chemical to clean the water. But there is the other way that you can clean water without using bleach. Without using chemicals, and we can clean water, we can purify water by using a …. Very importantly, a very valuable tree. And that tree grows in India. The name of that tree is the morenga tree. They take the seeds of this tree. There's no chemical in the tree (shares copies of pictures of the tree). OK, this is a very natural way of cleaning and purifying water.

4.3.3.2 Laura's learners' response patterns to questions

The learners were highly interactive in their groups and when presenting to the whole class. Also, they seemed to have internalised the language of DAIM as they could easily use it during the presentations and arguments made. In many cases, they would say: '*What's your evidence?' Or 'I disagree with you', etc.* In more than half of the cases where the learners made claims, they also provided the evidence for such claims. Learner-learner interactions far exceeded teacher-learner interactions. The learners were the real actors while the teacher acted as a facilitator or coach. A few excerpts from the class may help to buttress the point.

Presenter: Our group decided to claim that the family gets water from the river and our grounds were that they don't have taps.

Teacher: [To the whole class]. Do you want to comment?

Learner: What's the evidence?

Teacher: Can you come up?

Presenter: The evidence was from question four. The two girls that had to balance water pots on their heads.

However, some of the situations in Laura's class were surprises and rather unanticipated. For example, when a learner was presenting on the uses of water, baptismal water, water in the placenta, and holy water became part of the discussions.

Presenter: Our group discussed the uses of water. We made a mind map. … Fish water. Washing clothes. Holy water. ..Now I ask you to …..

Learner 1: Why is water holy?

Presenter: Water is holy because if you go to church and people sitting down … If your mother has a new child and you go to church, you can see how the pastor …. How the pastor puts …

Teacher: Anybody that wants to comment? Anybody? Kethiwe!

Learner 2: Reagan, I disagree with you when you … if a pastor comes into your house, you take some water, he puts his fore fingers in the water and sprays some around the house ….

In another incident, when the Deputy Minister for Science and Technology (DM) who had visited her class was about to leave, he gave a chance to the learners to ask a few questions. One of the learners (Learner 4) gave an explanation from her IKS background as to why sea water is salty. Her explanation was rather unanticipated and somehow shocking to many science teachers, and the DM. The scene went as follows:

Learner 1: Sir, what work do you do until now?

DM: I'm in parliament…. In the gov't, I serve in the cabinet and I am deputy minister of science and technology. So that's my work.

Learner 2: Sir, where does water come from?

DM: That's a difficult question. Can anybody help me? ….

Learner 3: Water comes from pipes and under the ground.

DM: Where does it come from before it gets to the pipes? … Didn't I hear you say that 97% of the water is salt water?

Learners: Y-e-e-s-s!

DM: Help me, where does it come from?

Learner 4: The salt water was normal water. My uncle first told me that when he was a child they told him that first there was magic light…. And they made a mistake and the magic light fell into the sea. So all the salt came out and made the sea salty.

4.3.3.3 Laura's DAIM lesson alignment with DAIM as taught at SIKSP

Laura's lesson aligned highly with DAIM as taught in the SISKP. The learners had mastered the structure and language of argumentation, and were very eager to use it. They expressed their views with a lot of confidence. After working in small groups, the learners presented their results through a presenter who was also interrogated by their peers.

Taking into consideration that Laura's learners were that young, it was amazing how they could use the dialogical argumentation approach with so much confidence. I asked Laura what she did to enable her learners grasp the concepts of argumentation so well. She explained how she had taken a gradual process through language and other classes, and daily life situations before making them learn the terminology of argumentation. Once they had mastered the main concepts of argumentation, they began using it very easily and almost naturally.

4.3.4 An analysis of the three teachers' DAIM lessons

The three DAIM lessons were rated by three science education researchers on items focusing on teachers' and learners' actions during the lesson (See Appendix E). According to the raters, the teachers all showed moderate to strong evidence of scaffolding the DAIM lessons. However, there were many differences when it came to learner interactions and the presence of IKS in the lessons. In order to have a more systematic assessment of the three lessons, I coded the transcribed lessons using a priori codes (Saldaña, 2013). The codes were influenced by literature and focused on the type of argumentation scaffolding techniques, as well as teacher-learner, and learner-learner interactions. The following codes were used: TQ (teacher questions); TI (teacher instructions); TE (teacher explanations);

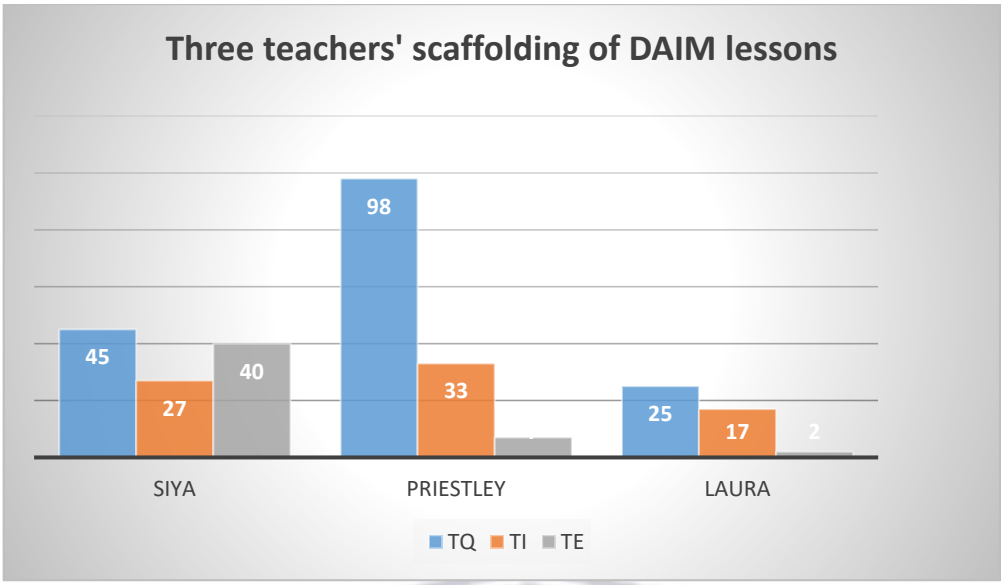

Fig. 4.1: Teachers' scaffolding of DAIM lessons

(TQ=Teacher questions; TI=Teacher instructions; TE=Teacher explanations)

A close examination of the patterns of lesson delivery by the three teachers and learners' activities suggests several commonalities as well as differences between the DAIM lessons. From Figure 4.3.1, each of the three teachers made use of the techniques of questioning, giving instructions, and explanations as techniques of scaffolding argumentation. However, they did so with different foci of emphasis. For example, Siya used questions, but focused more on explanations and demonstrations. On the other hand, the high number of questions by Priestley seem to suggest a Socratic style of instruction. In the Socratic style of instruction, the teacher uses a series of questions to prompt and guide the learner's thinking with the aim of eventually 'extracting' the information from the learner instead of just giving a direct explanation (Chin, 2007). In the preceding lessons, both Siya and Priestley dominated the interactions. In contrast to the two, Laura asked fewer questions, and also gave the lowest number of instructions and only engage in explanations on two occasions. She often assigned the task of explaining to the learners, while guiding them to discover for themselves what would have needed her to explain. She only intervened to explain when it seemed absolutely necessary.

The codes for learner interactions were as follows: LA (learner answers or claims without backings); LA/EV (learner answers supported by evidence); LQ (Learner questions); LR (learner rebuttals/ disagreements); LP (learner presentations); IKS (incidents of IKS).

4.3.4.2 Learners' Interactions patterns in the three DAIM lessons.

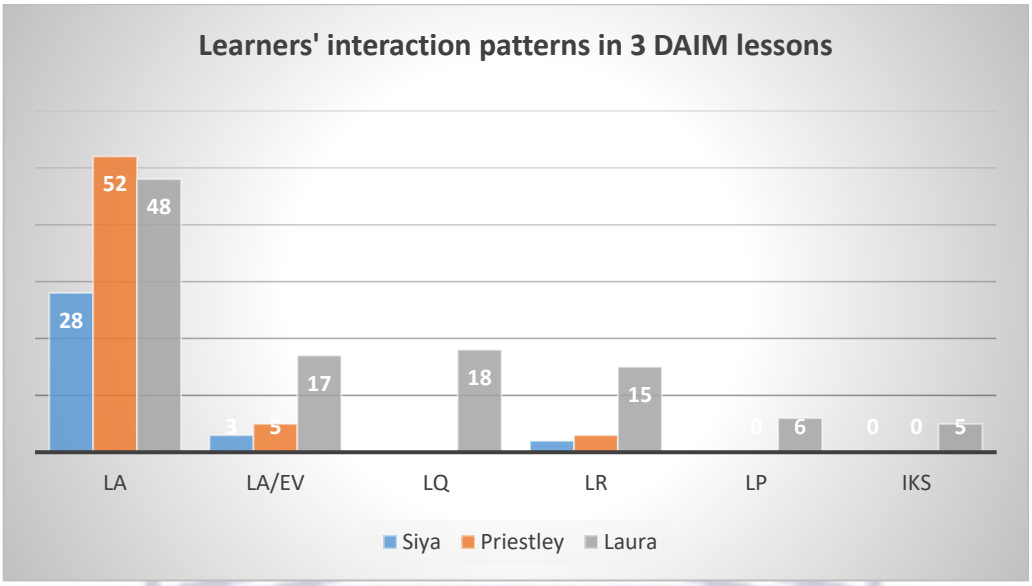

Fig. 4.2: Learners' interaction patterns in the 3 DAIM lessons

The figure shows the trends of learner interactions in the three classrooms. The analysis suggests that most dominant interaction by the learners was the answering of questions. However, the pattern of the learner response to questions was similar for Siya's and Priestley's learners - they only answered the questions of their teachers. In Laura's class, the learners answered the teacher's questions, but also those of their peers. Also, Laura's learners provided evidence to back their claims or answers 17 times while those of Priestley and Siya did so less often (5 and 3 times respectively). Laura's learners also disagreed many more times with their peers and did presentations.

In conclusion, the three teachers taught their DAIM classes differently. Of the three lessons, only that of Laura truly reflected what was expected of a DAIM lesson where learners actively express their views, and challenge each other to justify their claims, and so on. This was rather surprising because her learners were the youngest (8-9 years), and one would have expected that they would not be able to engage in argumentation activities.

I asked Laura how she taught her learners argumentation. She explained how she had taken time to gradually introduce the concepts of argumentation to her learners over a period of three weeks, patiently waiting to eventually reap the fruit of her labour later.

4.3.5 Laura's method of teaching argumentation

I used part of my Language Lesson Oral as introduction to argumentation.

Phase one.

- *Firstly, I introduced argumentation with everyday incidental topics every morning when school started.*
- *Example: When one learner arrived late: I would ask him:*
  Why are you late? Give me a valid reason. (He would answer, I overslept etc.)
  Then, I would involve the rest of the class. Give me other reasons why you think, he could be late. (Learners will come up with various acceptable reasons).
  This caused learners to start thinking…

- *This [process]would be repeated daily with simple examples; e.g. Why are you smiling? Learners would give various reasons. All learners were eager to participate and think of various reasons. They really enjoyed the part when giving reasons. I put the words on flashcards and it made part of their vocabulary list.*

Phase two

- *I repeated phase one but now bringing in the correct argumentation terminology [that] I wanted them to use when we would be busy with scientific topics.*
- *John said he lost his bag. I repeat: "John claims he lost his bag''.*
  Give valid reasons. Can you back your claim? etc. Then I slowly brought in grounds, backings and rebuttals if there was any.
  I can remember during the lesson with minister, they argued about the container, which had a transparent liquid in.
  One said It was water, the other said was cool drink, a third said it was vinegar. Then it became hectic: Then they came up with backings: One said water has no smell, Other one said vinegar has a smell, so it's not vinegar, third said, it's cool drink because it has a sweet taste and so it went on and on…

Phase 3*: I brought in agree and disagree with valid reasons.*

Phase 4*: More argumentation vocabulary was repeated daily with examples early morning and before they were dismissed. Before they went home, different learners got opportunity to make a claim daily. The last 15 minutes of the school day was used for wrapping up argumentation.*

Phase 5: *I started with socio-scientific issues and the rest is history. They challenged me. I integrated argumentation with every lesson and that is how it became second nature to them. E.g. Why is ten your favourite number? On what grounds do you say that 24 has 2 tens and 4 units, etc. Learners became argumentation crazy.*

4.3.6 Interpretive summary and comments

It is not a strange phenomenon that the three teachers carried out their DAIM lessons differently. Many studies (e.g. Jeanpierre, Oberhauser, & Freeman, 2005; Osborne, Erduran, & Simon, 2004) have shown that the implementation of instructional innovations such as inquiry and argumentation-based instruction is teacher-specific. As teachers implement what they learned during their training, they tend to lay emphases on different aspects (Berland & Reiser, 2011). Moreover, the teaching of argumentation classes also depends on many factors, including the language ability of the learners (Aguiar Jr., 2016; Hand et al., 2016), learners' knowledge of argumentation structure, the nature of scaffolding techniques used, the knowledge level of those involved in argumentation (Heng et al., 2015; Sadler & Zeidler, 2005), the type of subject – whether it is pure science or socio-scientific, content knowledge (Christenson et al., 2017; Sadler & Zeidler, 2005; von Aufschnaiter et al., 2008). , and so on. Hence the interplay between these different variables is rather complex, and the success or failure of the argumentation lesson depends very much on the contextual factors involved.

Since argumentation involves learners making claims and backing them with evidence (Erduran, Ardac, & Yakmaci-Guzel, 2006; Osborne, Erduran, & Simon, 2004), those involved in it should be able to externalise their thoughts and challenge opposing views. Hence language plays a pivotal role in the success of an argumentation lesson. Indeed several researchers have concluded that language is a necessary tool for an effective discursive, argumentation-based lesson (Hand et al., 2016; Lemke, 2001; Stears & Malcolm, 2003). It is thus clear that Siya's lesson was hampered by the inability of the learners to fluently communicate using English (the language of instruction). They tended to speak inaudibly, especially in the presence of the visiting observers from the university who had come to evaluate the lesson. Embedding language and argumentation into the science content of school science could possibly have improved the learning of science and interactions (Duschl & Osborne, 2002; Hand et al., 2016; Lubben et al., 2010). However, this should have taken a great amount of time, a commodity which is often scarce, given the amount of work teachers are required to cover over a definite period.

