PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS: THE A-TEAM HYBRID ECOLOGY OF LEARNING PRACTICE

Erica Pretorius
University of Johannesburg
South Africa
Email: ericap@uj.ac.za

Josef De Beer
Department of Mathematics, Science, Technology & Computer Education
University of Johannesburg
South Africa
Email: josefdb@uj.ac.za

Geoffrey Lautenbach
Department of Mathematics, Science, Technology & Computer Education
University of Johannesburg
South Africa
Email: geoffl@uj.ac.za

Abstract–Professional development interventions in South Africa do not always address teachers' needs or necessarily result in better realisation of outcomes in science. South African teachers' learning of science and their emerging science pedagogy need urgent attention and this issue can be addressed through focused continuing professional teacher development (CPTD) programmes. The University of Johannesburg launched a unique CPTD project named the *A-team project – Excelling in Science Education* in October 2010. This project focused mainly on developing the science teachers' inquiry-based teaching approaches, advancing scientific process skills and enriching their pedagogical content knowledge in CAPS themes. The aim of this longitudinal empirical qualitative study was to introduce both primary and secondary school teachers to new (and exciting) science experiences in hybrid ecology of learning practice. In this intervention the hybrid group of science teachers experienced a wide range of different activities. As the project progressed, we tapped into the overwhelming social capital resources of scientists, professors and the Natural Sciences, Life Sciences and Physical Sciences teachers themselves sharing a wealth of experience and information. The findings of this study revealed that hands-on activities in real laboratories not only improved the science teachers' technological pedagogical content knowledge but also motivated teachers to include inquiry-based teaching strategies in their classroom practices.

Keywords: Continuing professional teacher development, inquiry-based learning, teacher motivation, design-based research, hybrid ecology of learning practice

1. INTRODUCTION

We argue that South African teachers' learning of science and their emerging science pedagogy need urgent attention and that this issue can be addressed through focused continuing professional teacher development (CPTD) programmes. We believe that motivated philosophically literate science teachers could impact positively on learner outcomes. A philosophically literate science teacher incorporates the history, philosophy and sociology of science in an attempt to humanise science (Mathews, 1992). Connecting science with social scientific issues such as local, national and global societal concerns could make science classrooms more challenging, enhancing problem-solving and critical-thinking skills of learners (Andersen, Harty & Samuel, 1986; Hodson, 1985; Mathews, 1992; Ratcliffe & Grace, 2003). Moreover, the inclusion of personal, cultural and ethical values could contribute to the understanding of difficult science concepts (Mathews, 1992). Hence, the urgent call for teachers to reinstate the nature of science (NOS) into classrooms, as NOS incorporates "the values and assumptions inherent to the development of scientific knowledge" and "facilitates the understanding of science subject matter" (Lederman, 2006:3; Lederman & Zeidler, 1987:3). The true nature of science is empirically based, in that scientific knowledge is tentative, yet durable; scientific knowledge is theory-laden, yet partly subjective; imagination and creativity play a role in science; and there is no single scientific method (Vhurumuku, 2010). However, the hope of science teachers teaching learners to appreciate the true nature of science and to develop a scientific outlook has not yet been realised and calls for a new brand of CPTD. For this reason a unique brand of CPTD in science education was launched in September 2010 by the Faculty of Education at the University of Johannesburg, called the *A-team project – Excelling in Science Education.* The main objectives of this study were to motivate teachers to employ inquiry-based practices for the teaching of science in an attempt to promote and reinstate the true nature of science into classrooms, and also to develop teachers' PCK in some of the more "problematic" content areas in the CAPS, e.g. biotechnology, evolution, or chemical equations.

2. METHODOLOGY

This qualitative study over a period of three years followed a design-based approach in documenting science teachers' professional development in both a physical and on-line community of practice. Regarding sampling, a snowball approach was employed and teachers applied to become members based on word-of-mouth. Data were collected by means of individual interviews, focus group interviews, questionnaires, on-line reflections, observations and studying artefacts.

3. LITERATURE REVIEW

The concern is that learners find school, including science classes, progressively boring. To counter learner boredom it has been suggested that teachers should not only focus on content knowledge but also find ways to enthuse their teaching (Fullan & Langworthy, 2013). There are still many teachers who require learners to memorise key scientific terms and definitions of concepts without the excitement of experiencing true conceptual change. An increasing number of studies argue that most schools and their teachers still use textbooks for disseminating static bundles of information, assessing content recall and evaluating learners using test scores, despite having access to the latest information and knowledge through technological advancements (Hargreaves, 2003; Fainholc, 2005; OECD, 2009; Drucker, 2009; Lyons & Quinn, 2010; Nikkhah, 2011). Alberts (2009) also argues that science has lost its attraction for learners and that teachers often use chalk and talk teaching methods because as non-specialists they are dependent on textbooks (Lyons & Quinn, 2010). Thus, teachers and their learners reason intuitively instead of scientifically and instead of embracing the real nature of science (Carey, 1977). The learners cannot see themselves in monotonous science careers if the teachers do not make the subject interesting and dynamic (Lyons & Quinn, 2010). This may lead to fewer science teachers being educated and a spiral of decline in the numbers of science teachers and learners.

In a 1992 study Matthews (1992:11) already pointed out the "well documented crisis of contemporary science education – evidenced in the flight from the science classroom of both teachers and learners, and in the appallingly high figures on science illiteracy". We need to develop our teachers, convincing them that science teaching requires more than content knowledge and that teaching and learning should include values, goals and skills for orientation and transformation in an ever-changing society