The fact that Siya took some time to explain the terms used in argumentation during the lesson, suggests that he was not sure that his learners had mastered these concepts. For a successful argumentation-based lesson, many researchers suggest that the learners need to know the structure and content of argumentation (Macagno, 2016; Osborne et al., 2004).

Although argumentation is widely acknowledged as the language of science education (Tippett, 2009), many researchers argue that it does not come naturally, but must be taught to the learners (Cavagnetto, 2010; Dawson & Carson, 2018; Kuhn, 2010; Venville & Dawson, 2010). In the absence of teaching argumentation to learners, engaging them in DAIM lessons may be certain to fail. Thus, a language difficulty and lack of mastery of an argument structure probably hindered Siya's learners from engaging meaningfully in argumentative discourse.

Priestley's lesson was more interactive than Siya's as the learners in his class did not seem to have the acute language difficulties of Siya's. Priestley's approach to scaffolding argumentation was also different. Several approaches have been used to introduce argumentation to learners (Cavagnetto, 2010; Macedo, 2011). Priestley seemed to have taught his learners using the explicit teaching of argumentation structure and terminology. His learners, who were more fluent in English than Siya's, could understand argumentation terminology, but did not seem to have mastered it, so they were still handicapped to an extent. The science and mathematics topics of Siya's and Priestley's lessons seemed to have been a disadvantage in both lessons too. Several studies have come to the conclusion that engaging learners in argumentative tasks in the science context is more difficult than when they are made to engage in it in social and socio-scientific contexts (Kuhn, 2010; von Aufschnaiter et al., 2008). In the science context, for example, the learners have the uncertainty of the language of science as well as the language of argumentation (in addition to the content knowledge) of the science concepts to worry about. Hence their ability to engage in elaborate, fruitful argumentative discourses is therefore more reduced than would have been the case if they were using a socio-scientific context (von Aufschnaiter et al., 2008). In the socio-scientific context such as the case of Laura's lesson of water pollution, every learner would feel that he or she has a contribution to make; even from personal experience (Kuhn, 2010).

In contrast to Priestley and Siya, Laura had many advantages to her favour. First, she gradually introduced argumentation to her learners over a considerable period of time. This resulted in the learners having a good understanding of the argumentation approach, (with the terminology) as second nature. This approach, although more demanding in terms of time, is more rewarding in the long term (Kuhn, 2010). The socio-scientific context of her topic of water pollution was practical, and her learners could easily relate to it. These conditions predisposed her for success. Several researchers recommend that is better to start teaching

argumentation using socio-scientific topics (Chin, Yang, & Tuan, 2016; Kuhn & Moore, 2015). The argumentation skills can then be later transferred to scientific contexts (Kuhn, 2010).

The structuring of Laura's class into small groups that were actively questioning each other and their peers when presenting encouraged argumentative talk. Several researchers have found that arranging learners into small groups and encouraging them to ask questions as Laura did results in more sustained argumentative discourses and knowledge construction (Chin & Osborne, 2010)

In conclusion, the three teachers implemented DAIM differently, corroborating the results of earlier studies that the pattern of argumentation lessons is teacher-specific (Osborne et al., 2004). One teacher's lesson was more of a lecture demonstration. The second teacher's lesson more of a Socratic style teaching, but still dominated by the teacher. The third teacher followed the DAIM approach as required; with the learners being the main actors while she played the role of a coach or facilitator. A lesson to learn from these DAIM lessons is that DAIM can be used to teach science, mathematics as well as socio-scientific topics. However, the success of the DAIM lesson depends not just on the teacher, but on the learners and other contextual factors as well. Before implementing a DAIM lesson, it is important for the teacher to first introduce argumentation discourse to the learner gradually so that it will be more effective (Kuhn & Moore, 2015), and also to start with socio-scientific topics. Even after that, it is necessary to select science topics which are amenable to argumentation (Ramorogo & Ogunniyi, 2010).

4.4 Research Question 4: SIKSP's enhancement of participants' P.D. and science-IKS research capacities

The fourth research question was as follows: To what extent did SIKSP enhance the participants' professional development and research capacity in science-IKS?

4.4.1 Academic Advancement and graduation rates

It is difficult to have an empirical measurement of the knowledge and skills gained by the participants as a result of their participation in the SIKSP because no tests were given to assess them. However, the number of peer reviewed publications and completed theses by the in-service teachers might be indicative of their enhanced capacities and knowledge gains. Hence, I took them as some form of indicators of the gain in knowledge and skills by the participants who were involved in the project. I will start with some excerpts from the interviews. (Since DAIM was the main teaching strategy used in SIKSP to integrate science and IKS, DAIM is often used here as an alternative name for SIKSP).

During the interview with the project director, I asked him the following question: *What are some of the major contributions that the project has made towards research-capacity development in the Faculty of Education, the university, and the country as a whole?*

In reply to the question, he said that SIKSP had made considerable contribution to the science capacity building at the individual level for those students who come here for postgraduate studies, and also made contributions at the level of the faculty and far beyond.

> **Prof:** *So, in terms of capacity building, we are building people - students, including staff members who had joined the project. They are now utilizing the project in terms of teaching, even at university level. And then of course, in terms of capacity building, I believe that a project like this which is like a flagship for the faculty in terms of its significant features is making great impact. Somewhat it has made great impact over the years; and many of those who are where they are in different universities have been able to … continue similar studies.* [Prof, Interview]

A perusal of the project records showed some data about students who had graduated through the project since the beginning of the project. The records showed that number of years taken by full time students to complete a master's degree before the university policy to change to full theses was two years. After the change, it took between three and five years to complete the master's degree course. For the PhDs, the completion time was also much longer than

before, suggesting that the change from course work and a mini thesis at master's level to full thesis without the course work had a negative impact on the in-service teachers' throughput.

With regard to the progress made by in-service teachers who had passed through SIKSP, the Project director attested:

> **Prof:** *They started moving from honours to master's, and then to PhD…They have grown astronomically professionally. Academically, they are not the same type of people. Apart from promotion to other positional …. Headmaster, headmistress, and they have also grown. They are no longer the same people who came here a few years ago. For the faculty, in terms of research output, there have been several masters and PhD graduates using the SIKSP model of research which is based on dialogical argument instructional model; So, there have been many, many students since 2004 till now*. [Prof, Interview]

4.4.2 Research trends in the SIKSP from 2010-2020

In order to obtain an approximate direction of the trends of research at the SIKSP, I analysed 25 theses. Seventeen of the theses were at the master's level and 8 at the doctoral level. The analysis included the research design, the theoretical or conceptual framework used, the methods of data analysis, the nature of those who formed the sample, and the learning areas involved. The results are captured in Table 4.5 below.

Table 4.5: Trends of research work at the SIKSP (From 2010-2020)

Design	Frameworks	Methods	Sample	Learning Areas
Master's level	**N=17**			
Quasi-exp= 12 case studies= 4 Survey= 1	Argumentation=13 Social constructivism =2 Conceptual change = 1 Evaluation= 1	Mixed methods: 14 Qualitative:3	Primary Learners = 4 High Sch. Learners = 10 Pre-Service Teacher= 2 Practising Teachers = 1	Phys/Nat. Science = 9 Earth in space = 4 Socio-scientific = 3 Evaluation = 1
PhD level	**N=8**			
Quasi-exp= 2 Case studies= 6	Argumentation (plus other) = 7 Evaluation=1	Mixed methods: 5 Qualitative: 3	High Sch. Learners =3 Pre-Service Teachers=4 Practising Teachers =1	Phy/Nat. Science = 3 Curriculum = 3 Geography = 1 In-service= 1

The trends in the SIKSP show that between 2010 and 2020, seventeen in-service teachers (9 males and 8 females) completed the master's programme. Of these numbers, 6 males and 7 females enrolled for the PhD. The research at the master's level is largely dominated by quasi-experimental methods with pre-post designs to compare the DAIM and alternative instructional methods. Mixed methods are encouraged for one main reason – to make the in-service teachers get used to both methods so that they can be comfortable to explore or use them in research.

At the master's level, most of the research is also based in the high school or primary schools. This is understandable because this is where most of the in-service teachers are teaching.

At the PhD level, the picture is different. Most of the research uses case study designs and add another concept to the argumentation-based framework which they used at the master's level. The methods are still dominated by mixed methods, although this time, the qualitative is dominant. Also, the samples shift from primary and high schools at master's level to high school and tertiary level (pre-service teacher) at the PhD level. This is because after their master's degrees, some of the in-service teachers use their qualifications to obtain jobs at tertiary institutions. Another trend is observed in the learning areas of research where at the master's level, more research is done with learners in the classrooms where these teachers do the teaching. However, at the PhD level, some of them who may now be teaching at tertiary institutions begin to do their research in the area of curriculum where they do investigations with the science-IK integration curriculum; mostly with pre-service teachers.

4.4.3 Publications by SIKSP members in SAARMSTE conference proceedings

Many of the participants in the project have published a number of papers in peer reviewed conference proceedings either individually or with colleagues. The research focus has always been the integration of science and IK using the argumentation framework as the underlying theory. The main conference proceedings that have carried the publications are the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE); and more recently, the African Association for the Study of Indigenous Knowledge Systems (AASIKS). Each long paper published in the proceedings is about 6000 words long and reviewed by two reviewers. A glimpse of the research publications is shown in Table 4.6.

Table 4.6 Publication of SIKSP long papers in SAARMSTE proceedings

Year	Venue of SAARMSTE	SIKSP	TOTAL	%
2010	University of KwaZulu-Natal	3	9	33.3
2011	North-West University, Mafikeng	8	21	38.1
2012	University of Malawi	6	22	27.3
2013	Univ. of the Western Cape, Cape Town	11	27	40.7
2014	NMMU, Port Elizabeth	2	3	66.7
2015	Eduardo Mondlane Univ., Mozambique	1	7	14.3
2016	Tshwane Univ. of Technology, Pretoria	2	13	15.4
2017	Central Univ. of Technology, Free State	6	17	35.3
2018	University of Botswana	2	7	28.6
2019	University of KwaZulu-Natal	0	6	0.0
2020	Rhodes/Nelson Mandela Metropolitan U.	1	20	5.0

The information above can be represented in a bar chart as shown below.

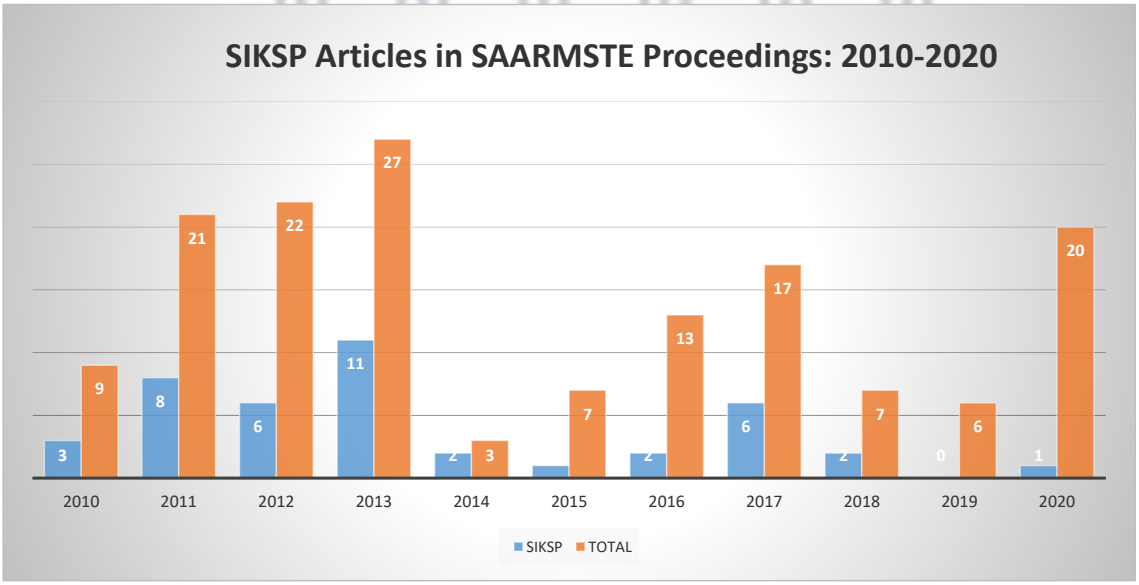

Fig. 4.3 SIKSP published papers in SAARMSTE proceedings from 2010-2020

The prublications trend shows that the SIKSP had their highest number of publications between 2011 and 2013. This is probably due to the fact that there was funding availble to take care of the transportation and accommodation of students to Mafikeng in 2011 and Malawi in

2012. The highest number of publications was in 2013 when the conference took place in Cape Town. This period coincided with the last phase of the project and many SIKSP members were reflecting on the effects of their involvement in the project through the reflective diaries (see Appendix D2). After 2013, the publication by SIKSP members in SAARMSTE conferences has remained persistently low, except in 2017 when the conference took place in the neighouring province of Free State. Another factor that could have led to the reduced number of publications is the coming into existence of AASIKS conferences in which SIKSP members also take active part. Compared to the conference papers, there have been fewer journal publications (mainly by the project director alone or in collaboration with other researchers), and a few other participants.

4.4.3.2 Impact of SIKSP research at faculty level

The impact of the project at the faculty level was also disclosed by the project director:

> **Prof**: *The faculty has gained a lot financially since each publication, whether in conferences or in accredited journals, the faculty receives a lot of subsidy from government, in thousands. Also, in terms of the faculty output, it has been a project that has made a significant contribution among all the other projects in the faculty; whether in terms of published number of papers that are published in various media or forums as well as creating the image for the faculty; not only in South Africa, but around the world.* [Prof, Interview]

4.4.3.3 Impact of SIKSP research at national and international levels

The impact of the project was not only limited to the faculty. The project director also mentioned how it had contributed to research in IKS internationally. For example, several participants had made presentations at the National Association for Research in Science Teaching (NARST), and Prof made a presentation at the World Academy of Sciences in 2010.

> **Prof**: *People have become more and more familiar with South Africa and its study of science and indigenous knowledge systems so much so that last April, the National Association for Research in Science Teaching (NARST), a worldwide association, had to set a special workshop which the project group ran for participants from different parts of the world… I have been invited, for example, by the World Academy of Sciences in 2010 to present a poster paper on this same project. And that's World Academy of Sciences; I made a presentation there. So it has been quite a very successful project.* [Prof, Interview]

The argumentation theory that forms part of the DAIM, according to the project director, is gaining grounds in the field of cultural studies of science education.

> **Prof:** *Besides, the theory that is now becoming more and more popularly known among science educators working in the area of cultural studies of science education. The Contiguity Argumentation Theory is no more just a local theory but is now used by researchers in different parts of the world. Either some people contributing as critics of the theory or actually using it and applying it to their various situations.* [Prof, Interview]

The international workshops and conferences that brought researchers from different parts of the world helped to somehow expose the DAIM, and people want to know more about what has been going on at SIKSP.

> **Prof:** *And then especially the different workshops; many who came now want to link with us to know what it is that we are doing so that we can collaborate across different nationalities. And the last one [workshop], people came from Germany, the US, from Canada, from Korea, … different countries; even North Ireland.* [Prof, Interview]

4.4.4 The creation of the African Association for the Study of Indigenous Knowledge Systems (AASIKS)

One of the greatest, unexpected achievements of the SIKSP was the creation of the African Association for the Study of Indigenous Knowledge Systems (AASIKS) during its last IKS International conference in 2013. This association has now become an umbrella organization that brings together researchers in the field of science and IKS in Africa. AASIKS has a broader scope, covering many areas of IKS like health, education, technology, and others. Geographically, it covers the whole African continent. The secretariat of AASIKS is located at the School of Science and Mathematics Education where the SIKSP is still playing a great role in its organising structures. Many SIKSP members also play leading roles in the running of AASIKS.

Although AASIKS is an outcome of SIKSP, it has grown to subsume many other areas of IKS beyond the original boundaries of SIKSP, and holds promise for taking IKS much further than what SIKSP could ever have done. Since its inception, AASIKS has organised research conferences in Namibia (2015), Mozambique (2016), Johannesburg [S. Africa] (2017), Tanzania (2018) and Venda [S. Africa] (2019). SIKSP members are emotionally and psychologically attached to AASIKS since they consider the association as their baby, although it is bigger in size and scope. AASIKS is also closer to SIKSP since it deals with indigenous

knowledge systems specifically, which is the specific domain of SIKSP research and practice. Indeed, AASIKS is like an extended community of practice for SIKSP members. Several SIKSP members form part of the executive running the AASIKS and many contribute conferences papers to the AASIKS conferences which usually take place in October every year.

4.4.5 How SIKSP helped in-service teachers to learn and develop professionally

4.4.5.1 In-service teacher learning of new attitudes, knowledge and skills

The in-service teachers learned many things that enabled them to grow in the profession as many of them attested in the interviews. For instance, Corrine declared that the most enriching aspect of her association with the SIKSP was '*to observe and participate in the development of young researchers and experience first-hand their transformation as confidant individuals and competent scholars'*. Emma said: "*In terms of profession, I really learned a lot because, for example, Contiguity Argumentation Theory was something really new for me…. I can say that I have learned a lot".* Edmund on his part said *"Prof Ogunniyi's CAT approach to SIKS helped me to re-evaluate my own beliefs about IKS and to my delight, I found that I could reconcile some of my deeply held cultural beliefs and unaccounted experiences with scientific fact.*" Yemie narrated some of the strategies that she learned to use in the project: *"I came to understand that with SIKSP we had many different students. They had different needs, different abilities in SIKSP. And what we did was that we worked with them individually. We paired` off the … I can say the staff with student, in writing papers for journals that helped the students."* And Zameka said, "*The SIKS project has enhanced my research skills as before joining the project I had never attended a conference or written or presented a paper."*

These excerpts are just a glimpse of the thoughts expressed by the in-service teachers about their experiences at the SIKSP. The learning approaches were not formal lectures, and took many different forms as Yemie expressed above. Learning took place in pairs, in small groups, through group activities, discussions, writing of academic papers, reviewing of journal articles, and so forth. Whatever the form used, the result was that the in-service teachers co-constructed new knowledge and skills, which is what constructivist teaching/learning is all about.

The facilitators also learned many organisational skills as they worked with the in-service teachers.

Yemie: *I learned leaderships skills; I learned conference organisational skills; I learned skills for documentation and systematic reviews, … I learned inter-relational skills with people from all over the world during those conferences which I was a major conference organiser. I learned a lot.* [Yemie, Interview]

Edmund: *I came to SIKSP already holding some competencies in leadership and research…. However, at SIKSP, I learnt to deepen these skills*. [Edmund, Interview]

4.3.5.2 In-service teachers learning through collaboration with peers

Collaboration at SIKSP took different forms. Besides pairing staff and students, students were also paired with peers to work collaboratively as Yemie further explains:

Yemie*: We paired off student and student and told them to collaborate and corporate and come up with papers which they would present at the conference. There was hounding them for those conferences, so the students themselves even before they finished their masters had presented papers; a lot of papers in accredited conference proceedings. That is one thing I learned. That, you know, it is possible to work with somebody in order to impart skills than to teach those skills… So I learned that from SIKSP*. [Yemie, Interview]

Collaboration was not just limited to the in-service teachers at the university. The South Africa-Mozambique Collaboration IKS project was a platform that promoted joint collaboration between researchers and postgraduate students from both countries. They learned to work together, despite the language challenges (Mozambique speaks Portuguese while South Africa uses English). With regard to this collaboration, Emma expresses,

Emma: *I know most of the participants at SIKSP, when they participated at the SAARMSTE, they were presenting work which was done from the SIKSP context. So I would say SIKSP really was a very good support in terms of having presentations from different … countries like Mozambique and South Africa presenting at SAARMSTE conferences.* [Emma, Interview]

4.4.5.3 In-service teachers learning through practical, hands-on SIKSP activities

Apart from the advanced seminar lectures, most of the other activities at SIKSP were mainly practical application of learned concepts. These activities included the DAIM discussions, the IKS reviews and the IKS materials development sessions. The following excerpts show what the participants said about the practical engagements at the project.

Corrine: *One of the key strengths of SIKSP was the Friday afternoon seminars where students shared their proposals, research agendas and findings and were critiqued by colleagues and academic staff. These sessions were handled in an atmosphere of*

support and camaraderie that enabled participants to hone their research methodology and data collecting documents. [Corrine, Interview]

Zameka: *The discussions held during the seminars also played a really big role in understanding integration of IK in science lessons. The compilation of the material and the practicals done during the seminars really helped me to be able to integrate science-IK in my class.* [Zameka, Interview]

Amanda: *Working with the development of materials to support teaching of IK which was held on Saturday mornings was also very interactive and hands-on; which gave me the confidence and skills to develop my own lesson plans.* [Amanda, Interview]

As part of the collaborative hands-on activities, SIKSP partnered with a team of researchers and students from Mozambique to document IKS published materials. This project which was more like a sub project of SIKSP was very practical in nature in that the format of the review was agreed upon and a template made and given to SIKSP members working in groups of two or three to review a group of relevant papers given them. Emma confirms the usefulness of this exercise:

Emma: *And because we extended SIKS Project with the Mozambique and South African Documentation Project – review of IKS and documentation, I could see even from the participants from Mozambique. Some of them are really applying what we learned from the workshops. They are still applying skills, maybe, not the content, the themes, but the skills they gained from the workshops. … So from my perspective, workshops were very, very useful in terms of capacity building.* [Emma, Interview]

4.3.5.4 Teachers learning through sustained engagement in SIKSP activities

Since 2009 when I joined the SIKSP, the Friday seminars have continued, with a few exceptions, over the years. Although the last phase of the funding ended in 2013, the group members have continued meeting because they saw the relevance of these seminars. They are the forum where the postgraduate students meet and discuss their research issues or get clarity on some research methods with the help of the advanced seminar lectures.

One aspect that, in my view, has been very useful in these seminars has been the light refreshments. During the period when there was funding, the project paid a caterer to provide the refreshments which were taken some 30 minutes before the commencement of the workshops. When the funding terminated, the members brought small bags (the Brown envelopes) of food items purely on voluntary basis. It was such a delight to share with colleagues. The feelings of togetherness were more real than ever. Not only were members of the SIKSP sharing knowledge in the group, but sharing food items was such a big motivation

in their own right. It reminded me of the way we share together during social occasions in my culture where each person comes with some food or palm wine and they jointly share to all, including those who could not afford anything.

> **Gwendoline:** *The SIKSP really met [me], you know, on a personal level. Also, it made a huge positive impact, you know, on my life. So, even after I'm done with my studies, I still feel like, you know, always going back to the seminars, conferences because you learn so much from the group*. [Gwendoline, Interview]

4.4.6 Some long-term effects of SIKSP activities on teachers

4.4.6.1 SIKSP activities led to social/Racial integration

A prominent feature of the SIKSP was its multicultural, multiracial nature and the closeness of its members despite their many differences. They were not perfect, for example, some of the time, two members would disagree so sharply and quarrel with each other. But through the intervention of colleagues, and especially the director, their differences would be resolved and they would move on. The excerpts below attest for themselves.

> **Corrine**: *The association with students from other countries including Cameroon, Kenya, Ghana, Eritrea, Namibia and Mozambique generated a spirit of positive inclusivity and respect for the way different cultures solve their problems and yet highlighted the universality of the human condition and the importance of acknowledging and indigenous solutions when solving local or regional problems.* [Corrine, Interview]
>
> **Zameka**: *In the SIKS project we are a group of different students coming from different countries and backgrounds with different ethnicity. I have learned to appreciate and respect other peoples' cultures and have learned more about them.* [Zameka, Interview]
>
> **Emma:** *I remember that when I first joined the project I thought that because there were Blacks, Coloured and White people, I thought that some White people won't understand what I was trying to say from my native Mozambican background; but I was really pleased to see that they all could understand.* [Emma, Interview]

4.4.6.2 SIKSP activities led to self-efficacy by teachers

Those who have been many years in the project feel more capable of teaching science-IK lessons and more confident as teachers. Their self-efficacy and self-image has consequently improved. This self-efficacy came as a result of practically learning to integrate science and IK during the Saturday materials development sessions, the use of DAIM to integrate IK with

science and the use of argumentation as a tool to aid reasoning and critical thinking in everyday life.

Amanda says:

> **Amanda**: *I feel so much more equipped to manage IK integration in my lessons as I have a more adept view of content and methodology to implement. Development of lesson plans which are IK friendly and the development of valid instruments of assessment. I employ both qualitative and quantitative analysis of data to gain a fair view of learners' progress. I am also more comfortable in writing proposals and submitting reports on academic progress of my learners.* [Amanda, Interview]

Similarly, Zameka also expressed:

> Zameka: *After being part of SIKSP I am now confident in teaching a science-IK lesson. I am able to come up with ideas to make IK part of my science lessons. The SIKSP has made me a more confident teacher in teaching science and integrating IK in my lessons*. [Zameka, Interview]

DAIM did not only enable the teachers to integrate science and IK, also equipped them with reasoning skills as the following excerpts indicate.

> ***Amanda****: I feel far more confident to state my opinion and views with respect to any matter and my teaching has improved as learners become critically engaged with the subject matter. [Amanda, Interview]*
>
> ***Laura****: It has empowered me. I'm more confident. Not scared to speak in front of a big audience. [Laura, Interview]*
>
> ***Fielding:*** *I think the programme the SIKS project was useful in giving me that skill to communicate effectively and critically and to analyse…_yah, reasoning. [Fielding, Interview]*

4.4.6.3 SIKSP activities led to the spirit of togetherness and self-sacrifice [Ubuntu]

> ***Corrine****: Over time I came to realise that at over seventy years of age the perusal of a further degree was perhaps too late to consider seriously, and participating and sharing in the development of younger colleagues and finding solutions to incorporating IKS in school science curricula would be a more productive option.*
>
> ***Yemie****: What I value is that the SIKS project is a very intimate group. Has a very intimate group of people, they learned to work together and they learned new things.*

***Amanda**: I was awarded a cum laude for my master's degree because I was able to interact and engage with colleagues of such a high calibre, whose inputs assisted me in achieving such a great award.* [Amanda, Interview]

***Corrine**: It was a great privilege to share in the achievements of fellow researchers as they completed their projects and graduated. Age and health problems unfortunately precluded personal achievement but the journey was stimulating and life affirming.* [Corrine, Interview]

***Albert**: And there's a sense of family relations when you deal with indigenous knowledge systems. Not the IKS part but the spirit. That spirit of Ubuntu; that spirit of togetherness, we share what is yours are mine you see. I am because of you. That's, the new eye opener when you deal with indigenous knowledge system. It's all about sharing and caring. It's not I'm, I'm on my own Island and I do things for myself. It's the togetherness of it, yah.* [Albert, Interview]

***Corrine**: My association with SIKSP was a truly enriching experience that gives me hope for the future of my grandchildren as they learn to work and play in integrated communities. The future of our children depends on tolerance and respect for one another in an environment where different viewpoints can be presented, argued, exchanged and finally agreed upon. The value of argumentation as learning strategy was played out and confirmed many times during SIKSP workshops and research findings of participants. It has been a privilege to participate with colleagues and students.* [Corrine, Interview]

4.4.7 Some case studies of how participants viewed DAIM's influence on them

The aim of this question was to find out how the DAIM has affected the participants' professional development and their abilities to do research on science-IKS. Although each participant has a unique story to tell, a general estimate of the impact of the project on the teachers can be estimated by taking a few lived experiences of some of the participants. These were captured in the interviews with the participants, who were purposively chosen. The case studies are based on the responses to questions 7 and 8 of the in-service teachers' interview (See Appendix B3 or B4 of the facilitators' interview):

What important contributions has the SIKSP made on your life as a science teacher and researcher? In what ways did the SIKSP enhance your research skills? Please, elaborate on some of the professional experiences or competencies that you acquired in the project. How have they affected you professionally?

4.4.7.1 Laura

Laura is a 59-years-old experienced primary school teacher who has been teaching for over 40 years. She was among the first cohort of in-service teachers who enrolled in SIKSP.

She was initially reticent using DAIM with her grade 3 learners, believing that they would not be able to construct arguments. However, during her master's programme, she used DAIM with her learners and became the reference of good teaching using argumentation strategy. During a visit by the then Director of the Department of Science and Technology, to the Western Cape, she carried out a DAIM-based lesson to showcase the method of teaching. Her lesson has been used many times afterwards during seminars and workshops to train in-service teachers on the use of argumentation-based strategies to carry out a science-IK lesson. She obtained her master's degree in 2012. At the moment, she is a headmistress of a school, and studying for PhD in science education.

In her view, the project has had a tremendous impact on her career as a teacher and researcher. She had written many research papers in collaboration with colleagues besides other responsibilities. In response to the question on how the project had contributed to her professional development, she said:

> ***Laura**: Wonderful contribution. I'm more confident than ever. Know how to plan my lessons and integrate it with IKS. I am writing and co-writing papers for conferences. I have been editing research papers. It improved my reading by the day as well as the critical enhancing of an article while reading it.* [Laura, Interview]

4.4.7.2 Gwendoline

Gwendoline is a 43-year-old teacher of mathematics and physical science with over 20 years of teaching experience. She has taught in several high schools in South Africa and the UK, as well as several tertiary institutions in South Africa. She has also held many administrative positions in the Education Department in the Western Cape. Her impressions of the contributions of the project are very positive.

> ***Gwendoline:** As a researcher I must say the SIKSP actually, you know, made me more open minded; open to many things. As a researcher I learned so much within the SIKSP group. Maybe that's why I got a cum laude (laughter). Because I really learned … to work very hard in that SIKSP group. We really worked very hard, you know? I was exposed to writing academic papers that were published in conference proceedings. I couldn't have done it without the assistance of that SIKSP group, because in that group we learned so much. So as a person, I think I grew a lot.* [Gwendoline, Interview]

She specifically thinks that the advanced lectures of the seminars which particularly targeted different aspects of the research process helped her a lot to acquire research skills.

> ***Gwendoline****: Yah, I can just say how it actually improved my research skills. I didn't do course work, so I was forced to learn the research methodology on my own. By just having the group, the SIKSP group, and those seminars, they took us from chapter one to chapter five. You know, that also helped a lot in order to improve my research skills,… Yah!* [Gwendoline, Interview]

During the seminars and workshops, in-service teachers had to present their research work and receive critical comments from colleagues in order to improve on their work. Gwendoline feels that this process was very helpful in making her prepare to accommodate alternative views and critique by developing "a thick skin".

> ***Gwendoline:*** *We had lots of arguments in a positive way and discussions. I can still remember that made you a stronger person, do you understand? And it also allows me to develop a thicker skin, you know? You must have a thick skin* [laughter].
>
> **(**During presentation of research proposals or results, the project director often admonished participants to develop a thick skin in order to be able to absorb the punches of critique from colleagues without breaking down). *So, I have grown as a person intellectually… as well as spiritually as well.* [Gwendoline, Interview]

The research process often has its highs and lows. At times the researcher may feel so discouraged or overwhelmed by the turn of things or when everything seems to grind to a halt. Gwendoline had such an experience, and acknowledges the role played by the SIKSP group in helping her overcome such moments.

> ***Gwendoline:*** *And I also learned to persevere within that group. Many times I just wanted to throw in the towel with my own thesis thing or whatever I was doing, but you see, the way that the group encouraged one another and all that was very positive to me and supportive. So the SIKSP really made, you know, at a personal level. Also, it made a huge positive impact on my life. So even after I'm done with my studies, I still feel like always going back to the seminars and conferences because you learn so much from the group.* [Gwendoline, Interview]

Exposure is one of the most exciting things that could happen to aspiring researchers. Gwendoline still remembers her first experience of research presentation in an international conference and the lasting impact that it has had in her life as a teacher.

> ***Gwendoline*****:** *Oh but you know just the exposure that we got! I can still remember the very first paper I wrote is when we went to Malawi to present it there. Yah! That was for me the greatest experience…Yah, it's about five papers that I wrote with others… and I made so many good friends as well, you know? Good friends; connections...friends. Yah!… But now unfortunately, I can't now attend any more conferences because of the funding and all that.* [Gwendoline, Interview]

During the interview, I asked Gwendoline whether she thought that the knowledge she had acquired in the SIKSP activities was useful to her out of the classroom. Her response was very definite and affirmative:

> ***Gwendoline:*** *Yes, most definitely. You see, I will always take what I have learned with me wherever I go or whatever I do. So … it will always be useful to me even outside the classroom as well; not just in the classroom. As I told you earlier what effect, positive effect it had on myself, on my character as a human being as well. So I will always, you know, take it with me wherever I go.* [Gwendoline, Interview]

When prompted further how she was putting the knowledge she had learned into use, she explained how she was applying the argumentation-based skills she had learned during the workshops in the workplace where she manages lecturers.

> ***Gwendoline:*** *I mean like in my situation now I'm managing lecturers, do you understand? So you need to be able to develop a thick skin [laughter] for whatever challenges come on your way. And SIKSP made me what I am today. You see, I can debate about anything… For every claim or whatever, you must have evidence. You can't just say: 'You mustn't do it this way.' I want to know why…Why do you say so?... So … as I said, I'll follow the TAP and the CAT framework, you know? … Some people see it, maybe, in a negative way…. But argument is not just negative, but like we have been taught, it's in a good way, you see? You can't just say something or make a claim if there's no evidence.* [Gwendoline, Interview]

4.4.7.3 Albert

Albert is a vivacious 48- year-old science education in-service teacher who joined SIKSP in 2009. He is full of energy, generous, encouraging and always ready to help colleagues. He is the type of person one would like to always rush to when one is facing any challenges, academic or otherwise. During argumentation and discussions, he would often have so much to say that in most cases he has to be stopped more than once. He was fortunate to have the NRF bursary that covered his expenses and travelling for his doctoral studies. When he went to NARST, he made everyone envious of attending that conference one day. He narrated his experiences at NARST and took photographs of himself with some of the gurus of science education that we have always been reading about. Indeed, his motivation was very high and contagious. When I asked him the impact of the project on his life as a teacher and researcher, he had this to say:

> ***Albert:*** *It's life-changing….Ten years ago I would never imagine being a full researcher. Uhm… As I am speaking, within a few months I will be graduating with*

my doctorate degree, you see? So life-changing; that is life changing, really life changing and I wouldn't have imagined myself ten years ago being in this field of indigenous knowledge…. I've been publishing various articles on IKS related to meteorological science… I've got a big understanding. We give some feedback to material developers… I've been personally involved in many local organising committees for conferences. [Albert, Interview]

Albert has also been able to attend many local and international conferences presenting his research on IKS-related research. With a sense of fulfilment and self-actualisation, he said during the interview:

Albert: *I myself has been overseas three times with NARST, SAARMSTE conferences and AASIKS… I've written about twenty-two to twenty-six articles … Yah. That's including international work that's been published; that's including long papers for conference proceedings. I've attended many SAARMSTE conferences…Since 2009 I've been involved; … it's now 2017. So there's a lot of things that happened throughout the SIKSP programme that's been very much beneficial to my academic life. I've just published an international paper in an international journal. So it just shows that you get recognised.* [Albert, Interview]

Albert also loves the idea that he is making an impact in the world of research on IKS. Through social media platforms, he has been able to reach wide range of people and gain media visibility.

Albert: *I'm on Research Gate currently for the past two, three years and people are reading your work and citing your work. So I have become an author! I can give you an example, … I've submitted some interview questions where somebody from Czechoslovakia invited me to have an interview … because she read my work on Research Gate and she invited me to answer a few questions pertaining to her own research on indigenous knowledge. So it's been a journey that took me across the globe, yah. The positive part is where you gain a lot of knowledge; where there's such a lot of knowledge still available to document… Yah.* [Albert, Interview]

Albert also recognises the spirit of togetherness in the SIKSP group as having played a vital role in his career. Indeed, he seems to have been much affected by the IKS way of life where people prefer to share their lives and care for one another rather than the individualistic worldview prevalent in most western societies:

Albert: *But the support of the team, the people that you've been involved with … it's tremendous, you see? And there's a sense of family relations when you deal with indigenous knowledge systems. Not the IKS part but the spirit. That spirit of Ubuntu. That spirit of togetherness. We share. What is yours is mine, you see? I am because of you. That's the new eye-opener. When you deal with indigenous knowledge systems, it's all about sharing and caring. It's not 'I'm on my own island and I do things for*

myself.' It's the togetherness of it…. Yah! …You're more of a person that's a giver and not a taker. Yah! And you want to share and I mean that, that is what the SIKSP involvement changed in me. Because you're more caring, you look at things differently. Besides the research that you do, you get in touch with other people and their views. So it changes your perception of things and it makes you more humane… Yah! [Albert, Interview]

4.4.7.4 Fielding

Fielding is a 49-year-old calm and composed man who has been teaching physical science for over 22 years. He joined the project in 2009 at the honours level and eventually obtained his master's degree in 2014. Now he is about to round up with his PhD. Through the years, he had moved from the high school, and has been teaching at tertiary level for over five years. His response during the interview shows that he perceived the project as having made many positive contributions at the academic, professional, and personal dimensions. When I asked him what contribution SIKSP has made to his professional development he said:

***Fielding*:** *Yeah, positive contributions. In one sense, it's professional development. It made me view science, and it opened up a different worldview on how to teach science and also how to incorporate the IKS. So on the one aspect, it improved my professional development. And even I started to see things in a different light. Because [when] teaching science, you have to be aware also of the alternative worldview; of the IKS worldview.* [Fielding, Interview]

Fielding acknowledges the contribution of the project, especially the argumentation framework, to his personal characteristics. The project has not only affected his teaching, knowledge and skills, but his way of looking at life as well as the way he communicates.

Fielding: *And then the personal life… Yah! You also start to … reason with yourself and you have to try to reason things out and you first have to understand things. … you don't have to take things at face value. … It also gives you skills in terms of how to interact with people in terms of communication, argumentation, how to interpret and how to be, especially, to be critical of things. I don't mean critical in a negative way, but to interrogate and to try to understand… So, I think the programme, SIKS project, was useful in giving me that skill to communicate effectively and critically; and to analyse reasoning. And … when you interact with old friends, they also realise the difference in the way you argue and the way you put your points across. So I would attribute that to the involvement of the project.* [Fielding, Interview]

Career-wise, Fielding, like most other in-service teachers in the project, has been involved in research and publication in the field of science and IK, with the help of knowledge

acquired through the SIKSP. When I asked him about his research publications his response was:

> ***Fielding*:** *I've written about six papers; conference papers... I think two articles. And most of them are basically on the work that we have done in the SIKS Project. So most of them are on the dialogical argumentation model and which means that the SIKS Project equipped me with the skills to write those papers*. [Fielding, Interview]

4.4.7.5 Edmund

Edmund assisted with the SIKS Project from July 2009 to September 2011, coordinating SIKSP activities under the mentorship and guidance of the project director, as a post-doctoral fellow. He also supervised postgraduate students (especially Master's students), did some teaching at PGCE and Honours level, and research activities. Furthermore, he helped to coordinate SIKSP events such as national and international Science/IKS meetings and workshops, where SIKSP invited groups and individuals from other institutions interested in Science-IKS research. Edmund already had some competencies in leadership and research before joining the project in 2009.

According to him, science-IKS was a challenging field as he had to learn new knowledge. Before 2009, he attests to the fact that he was ambivalent about indigenous knowledge and its relevance in science. Although he considered IK to be nice to have, and a useful tool to aid student / learner understanding of physics concepts, he never thought that IKS in itself might be based on scientific fact. He said that at that time, he always associated IKS with mysticism, fantasy, magic and superstitious beliefs. At the SIKSP, he says the underlying theory helped him to change his perceptions of IK. "Prof Ogunniyi's CAT approach to SIKS helped me to re-evaluate my own beliefs about IKS and to my delight, I found that I could reconcile some of my deeply held cultural beliefs and unaccounted for experiences with scientific fact. This ignited my interest in the SIKSP."

In late 2011, he had a full lecturer position in one of South Africa's most reputable universities where he has continued to be influenced by the experiences he had at the SIKSP. His worldview had changed for good, as he says:

> ***Edmund:*** *I realized that most cultural beliefs and traditions, good and bad, have a sound scientific basis underlying their practice, and this seems to explain some strange experiences that most African students undergo which seem to defy logic. An example, is that I have personally experienced events where lightning is said to have been sent*

to attack a homestead. While I could not explain what I witnessed and for a long time was puzzled, the use of CAT helped me to interrogate my experience and come to the conclusion that I could not just dismiss my experiences as figment of the imagination, but that perhaps, some underlying scientific process was at work that science could not as yet explain. Further reading and research on the works of Nicola Tesla, Bruce Lipton, Gregg Braden and other unorthodox scientists has confirmed my views that IKS science is a sound scientific practice that is not as yet confirmed. [Edmund, Interview]

At the institution, he has adopted his research focus on IKS. He says "Through this exposure, I adopted a three pronged research study on IKS: Teaching scientific concepts through IKS; Teaching IKS through science; Identifying IKS / Culture-based misconceptions of scientific concepts. My master's students usually work on the 3rd trajectory. My PhD students focus on the first two trajectories. Thus I can say SIKSP has affected my research trajectory greatly."

4.4.7.6 Emma

Emma, a focused, approachable lady in her early 50s, to whom English is her 8th language, joined the SIKSP in 2009 as part of her postdoctoral programme. As a postdoctoral student, she played the role of a facilitator of workshops, planning, mentoring postgraduate students, besides many others. When I asked her the role she played in the project, she smiled and said:

Emma: *As I was saying, most of the people in the project had difficulties saying if they were learners or they were facilitators. That's how I felt myself, you know - I was a learner; I was a facilitator; I was a collaborator. I was a forming a part of the project. So my role is not a fixed one; wasn't a fixed one, I would say*. [Emma, Interview]

Emma is now a full professor of science education and championing IKS research, giving credit to SIKSP for having influence her professionally. Her contribution to IKS research can be attested by the number of journal and conference articles that she has written alone or in collaboration with other researchers since she left SIKSP. She has also consistently played a major role in the organization and running of AASIKS, attesting that the SIKSP's multiracial, multicultural nature was very useful in shaping her views:

Emma: *I remember that when I first joined the project I thought that because there were Blacks, Coloured and White people, I thought that some white people won't understand what I was trying to say from my native Mozambican background; but I was really pleased to see that they all could understand. And that was a way too for myself to learn to understand different perspectives; different backgrounds. So I really*

felt, … how can I say? …. I really felt blessed, really privileged to have been in a group with such a diversity. [Emma, Interview]

Although Emma had been involved in IKS research before coming to SIKSP, she is of the view that the knowledge gained at the project, especially about argumentation theories, was very useful.

> ***Emma:*** *In professional terms, I really learned a lot because for example, Contiguity Argumentation Theory was something really new for me. And as I said, my interest is also in integrating IKS in curriculum and coming to hear about the Contiguity Argumentation Theory was really enlightening for me professionally. And that's something that now I continue to think about not only agreeing with it, but critically thinking about it. And today I have some of my students who have done their master's degrees on argumentation in science for example. And that came from my inspiration being in that project. So yes, there is a lot I can say professionally, yes. That Contiguity Argumentation Theory was without doubt the main enlightening issue I got.* [Emma, Interview]

Emma acknowledges research skills that she learned at the SIKSP, which in her view, are still very useful to her career.

> ***Emma*****:** *In terms of skills – technical skills, you know – We participated in so many conferences during the time in the project. I think (I am assuming), I have improved my own skills in writing papers to conferences and presenting papers because we did a lot in conference participation in writing papers, co-writing papers; so that's one area in which I can say I learned a lot and improved my skills - writing and presenting at international conferences.* [Emma, Interview]

In Emma's view, one of the things she learned from the group was how to work in a multicultural context. With the effects of globalization becoming more real in our societies nowadays, learning such skills is an assert that one cannot ignore.

> ***Emma***: *Being at the SIKS Project, we had people coming from different backgrounds; people with different colours, different ages, different professional experience[s]. So one of the things I think I really improved during the project was to learn to negotiate my own perspective with the others' perspectives because diversity was eh …. there was a big diversity in the group. So I had to learn; so I improved a lot my natural skills in terms of understanding others' perspectives and, you know, learning to adapt and adopt sometimes different perspectives.* [Emma, Interview]

4.4.8 Interpretive summary and comments

In the fourth research question I wanted to find out extent to which SIKSP might have enhanced the participants' professional development and ability to carry out science-IKS research. In the structure of the CIPP evaluation model, this question falls under product

evaluation and seeks to determine the long-term effects or impact of the project on the project participants. The results of the study suggest that SIKSP had many diverse long-lasting positive effects on the participants' knowledge and classroom practices, as well as research capacities at the institutional, national and international levels. At the personal level, SIKSP enabled the in-service teachers to gain knowledge of NOS, IKS, and other skills; corroborating the results of some earlier studies (e.g. Ogunniyi, 2005, 2006, 2007a, 2007b). SIKSP also enabled the participants to alter their teaching practices in many ways, and to acquire new attitudes and skills necessary for the implementation of a science-IK curriculum. The participants also made gains in professional as well as psycho-social domains, resulting in greater self-confidence as teachers of an inclusive science-IK curriculum. Furthermore, the project also greatly enhanced the participants' capacities to carry out science-IKS research. Professionally, after their involvement in SIKSP, many of the participants had moved to higher positions in the educational field as a result. Several years after the end of the project, participants are still using DAIM, the teaching approach they learned at SIKSP, to pursue their educational and research goals.

These results seem to point to the argumentation-based approach (DAIM) as a potentially versatile tool capable of leading to many desired educational outcomes. It has been used in science classrooms to construct knowledge (Jimenez-Aleixandre et al., 2000; Osborne et al., 2004; Zohar & Nemet, 2002), used with preservice teachers (Aydeniz & Ozdilek, 2015; McDonald, 2010; Siseho, 2013) and in-service teachers (Ogunniyi, 2006, 2007a).

4.5 Summary and Discussion

This study was about the evaluation of the SIKSP from the view of the participants, of whom I formed part. From the results expressed in questions one to four, one can gather that the project through its flagship, the DAIM, accomplished much. For example, it helped most in-service teachers to change their perceptions from a positivist, science-dominant worldview to a dualistic worldview where IK was accepted as a source of knowledge in science classrooms. Not only did their worldviews about science and IK change, but the teachers also found a means of changing their classroom practices from teacher-centred to learner-centred methods using the argumentation-based DAIM approach. A practical application of DAIM by three teachers showed that its implementation was a rather complex issue. The conclusions of the observed DAIM lessons suggest that the success of the instructional approach depends on many factors. These include, among others, the teacher's scaffolding techniques, the teacher's

structuring of argumentation tasks, and the learners' language and communication abilities. With regard to the impact of DAIM on the teachers, it was found that SIKSP, or DAIM in particular, most probably produced many far-reaching effects on the teachers' worldviews, instructional practices, social lives, self-efficacy, and self-actualisation. Beyond the individual level, SIKSP had produced many publications, organised many international workshops and conferences on IKS, and has presented research insights at world renown conferences such as NARST and the World Academy of Sciences.

As a result of the argumentation-based courses, dialogical argumentation-based workshops and seminars, the in-service teachers were able see science and IK in a different perspective – that they could be used together in a science class. This corroborates earlier findings about the effectiveness of argumentation-based instructional methods in literature (Ogunniyi, 2007a, 2007b; Ogunniyi & Hewson, 2008; Ramorogo & Ogunniyi, 2010). In the study of Ogunniyi and Hewson (2008), for example, nine in-service teachers who took part in an argumentation-based course for six months to enable them understand the NOS and IKS were more willing to accept IK as valid knowledge in the science classroom, more capable of distinguishing between science and IK, and more capable of knowing the context in which to use them. Similarly, in the study of Ogunniyi (2007a&b) carried out to investigate the effectiveness of a Practical Argumentation Course (PAC) on four teachers who were subjected to the argumentation course for six months found that as a result of the course, the in-service teachers' understanding of NOS, IKS, as well as their awareness of the need to integrate IK and science were enhanced. In the present study, the newest in-service teachers had been using DAIM for over two years, and a majority of them for over seven years.

The DAIM approach of integrating science and IK is emancipatory in that it opened the eyes of the participants to see the value of their cultural knowledge. Science education in Sub-Saharan Africa (South Africa inclusive), has followed the footprints of the colonialist agenda established before independence (Ogunniyi, 2004; Ogunniyi & Mushayikwa, 2015; Ogunniyi & Rollnick, 2015; Semali & Kincheloe, 1999). Many decades after independence, little has changed with regards to the dominance of the Eurocentric worldview, and the concomitant denigration of African IKS in the science classroom. In the colonialist agenda, the science curriculum presented Euro-centric science as universal, tested, and credible (Bauer, 1992) while on the other hand, indigenous knowledge was denigrated and rubbished as useless and unfit for the science classroom (Semali & Kincheloe, 1999).

This worldview affected most science teachers negatively, to the extent that many of them became active propagators of the western worldview, disregarding their own knowledge or that of their learners as useful prior knowledge on which to build scientific knowledge in their classrooms (Semali & Mehta, 2012; Shizha, 2007, 2008; Shumba, 1999). This attitude of science teachers had the negative consequence of alienating many learners from science, which was seen by the learners as foreign and not relevant to their daily lives. So it was necessary to start the integration of science and IK by making the science teachers accept IK as valid knowledge. That is, to deconstruct the colonialist view of science as Western and IK as unqualified to be classified as science. Through the DAIM-based activities in the SIKSP, teachers were able to come to this realisation when they began to value IK as valid knowledge. This points to DAIM as a possible tool for decolonising the minds of science teachers, and enabling them to implement an unbiased, inclusive science-IK curriculum - a curriculum that does not accept or reject any view because of its source, but on the basis of the evidence supporting it, and the context.

The use of DAIM in the classroom had very positive feedback. All in-service teachers who had used DAIM in teaching reported that the learners were very active, excited and showed greater interest in the lessons. Some of them reported that more complex learning took place as a result of using DAIM. These results corroborate similar findings where argumentation has been used (Bathgate et al., 2015; Dawson & Venville, 2010; Diwu & Ogunniyi, 2012; Moyo & Kizito, 2014). In the non-Western contexts, the learners have always got excited when their local knowledge and artefacts were used as part of the science lesson (Diwu & Ogunniyi, 2012; Manzini, 2000). By including learners' cultural knowledge in the science lesson, the learners are motivated to study science as they see it more relevant to their lives. On the other hand, many studies have concluded that excluding or denigrating the learners' culture in the science classroom tends to alienate them from science (Aikenhead & Elliott, 2010; Cobern, 1996; Jegede & Aikenhead, 1999; van Wyk, 2002; Woods-McConney et al., 2013). This explains why many science education researchers (e.g.Kaya, 2013) call for the inclusion of IK in the science curricula in order to increase its relevance to the learners. Through the use of DAIM, science and IK have been used together in the classroom, causing excitement and increased interest in science as many studies have shown (Diwu & Ogunniyi, 2012; Manzini, 2000; Moyo & Kizito, 2014; Ramorogo & Ogunniyi, 2010). The implication is that argumentation-based methods have a great potential for making science more relevant to learners in the South

African context, and by extension, possibly leading to an increase in the number of learners opting to subsequently pursue science-related careers.

Despite these positive results from the DAIM, there were some challenges. Firstly, the in-service teachers had a predominantly Eurocentric worldview of science prior to joining the project, with a partial or total ignorance of, and misconceptions about IK. Secondly, there was lack of a practical instructional method to integrate science and IK. The challenges encountered when teaching using DAIM included high noise levels, difficulty of class control, greater demands of lesson planning, and time management issues.

One theme that stood clearly was the unifying factor of argumentation-based discursive workshops and seminars, despite the wide differences in age, education, cultures, and other factors. Working with people of different backgrounds is an assert in today's multicultural, globalised society. The SIKSP members, most probably influenced by the philosophical foundations of the Contiguity Argumentation Theory which allows for seemingly opposing worldviews to co-exist without necessarily having any confrontation, exhibited much tolerance and understanding. This sort of influenced the SIKSP members to be very receptive and tolerant to differences of worldviews and opinions. Human relationships are at the heart of SIKSP group. In an earlier study by Nhalevilo and Ogunniyi (2014a), the participants in the same project echoed similar sentiments. In this study, some of the participants revealed that they would have abandoned studies but for the concern and encouragement of colleagues. The study has also shown that besides the learning of science and IK, argumentation is useful in enabling participants to cultivate practices that could engender good citizenship (Jiménez-Aleixandre & Puig, 2012).

Besides the collaboration in the group, individual members of SIKSP have obtained higher degrees and advanced professionally. For example, one of the postdoctoral students is already a full professor of science education, and another is senior lecturers, doing research in science and IKS. This shows that much has achieved and much is still being achieved. The many research presentations and plenaries by SIKSP members on IKS at regional and international conferences such as the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE), the National Association for Research in Science Teaching (NARST) have helped to highlight the relevance of the field to other researchers. With the coming into existence of AASIKS, there is a great possibility of

infusing IK into many areas of science, technology, engineering and mathematics (STEM) at different levels, and at a larger scale in Africa than would have been possible with SIKSP alone.

Arguably, there are challenges using DAIM as a basis for integrating science and IK as some researchers (e.g. Martínez, 2011; Òtúlàjà, Cameron, & Msimanga, 2011) have argued. However, the results of this study suggest that if well managed, the argumentation-based strategy used at SIKSP would not only be useful integrating science and IK, but would have many other benefits. This strongly suggests that in the absence of a better alternatives, it should be worth giving more attention in South African classrooms. In the next chapter I will draw the final conclusions to the study, and make some recommendations.

CHAPTER FIVE: CONCLUSION, IMPLICATIONS, AND RECOMMENDATIONS

This study was a case study of the evaluation of the Science and Indigenous Knowledge Project that took place in a Western Cape university, South Africa. The main aim of the study was to find out the how the SIKSP fulfilled its goal of training in-service science teachers to implement a science-IKS curriculum, and to equip postgraduate students with the necessary skills to carry on research in the domain of IKS. I used a constructivist-pragmatist worldview, but also drew from several other concepts such as Stufflebeam's Context, Input, Process, Product (CIPP) evaluation model, as well as Guba and Lincoln's Constructivist evaluation. I gathered some information about the achievements of the SIKSP from the view of the participants as put down in chapter four. A summary of the main findings follows next. For ease of understanding, the summary will follow the same order as the research questions.

5.1 Summary of the Main Findings

5.1.1 Question One

What opportunities and challenges emerged for the SIKSP participants as they were being trained to implement a science-IK curriculum?

The findings suggest that the in-service teachers who enrolled in the SIKSP had many opportunities to acquire new knowledge in the field of science and IKS. The design of the postgraduate courses included modules specifically aimed at raising the in-service teachers' awareness about the nature of science and the nature of IKS, among others. The in-service teachers also attended workshops, seminars, IKS conferences, and participated in IKS materials development, systematic review of IKS articles, and an argumentation-based instructional approach that enabled them to view science and IKS as valid sources of knowledge in the science classroom. As a result of the exposure to all these learning opportunities, the in-service teachers' knowledge of IK increased, and their attitudes towards the inclusion of IK in science became more favourable to a science-IK integrated curriculum than when they first began the training. After going through the training, all the in-service teachers reported that they were

more confident to teach an integrated science-IK curriculum thanks to the training they received.

The study also shows that the in-service teachers faced some challenges as they navigated through the programmes. These include:

- Teachers' prior beliefs about science and IKS where they were ignorant of IKS or looked low on it.
- Teachers' challenge of changing previous approaches to teaching. It was not easy for the in-service teachers to give up their former teaching approaches.
- Teachers' challenge of learning DAIM approach to teaching. It took long for the teachers to master argumentation and DAIM.
- School environments that did not support DAIM approach of instruction
- Change of university policy: Stopping course work that could help master's students and insisting on full theses.
- Managing job, family and in-service training was very demanding for the teachers.

5.1.2 Question Two

What were the participants' perceptions of the effectiveness and challenges of using DAIM as an instructional tool for implementing a science-IK curriculum?

Most of the in-service teachers' perceptions were that DAIM was an effective teaching strategy to integrate science and IK if well managed. Most of them believed that DAIM enabled learners to externalise their thoughts, develop interpersonal skills, construct new knowledge as well as change their views in the face of convincing evidence. Many teachers reported DAIM classes as highly interactive, and interesting. They regarded DAIM as very useful in helping them gain confidence to integrate science and IK in the classroom.

- The teachers expressed the following positive experiences about DAIM:
- DAIM resulted in more active and excited learners
- DAIM drew the interest of other teachers
- DAIM resulted in the learners engaging in more complex learning

Challenges of DAIM lessons as identified by in-service teachers:

- Time factor: DAIM lessons took more time both in preparation and delivery
- Planning a DAIM lesson is more demanding
- Managing a DAIM lesson is more demanding because the noise levels can be higher and the learners can take the lesson to unexpected directions during discussions
- Pressure to complete syllabuses
- Initiating learners to start participating can be challenging since they are not used to speaking in class.
- Large class sizes in many schools that make it difficult to organise DAIM classes easily.

5.1.3 Question Three

How did the teachers apply DAIM in their classrooms?

DAIM was used to teach science, mathematics as well as socio-scientific topics. The three teachers implemented DAIM differently. Two of the teachers' lessons were teacher-dominated while the third was learner dominated. The learners in the socio-scientific class could interact, making claims and refute others. On the contrary, learner-learner interaction was not noticeable in the science and mathematics DAIM lessons where nearly all interactions were between the teacher and a learner.

The lessons showed that language played an important role in the argumentation classes. Learners in the science class especially, showed great difficulties expressing themselves in English, the language of instruction. There was also evidence to suggest that whereas the learners in the socio-scientific lesson showed a mastery of argumentation terminology and usage, the learners in the other lessons did not. It could therefore be suggested that an argumentation lesson should be preceded by the teaching of argumentation language and structure. Also, the science or mathematics teacher should select topics which are amenable to argumentation for DAIM lessons.

5.1.4 Question Four

To what extent did SIKSP enhance the participants' professional development and ability to carry out science-IKS research?

As a result of participation in the project, many of the in-service teachers developed professionally and academically. Many of them have obtained higher qualifications (master's

and doctoral degrees). Through the SIKSP, many of the teachers have developed and improved on their professional and research skills, and some have had promotions to higher positions of responsibility in their fields. The participation in the SIKSP also led to social and racial integration, greater skills of dealing with cultural diversity, improved self-efficacy of the teachers to teach or do research in science/IKS, and a stronger sense of belonging to a community of practice (*Ubuntu*). The birth of the African Association for the Study of Indigenous Knowledge Systems (AASIKS) is an innovation that could ensure continuity of research in science and IKS by SIKSP participants and alumni.

5.2 Conclusion

This study found that the SIKSP through DAIM offers an approach of integrating science and IK in the science classroom that apparently holds promise as a means of transforming instructional practices and ideas. From the results of the teachers who used the DAIM as well as the learners, one can conclude that the use of the approach led to belief revision (the change from seeing science as the only source of knowledge and IKS as having nothing to do with science), acceptance of alternative views, and the desire to lay emphasis on evidence to justify claims. It should therefore necessary to give this approach a try and to adapt it to other contexts in South African schools.

The recognition by the participants of IK as authentic knowledge in the science classroom is in itself emancipatory and empowering for the in-service teachers as they have come to realise that the colonial version of science had a hidden agenda of exalting the Euro-centric worldview and denigrating the African perspectives of interpreting the world. The implication of this recognition is that by indigenising the curriculum, their science classrooms would become more relevant, exciting and meaningful as they include local examples with which the learners are familiar. From the constructivist perspective, this is very useful as prior knowledge of the learners is now valuable material for teaching science. By comparing the knowledge from two worldviews, both teachers and learners can learn in what context they can use each of them.

Looking back as an insider in SIKSP, I have learned to ‘listen carefully to diverse voices’ (Kincheloe & Tobin, 2009, p.722) in the science classroom. This means considering different worldviews other than the positivist position which had dominated my thinking for as long as I was studying and teaching science. Now I try to understand rather than to dismiss a view as

meaningless without questioning, because it did not align with 'science'. This learning did not come easily. I had to question many things and sometimes got confused, and at times things made sense after the confusion has been cleared through discussion with others.

This evaluation study, I believe, contributes in synthesising the views of most of the participants with regard to the usefulness and impact of the project. It underscores some of the successful approaches and makes some suggestions for possible expansion and improvement.

5.3 Implications

The results of this study have some implications for education stakeholders.

5.3.1 Implications for current practice

Learning Outcome 3 Assessment Standard 1 of Physical Sciences at FET level expects learners to be taught how '*to evaluate knowledge claims: recognise, discuss and compare the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims.'* The results of the study suggest that DAIM stands a good chance of equipping learners to be able to achieve the above-stated goals of the curriculum if well managed. The argumentation-based approach requires learners to seek justification for the claims made and also to accept IK claims as equally valid alternative explanations to those of conventional science. The implication is that using DAIM as an instructional approach has a high probability of bringing benefits to attaining the goals of the curriculum better than would have otherwise been the case.

The results of this study also suggest that engaging learners in DAIM approach gives them an opportunity to express their views and defend them while critically questioning the claims made by their peers and demanding their justifications. A principle of the Curriculum and Assessment Policy Statement (CAPS), Grades R-12 is to engage learners in active and critical learning by "encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths" (CAPS, 2011; p. 4). Thus, the DAIM approach seems very appropriate to the CAPS policy demands just stated above.

The same CAPS document for physical science on page 5 states that the aims of the curriculum policy is to produce learners that are able to: 1) identify and solve problems and make decisions using critical and creative thinking; 2) work effectively as individuals and with

others as members of a team; 3) collect, analyse, organise and critically evaluate information. The results of this study suggest that using DAIM as an instructional approach may be a means of achieving these aims. The argumentation-based approach prepares learners to think critically, weighing the evidence advanced in the justification of claims, and working and discussing together in groups in order to reach a consensus if possible. This predisposition to interrogate claims before accepting them on the basis of convincing evidence is a virtue that DAIM can contribute to the science learners if well utilised in science classrooms.

5.3.2 Implications for long term impact

South Africa is a multiracial, multicultural society, with people from many African countries studying in most classrooms. This kind of globalised environments have a great need for the learners and teachers to understand and accept other people, with their cultures and worldviews. In this study, many participants spoke positively about the multiracial, mix in the SIKSP and the ability for all these diverse cultures to mix without clashing in the SIKSP environment. These results suggest that DAIM could be a successful instructional approach in the country's multiracial and multicultural contexts. This assertion seems very plausible since the argumentation framework is based on accepting all opinions without denigrating others, and enables learners to tolerate, accommodate, and value people from other cultures, races and worldviews.

Very often, people may act with inherent prejudice and bias, but with the argumentation-based framework, many in-service teachers testified that they were more prone to look for evidence rather than just accepting or rejecting an opinion based on stereotypical stances. The effect of DAIM was also expressed in terms of tolerance of other views and opinions. With this mind set, learners who engage in argumentation would likely make better citizens because they would be better able to tolerate diverse views.

The results show that the DAIM could enable learners to engage in discourses involving opposing concepts such as science and IK. This same principle could be useful in preparing a citizenry that is prepared to discuss different concepts as diverse as politics, science, environment issues, economics, society, culture, etc. This is in line with the aim of raising a scientific literate generation capable of taking informed decisions about the world and the environment based on evidence (Lederman et al., 2014; Sadler et al., 2007; Zeidler & Nichols, 2009).

Learners enjoyed the lessons which included aspects of their culture and they could actively contribute ideas when they were taught using the DAIM approach. Several studies (e.g. Aikenhead, 2001, 2002; Mavuru & Ramnarain, 2017) have concluded that valuing learners' cultures in the science classroom makes them more interested in science, and casting aspersions on their cultural values alienates them from science and science-related fields. This suggests that using this approach might be a means of raising the interest of learners in the science-related fields of study.

5.4. Recommendations

Following the results of this study and the challenges identified by various participants, I would make a few recommendations.

5.4.1 The need for expansion

This study is about the SIKSP situated at one university in Cape Town, which from the numerous publications produced so far, can be said to have largely succeeded in changing the lives of many in-service science teachers. Although the number of in-service teachers trained so far may be in their tens, the number is very insignificant compared to the demand in such skills throughout South Africa. It is therefore necessary that the project should expand to include a greater number of teachers. This expansion could take several forms, as there are many designs of effective professional development (Bates & Morgan, 2018; Darling-Hammond et al., 2017; Desimone, 2011).This sentiment was held by several participants who felt that SIKSP should expand with the training of science-IK integration to include a wider audience, for example, to District and Provincial levels. A few excerpts are given to substantiate this view:

RES: What areas of the SIKSP need improvement? What do you suggest should be done?

> ***Fielding****: Trying to contextualise it more to get it to a certain context of the different schools and then the other one is a SIKSP project. Rolled out to bigger or a greater audience… We in the SIKS project it seems like we are cross-fertilizing within the group. We have to roll it out to a wider audience to do more advocacy in terms of the, in terms of the project.*

RES: How do you suggest ... What approach can we take to roll out, for an example?

Fielding: *One way to reach a wider audience is to try to work with the surrounding schools. Try to involve the teachers of those schools and go out; other ways also to go out to the schools and maybe have workshops with the teachers and also the department. I know that in the past we tried to do that, but it didn't work out. But we should, … the fact is that we have to reach more people in order to grow; to improve the audience, to improve the project.*

Zameka*: The project needs to reach out to more students especially those doing honours degree so that they are motivated to enhance their research skills and continue with their studies in science education.*

I agree with Zameka who has raised a pertinent issue. For the project to be sustainable, there must be new trainees coming in on yearly basis. The present number of in-service teachers is largely at the final stage of their studies, doing their doctoral degrees. Besides, most of them are already old (mean age over 50) and there is a pertinent need to recruit younger teachers in their 20s who would continue with the vision, but funding is a challenge.

It is true that multinational companies often fund some IKS research. But the funding is mostly for research on indigenous medicinal plants by pharmaceutical companies with purely commercial interests and not to develop capacities of science teachers as SIKSP was designed to do. The most important source of funding therefore remains the government and some of its departments, such as the Department of Science and Technology. But with the prevailing budgetary constraints, it becomes less and less probable that such funding would be available in the nearest future. Also, in order to roll out the programme beyond the institutional level, certain things must be put in place. For example, the education policy makers have to design how such an expansion could be done, and also make provision for the expenses incurred. This points to the need for funding.

5.4.2 The need for funding

Funding plays a pivotal role in any project or innovative programme such as the integration of science and IK. It is necessary to provide more funding to expand the project and to enable the publication of IKS resource books that were started but not completed. The new approach to integrating science and IK has been tested in the SIKSP for over a decade already, with many reports of success in achieving the desired results (see Hewson & Ogunniyi, 2011; Nhalevilo & Ogunniyi, 2014; Ogunniyi, 2014; Ogunniyi & Hewson, 2008). It should therefore

recommendable that funding be provided by the appropriate governmental agency for the possible rolling out of the programme on a larger scale. That phase should not only involve an institution, but possibly the schools in the whole Education District. Unless this is done practically, the method may remain the subject of research and finally benefit just a few individuals.

In the interviews many of the in-service teachers suggested that funding for the project was a big necessity. In response to the researcher's question of what challenges the participants perceived as facing the project, the need for funding came up from several of them.

***Gwendoline**: I think it's just funding. That's all that we, that the group is actually lacking. It's funding… I feel like, you know, … I'm despondent to write a paper … because I can't go and present the paper, do you understand? ,…. It's just the money issue, the funding. **Albert**: I would say we need funding…Specifically, from our SIKSP side, yes, we get a bit of NRF funding but not that much, but we need more. We need more stakeholders to get involved. Business. We need businesses to get on board. We need private companies to get on board. We need government to get on board. **Emma:** I think if we could have more invited speakers to our workshops that will be good; like from different parts of Africa especially, that will help a lot. But as I said, this will depend on finance. **Edmund:** I think the current framework is quite good except that it is heavily dependent on the availability of funding.*

It is also necessary to provide funding for the completion and publication of IKS resource books which were started but not completed because of technical challenges. If such resource materials are made available, they would be a great relief to the teachers who are still struggling to integrate science and IK. The retirement of the project director has created a vacuum with no one with the necessary skills and experience to seek funding for the project. Hence there has been a lack of funds to sponsor activities. The challenge of continuity of any successful project is a common problem in Africa. Once a leader leaves the project either due to transfer or retirement, it is often difficult to get replacement.

5.4.3 Need for assessment of IK

The South African education system places a very high value on assessment. The results of the Matriculation Examinations are often taken by parents, learners and other education stakeholders as the measuring rod of performance, and is used to distinguish between good and bad schools. In such a system, any reform initiative that is not assessed would be difficult to

implement effectively because teachers would prefer to teach to in order to gain higher scores in official examinations (Shizha, 2007). This is one of the main challenges expressed by teachers as they struggle to implement a science-IK curriculum (Onwu, 2009) It is therefore very necessary to begin assessing IK so that more teachers and learners will take IK more seriously. The assessment may start in the form of culturally-based scenarios and comprehension questions.

5.4.4 The need to teach IK and NOS at school level

The in-service teachers' predominantly Eurocentric worldview of science and their partial or total ignorance of, and misconceptions about IK, is an indication that the school system and the teacher training programmes did not do well in teaching NOS and NOIKS. Teaching about NOS would make learners and teachers more aware of the dangers of scientism and to admit that science is "a multifaceted, tentative and revisionary human enterprise, arising in a socio-cultural context" (Ogunniyi, 2006; p.100). There is therefore the need to effectively start teaching NOS and NOIKS at school level. Researchers had suggested that if the aims of RNCS had to be achieved, then the NOS and IKS should be taught (Onwu & Ogunniyi, 2006). Doing so would better prepare learners to abandon the positivist view of science and to more readily accept alternative explanations to natural phenomena; possibly accepting the IK worldview with less resistance than is the case at the moment.

5.4.5 The need to teach argumentation

Argumentation, especially dialogical argumentation, is widely acknowledged as a versatile tool for constructing scientific knowledge (Driver et al., 2000; Hogan & Maglienti, 2001; Llewellyn & Rajesh, 2011; Manz, 2015). However, it is also acknowledged that engagement in argumentation does not come naturally and that argumentation has to be taught either explicitly (Dawson & Carson, 2018; Kuhn, 1993b; Simon et al., 2006; Venville & Dawson, 2010)or implicitly (Kuhn, 2010). It is my view that argumentation should be taught to in-service teachers and pre-service teachers during their years in training schools so that they would be able to teach it to their learners when they get to their classrooms. Teaching learners the skills of dialogical argumentation would enable them to stand a good chance of engaging in many scientific and socio-scientific discourses necessary in the contemporary world.

5.4.6 The need to develop IKS materials to support science teaching

One of the aims of SIKSP was to produce IKS materials to support science teachers in their endeavour to implement a science-IKS curriculum. This objective not been met. It would be good if this goal is pursued and realised.

5.4.7 The need for online meetings

All participants testified to the usefulness of the SIKSP workshops and seminars in building their capacities as science teachers and researchers. With the present situation of COVID-19, and its unpredictable nature of variants coming out, we do not know when the situation will ever go back to what it was before 2019. It will be good if an effort is made for interested SIKSP members to start attending these workshops and seminars online. An advantage of this platform is that many alumni who may be beyond Cape Town or South Africa will be able to take part in such online workshops.

5.4.8 Recommendations for further research

In this study I looked at the effects of the SIKSP on participants from the view of the participants. The focus was on two of the SIKSP's objectives, namely, the extent to which the project succeeded (or failed) to prepare in-service science teachers to enact a science-IK curriculum and to carry out research in the area of IKS in South Africa. There are still more areas which need research:

- The project involved five institutions in five provinces of South Africa. It might be of interest to investigate the benefits and challenges of the collaboration between the institutions involved in the Science and Indigenous Knowledge Systems Project.
- One of the areas where participants expressed difficulty at the SIKSP was the development and publication of IKS support textbooks. (And the leaders of the different resource books failed to submit their responses to the critical comments made by an independent reviewer despite several reminders by the project director). It would be interesting to investigate the challenges involved in the development and production of IKS teaching materials and what it takes to produce such resource materials.
- This study did not delve into issues that concerned finances. A study of the SIKSP that may include cost would surely be of great value.

- Some researchers have questioned the use of argumentation-based strategies in integrating science and IK. It might be of interest to investigate the relative effectiveness of argumentation-based methods and another method in integrating science and IK.
- One problem faced in the science-IK integration is how to assess IK. A study on the possible ways of assessing IK within the curriculum will probably be very useful.
- Most of the argumentation has been carried out in English, which is a second language to many teachers and learners. It might be useful carrying out research in an environment where a language other than English is used for the main discussions and argumentation in an attempt to integrate science and IK.

5.5 Limitations

This study had some limitations. It was my intention to present the preliminary results of this evaluation study to the SIKSP workshops for discussions, critique and further refinement of perspectives by SIKSP members before drawing the final conclusions through some form of consensus. This is the final stage of the constructivist approach whereby stakeholders try to reach a consensus. However, the unexpected appearance of COVID-19, with its restrictions, did not permit this to happen. Moreover, at the time the pandemic stroke, the technologies now used for teleconferencing, such as *Zoom*, were not yet popular.

Due to space and logistical problems at the university, some of the materials of SIKSP was moved to smaller venues. During the movement, some of the archived documents could not be traced, leaving some gaps that would probably have thrown more light. I limited this study to one university due to financial and logistical implications because I had no funding, even though the project involved other universities. Since this research is a case study, its results cannot be generalised to other contexts. The views of the in-service teachers who dropped out of the project have not been represented in this study. Although I did contact three of them, only one accepted to make any contribution.

5.6 Final conclusion

This study was a great learning opportunity for me. I learned that when carrying out research involving human beings, one had to have several virtues in addition to intellectual and

creative abilities. One needed, for instance, transactional, diplomatic and organisational skills. Also, I learned patience and self-control because things did not always go the way I anticipated. With each unanticipated huddle encountered, I had to make changes in the plans to accommodate the new situation. With the coming of the present pandemic (COVID-19), the adaption became much more necessary. Ironically, it was during the first lockdown period in South Africa in 2020 that I made the greatest strides in my research report. I came to understand what it means to say that evaluations are messy. For example, I started looking at the evaluation from a purely positivist perspective, trying to force things go the only way I knew. However, as I interacted with my supervisors and moved further and further into the evaluation, things changed progressively in the face of the reality I encountered. In the end, I found myself completely at the opposite side of my initial position.

This study provided an evaluation of the SIKSP project from the view of its participants. The views point to SIKSP as a successful project at training in-service teachers to implement a science-IK curriculum in South Africa as demanded by the policy statements. Despite some limitations, the argumentation-based approach seems to have many positive effects besides its use in the classroom. The knowledge gathered from this study could be used, with adjustments (depending on the contest), to carry out similar activities in other provinces of South Africa and beyond.

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Appendix A. Ethical clearance

UNIVERSITY of the WESTERN CAPE

Department of Institutional Advancement
University of the Western Cape
Robert Sobukwe Road
Bellville 7535
Republic of South Africa

60 YEARS of hope, action & knowledge

05 February 2021

Mr DA Anga'ama
SSME
Faculty of Education

Ethics Reference Number: HS20/10/39

Project Title: An evaluation of a Science and Indigenous Knowledge Systems Project at a Western Cape University.

Approval Period: 02 February 2021 – 02 February 2024

I hereby certify that the Humanities and Social Science Research Ethics Committee of the mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report by 30 November each year for the duration of the project.

The permission to conduct the study must be submitted to HSSREC for record keeping purposes.

The Committee must be informed of any serious adverse events and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

Director: Research Development
University of the Western Cape
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Appendix B. Interview schedules

B1. Project director's interview schedule

No.	Questions
1	People often react differently to new ideas. What were the reactions of the faculty, university, and students when the SIKSP began?
2	What has been the attitudes of SSME colleagues, the education faculty, the university, the WCED and other education stakeholders in terms of collaboration with the project team?
3	What challenges did you have as far as available resources (human, material and financial) were concerned?
4	How was the SIKSP organised?
5	What informed the content and approach used in the project offered?
6	Of what importance were the seminars, workshops and conferences to the project?
7	What critical role did dialogical argumentation instructional model (DAIM) play in the project? What alternative approaches were also considered?
8	What are the advantages of DAIM over the other alternatives?
9	From your experience, what difficulties did the teachers involved in SIKSP encounter in implementing DAIM in their classroom?
10	There was a change of approach used in training master's students: from course work and a mini thesis to a full thesis with no course work. In your view, what are the advantages and disadvantages of that change?
11	In your view, what are some of the major contributions that the project has made towards research-capacity development in the Faculty of Education, UWC and the country as a whole?
12	Are you satisfied with the achievements of the project as a whole?
13	Was the project implemented as originally planned?
14	What major challenges has the SIKSP been facing? What effort is being made to overcome them?
15	Are there any surprises (positive or negative) that came about as result of the project?
16	How do you see the future of the SIKSP vision in the next few years?

B2. Lecturers' interview schedule

Q	Questions
1	What was the climate surrounding the project when things began?
2	How did things evolve as time went on?
3	In what ways did you equip yourself to carry out such a novel idea in training teachers to implement a science-IKS curriculum?
4	What are your views of the seminars and workshops? Do you think they achieved the desired purpose?
5	There was a change of approach used in training master's students: from course work and a mini thesis to a full thesis with no course work. In your view, what are the advantages and disadvantages of that change?
6	What are the most successful components of the SIKS Project in your view?
7	What components of the project did not succeed very well? Please explain.
8	What have been the major difficulties faced by learners in your view?
9	How have you tried to resolve them?
10	In your view, was the SIKSP successful? Please explain.
11	Are you satisfied with the quality of work done by SIKSP?
12	How do you see the future of the SIKSP in terms of relevance and sustainability?

B3. SIKSP resource persons' interview schedule

Q	Questions
	Please, tell me something about your academic and teaching background
1	When did you get involved with the SIKSP?
2	What role did you play at SIKSP?
3	Did the SIKSP add anything to your experience? Please, elaborate.
4	What are some of the positive things about the SIKSP?
5	What challenges did you face while at the SIKSP? How were they resolved?
6	Please, what are some of the ways by which the SIKSP can be improved to make it more effective in training in-service teachers to integrate science with IK?

Thank you very much for taking time to answer the questions

B4. In-service teachers' interview schedule

Q	Questions
0	Please, tell me about yourself as a teacher; your background and teaching experience.
1	Please, describe your state of readiness or preparedness to integrate science and IK in your classroom as demanded by Learning Outcome 3 (LO3) of the new science curriculum before you joined the SIKSP.
2	After your time at SIKSP, what is the situation now? How prepared are you now to teach a science – IK lesson?
3	What programmes and activities particularly helped you to be able to integrate science with IK in your classroom? Explain.
4	Have you ever tried to implement the SIKSP method in your classroom or school practically? [Yes/no]. **If yes,** what were the reactions of your learners, colleagues, or principals when you used DAIM as a teaching approach in your classroom?
5	What are the practical difficulties encountered when implementing the DAIM?
6	What are some of the difficulties that you faced during your training? How were they resolved?
7	What important contributions has the SIKSP made on your life as a science teacher and researcher?
8	In what ways did the SIKSP enhance your research skills? Please, elaborate.
9	What areas of the SIKSP need improvement? What do you suggest should be done to improve the situation?
10	Are there any surprises (positive or negative) since you were involved with SIKSP?
11	Do you think the knowledge and skills gained from SIKSP are useful to you outside the classroom? Please explain.

Thank you very much for taking time to answer the questions

Appendix C. The SIKSP Evaluation Questionnaire

Evaluation of the Science and Indigenous Knowledge Systems (SIKS) Project: QUESTIONNAIRE

I am doing a research on the evaluation of the Science and Indigenous Knowledge Systems ***(SIKS)*** *Project which existed from 2004-2013. Please, in the following questionnaire I will like to know your opinion concerning the SIKS Project activities and how you have been affected by them. The information is required for research purposes only and the confidentiality of the information as well as the anonymity of individuals is guaranteed. Thank you very much.*

Daniel Angaama (PhD student)

PERSONAL INFORMATION

Name: …… Gender: M/F …… Age: (put an **X** below)

‹30	30-39	40-49	50-59	60-69	›70

What is your nationality? …….

How long have you been teaching? ……..

In which year did you join SIKSP? ……..

What was your highest academic qualification when you joined SIKSP? ……..

What is your highest academic qualification now? ……

At what level of education [GET, FET, Univ., etc.] are you teaching? ……

What duty and administrative post (if any) do you hold? ……

Please indicate the **number** of conference papers and journal articles that you have published either alone or with other colleagues since your involvement with the SIKS Project.

Short conf. papers	Long conf. papers	Journal articles	Others (e.g. workshops)

Give the subjects and grades you have taught since joining SIKSP…….....

THE SIKS PROJECT EVALUATION QUESTIONNAIRE

Please for all responses, place an (X) in the appropriate column to the right of the statement

Q1	To what extent did the following SIKSP activities contribute to your **professional development** as a science teacher in a multicultural context? **1= not at all 3=modestly** **2=very little 4=Very much**	1	2	3	4
1.1	The Practical Argumentation Course				
1.2	The bi-weekly science-IKS workshops and seminars				
1.3	IKS materials development sessions				
1.4	Participation in national and international IKS Conferences and Workshops				
1.5	Participation in SAARMSTE conferences				
1.6	The Toulmin's Argumentation Pattern (TAP)				
1.7	The Contiguity Argumentation theory (CAT)				
1.8	The use of Dialogical Argumentation Instructional Model (DAIM)				
1.9	Participation in the science IKS systematic reviews				
1.10	The lectures given by experts in the field of science education				

Q2	Please, read each statement below and according to the level of your agreement or disagreement, mark using an X in one column to the right as follows: **1=Strongly Disagree 3=Agree** **2=Disagree 4=Strongly Agree**	**1**	**2**	**3**	**4**
2.1	Before joining the SIKS Project, I believed that science was what was written in the textbooks only				
2.2	Before joining the SIKS Project, I believed that there was science in my culture				
2.3	Before joining the SIKSP, I did not regard IK as a valid source of knowledge				
2.4	Before joining the SIKS Project, I did not believe that school science and IK were compatible				
2.5	Before joining the SIKS Project, I was not so sure how I could integrate school science with IK in a science lesson				
2.6	I experienced great difficulties about integrating science and IK before joining SIKS Project				
2.7	My anxiety about integrating science and IK greatly reduced after attending the SIKS Project workshops				
2.8	School science textbooks should include IK as an essential component of science				
2.9	My knowledge of IK has increased as a result of joining the SIKS Project				
2.10	There is no need to include IK in the school science curriculum in the present technologically advanced, modern world of today				
2.11	Participating in the SIKS Project has enabled me to see that School science and IK are compatible				
2.12	Through the SIKS Project I have acquired skills to integrate school science and IK in my classroom				
2.13	The use of the DAIM could help learners to know when to use science or IK				

2.14	The DAIM draws from both indigenous and scientific methodologies of knowledge construction				
2.15	Argumentation is a useful way of enabling learners to express their views.				
2.16	Argumentation method could help learners to acquire many interpersonal skills which are useful in life outside the science classroom				
2.17	With the knowledge gained from the SIKS Project, I could easily adapt my lessons to the cultural context of my learners				
2.18	My experiences in the SIKS Project have permanently altered the way I used to view science as the only valid way for interpreting human experience				
2.19	My experiences in the SIKS Project have permanently altered the way I view IK				
2.20	My experiences in the SIKS Project have made me to recognise both school science and IK as valid ways of knowing.				
2.21	My experiences in the SIKS Project have made me to respect the indigenous knowledge worldviews of my learners in the science classroom				
2.22	My participation in the SIKS Project has enabled me to increase my research capacity in integrating science and IK				
2.23	Participating in DAIM-based hands-on activities helped me to realize the scientific processes involved in indigenous ways of doing things.				
2.24	My participation in SIKS Project has greatly enhanced my understanding of the educational and cultural values on a science-IK curriculum				
2.25	Knowing about the indigenous knowledge of others is useful for both teachers and learners				
2.26	Argumentation is a useful tool to help learners to construct knowledge in their classrooms like scientists.				

Thank you very much for participating

Appendix D. Some SIKSP documents used

D1. Short Project Description

[Source: *An argumentation-based package on the nature of science and indigenous knowledge systems: Book one: the nature of science*)

The aim of the project is to equip science teachers in South Africa with necessary knowledge and skills to implement a science-indigenous knowledge curriculum. Specifically, the SIKSP will assist teachers to develop curriculum materials and instructional methods which facilitate learners' ability to develop critical process skills such as: collecting, analysing, organizing, evaluating and using information (including the use of arguments, dialogues and reflective activities) to solve the puzzles in nature; make informed decisions; engage with contemporary ethical and socio-cultural issues; appreciate the knowledge, skills and values derived from science and Indigenous Knowledge Systems (IKS) to create a wholesome physical and socio-cultural environment. The thrust of this curricular goal is to prepare learners, and ultimately individuals who are not only scientifically literate but are able to participate actively in a democratic society that values human rights and promotes sensitivity to the environment. This implies that learners must be adequately equipped to make thoughtful decisions about societal issues derived from valid scientific and cultural ways of giving value to experience.

This curriculum package offers a set of lessons that can be used to enhance science teachers' ability to increase their competence in teaching the science that is relevant to socio-cultural backgrounds of their learners. The project entails the development of learning resource packages related to thoughtful decision-making about socio-scientific issues. The specific aims of the project are:

(i) The design, development and implementation of exemplary instructional package on the Nature of Science (NOS) and Indigenous Knowledge Systems (IKS) based on argumentation frameworks.

(ii) Evaluate the implementation of the instructional package and how teachers handle topics on socio-scientific issues in the classroom.

Short description:

Target group: Primary/ secondary school science teachers

Suggested context: Teachers enrolled in argumentation-based workshops wanting to implement Learning Outcome 3 (LO3) of C2005 for the natural sciences dealing with science, technology, society and the attainment of a sustainable environment.

Duration: About a 24 three-hour workshops i.e. 12 bi-weekly workshops on the Nature of Science (NOS) and the other 12 on the Nature of IKS (NOIKS).

D2. Reflective Diary Questions

You have been involved in the SIKSP Argumentation Instruction Model through lectures, seminars and workshops for a while now. Some of you took modules relating to integrating science and indigenous knowledge (IK) in the classroom e.g. the Socio-psycho-cultural module and the Philosophy of Science Module which focused on the Nature of Science. Most if not all of you have read books 1 and 2 of SIKSP dealing with the Nature of Science (NOS) and Indigenous Knowledge (IK). Some of you have been involved for three years or more. It is now apposite to find out how some or all these experiences have informed the way you navigate, frame or make sense of controversial socio-cultural issues such as the teaching or the implementation of a science-IK curriculum in the classroom. In view of this, please answer the following questions as freely and as candidly as you can:

1. What narratives can you tell about your experiences and your evolving stance (position) on the issue of implementing the science-IK curriculum or integrating science and IK in the classroom?
2. a) In what ways have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you frame (i.e. bring coherence to, or make sense of the pieces of information or experiences) you have acquired in terms of the way you construed the controversial issue of integrating science and IK at the time you started participating in the activities, during the period of your involvement, and now?

   b) Were you once opposed to the new curriculum? If yes, why? If not, why not. Have you changed your view over time and if so how?
3. How have you, or in what ways have you leveraged, reorganized or integrated your frames with personal experiences with respect to science, IK or the integration of both in the classroom?
4. How have the frames constructed from your experiences in the lectures, seminars, and workshops prepared you to use argumentation instruction in teaching a controversial subject such as the integration of science and IK?
5. a) Based on your experience over time, what abilities do you consider critical to your participating in argumentation?

   b) What factors have you found to facilitate or hinder the development of such abilities?

D3. Nature of Science Questionnaire

Please answer all items of this questionnaire. We would like to know *your views*, this is not a test. Your answers will be used for educational research purposes only. Your responses will be treated confidentially: your identity will not be revealed and is known only to the researcher. The researcher may ask you, later, to clarify your answers verbally: for this purpose only, please provide your ID number below.

Gender: Male ( ) Female ( ) **Age:**….. **ID:** ……..

Grade you have taught/are still teaching:( ) Years of teaching experience:……

Religion: Christian( ) Moslem( ) Others:…… **Home language:** ……

Race: African ( ) Coloured ( ) Indian ( ) Others:……..

Please respond to each item in the space provided.
Most questions provide a statement. Please tick one box to indicate whether you agree or disagree with the statement. Next, please give your reasons, **why** you agree or disagree. Also indicate the source(s) of your beliefs or views. Possible sources of your ideas could be Science, Media, Religion, Family, Traditional beliefs, etc.

Example: "China is a beautiful country."

If you agree because you like the Chinese people and the landscapes in China, and your view is derived from the news media, then write:

I agree: √ **I disagree:** ☐	
Reasons	I like the Chinese people and China has beautiful landscapes
Source(s)	News media

1. "Science tells us the truth about the natural world."

2. Does the statement in Question 1 reflect the way you present science in class? Or do you present science differently? Please explain, provide examples.

……...

……..

3. “Scientific knowledge is trustworthy because it was proved in experiments.”

4. “Scientific facts can be tested, and every test should give the same result.”

8. “The purpose of school practical work is to confirm scientific theory.”

9. “In their work, scientists are influenced by their socio-cultural and psychological frameworks (mind set).”

10. “To understand what science is, there is no need to consider, e.g., philosophical, religious, psychological, sociological, or linguistic questions.”

11. All teachers who use demonstration experiments in class know that the results are sometimes unexpected, and do not always confirm the theory. What do you do when an experiment does not work out as expected? (Give examples if you can.)

……...

……..

12. “Before a scientific discovery is accepted, many scientists have to test and confirm the discovery, and reach agreement about it.”

13. Does the statement in Question 12 reflect the way you present science in class? Or do you present science differently? Please explain, provide examples.

……...

……

14. “The truth of science is the same for everybody. It does not depend on anyone’s personal beliefs or situation.”

15. Does the statement in Question 14 reflect the way you present science in class? Or do you present science differently? Please explain, provide examples

……..

16. “Scientific theories are like maps of reality. They help us see order and structure in a very complicated and confusing world.”

17. “Scientists do not listen to just anyone. Whether they accept what you say depends on who you are.”

18. There is a step-by-step procedure for doing all scientific investigations.

…….

D4. Characteristics of IKS Questionnaire

Part A

Gender: Male ( ) Female: ( ) Age: ID:
Grade you have taught/are still teaching: ( ) Years of teaching experience:
Religion: Christian ( ) Moslem ( ) Others: Home Language:
Race: African ( ) Coloured ( ) Indian ( ) White ( ) Others:

Indicate your ID for follow-up purposes only. Your anonymity is guaranteed.

(Pre-test)

Part B

Characteristics of Indigenous Knowledge Systems Questionnaire

One of the aims Learning Outcome 3 (LO3) of the RNCS for the Natural Sciences is that learners should be helped to integrate their traditional worldviews with the scientific worldview they learn at school. This implies that science teachers themselves are knowledgeable of the nature of both worldviews. The questions below are intended to explore the status of this knowledge among prospective and practicing teachers and how to help them perform this important task effectively.

Please answer each question as honestly and as fully as you can.

Please indicate the source of your scientific understanding: e.g. arising from books (B), media (M), institutions (I), etc., and the source of your personal explanation: e.g. arising from family (F), religious (R) or cultural (C) beliefs.

Question 1

Many scientists believe that the universe occurred by chance, and since then has been undergoing continuous evolution. On the other hand, many people adhere to the religious or cultural view that a supernatural being created and controls the workings of the universe. Express your candid opinion on both worldviews:

a) Scientific understanding:

Source:

b) Personal understanding:

Source:

Question 2

A girl suffering from severe hysteria (excessive or uncontrollable fear) could not be cured in a modern hospital but was cured within a week by a traditional healer. What is your view in terms of your:

a) Scientific understanding:

Source:

b) Personal understanding:

Source:

Question 3

Various opinions and explanations have been expressed about 'after life' such as: (a) when a person dies, his/her soul and/or spirit lives; (b) the brain does not stop immediately the heart stops, so 'after life' experience is like a dream stored up in the brain before it stopped working; (c) a person's soul and/or spirit does not die with his/her body; (d) the soul and/or spirit leaves the body at death but may return to the same body if it cannot find a body in the other world.

Indicate the source from which your view has been derived e.g. if your view is based on your religious belief place R under Source.

Please complete the following table:

Scientific understanding			
STATEMENT	Agree/ Disagree	Reason(s)/Examples:	Source
(a) when a person dies, his/her soul and/or spirit lives.			
(b) the brain does not stop immediately the heart stops so 'after life' experience is like a dream stored up in the brain before it stopped working.			
(c) a person's soul and/or spirit does not die with his/her body			

(d) The soul and/or spirit leave the body at death but may return to the same body if it cannot find a body in the other world.			
STATEMENT			
(a) When a person dies, his/her soul and/or spirit lives			
(b) The brain does not stop immediately the heart stops so 'after life' experience is like a dream stored up in the brain before it stopped working.			
(c) A person's soul and/or spirit does not die with his/her body			
(d) the soul and/or spirit leaves the body at death but may return to the same body if it cannot find a body in the other world.			

Question 4

Scientists describe the occurrence of the rainbow as a result of the refractive dispersion of sunlight. However, in many traditional beliefs, the rainbow is seen as a good or bad omen. What is your view in terms of your:

a) Scientific understanding:

Source:

b) Personal understanding:

Source: B

Question 5

Lightning is an electric discharge in the atmosphere. The very large and sudden flow of the charge that occurs in lightning has enough energy to kill people or do serious damage to buildings or infrastructures. In many traditional beliefs lightning can come from other sources. What are your views in terms of your:

a) Scientific understanding:

Source:

b) Personal understanding:

Source:

Question 7 [For the old MEd only]

What ideas of IKS did you hold before and after being exposed to the workshops?

(a) Ideas about IKS before the workshops:

_____
_____
_____

(b) Ideas about IKS after the workshops:

_____
_____
_____

(c) How has the knowledge of IKS gained from the workshops influenced (or will influence) your instructional practice?

_____
_____
_____

(d) Based on your knowledge of IKS gained from the workshops, do you think that the IKS worldviews should also be presented alongside the scientific worldview? Express your view.

_____
_____

(e) From what you gained from the workshops, do you think that the content of the workshops should

be of part of the training needed by science teachers to implement LO3 dealing with IKS?

Explain:

_____

_____

Do you have other suggestions on how higher institutions can prepare science teachers adequately for the implementation of C2005 dealing with IKS?

_____

_____

Question 6

A learner asked her classmate, “How did the world come about?” Her classmate replied, “Science states that it probably occurred by chance or due to the force of a big bang or something like that.” The first learner then asked further, “Where did the force that produced the bang come from?” Her classmate retorted, “I don’t know, ask the science teacher.”

a) What is your view about the ideas expressed above in terms of your:

Scientific understanding:

Source:

Personal understanding:

Source:

b) Do you or your learners ask similar questions? Yes/No

If yes, please give an example, if no, please try to explain why you think this is so:

How would you deal with such questions if they were asked in your class?

Appendix E: DAIM Lesson Rating Scale

Please, use this instrument to rate each DAIM lesson

	RATING: **1=not evident;** **2= somehow evident;** **3= very evident**	Rating
1	Teacher's instructions are clear and unambiguous	
2	Teacher gives enough time for learners to express their ideas	
3	Teacher *prompts* learners for evidence in support **of their** claims	
4	Teacher facilitates group work	
5	Teacher mediates whole class discussions	
6	Learners challenge each other's claims and/or evidence	
7	Learners discuss in small groups	
8	Learners use argumentation terminology such as claims, evidence, etc.	
9	Learners express their views with confidence	
10	There is evidence of IKS in the lesson	

Appendix F. Letter for permission to use archived documents

The Director,

School of Science and Mathematics Education,

University of the Western Cape

Sir,

I am one of your PhD students and the title of my study is "An evaluation of a science and indigenous knowledge systems project at a Western Cape university".

I was a research assistant in the Science and Indigenous Knowledge Systems Project (SIKSP) from 2010 to 2013 when the project officially wound up. Despite the end of the funding of this project, some of its activities have continued until today, sustaining a community of postgraduate students in the School of Science and Mathematics Education as they pursue their educational objectives.

I got much interested in the SIKSP and chose to do an evaluation of the project, with the view to disseminating the results of such a study. I would like to ask your permission to use stored documents of the SIKSP. I do promise to treat any information from the documents with maximum confidentiality. The information will be used for the purpose of the research only. I will not disclose it to anybody, except my supervisor if she wants to cross check something within the period of this research.

The results of the evaluation will probably provide data for informed decisions by education policy makers and many other education stakeholders, especially those dealing with innovative ideas such as the integration of science and indigenous knowledge. The results of the study will be made available to the university and the SSME in particular.

Thank you for your kind consideration.

Yours sincerely

……

Daniel Angaama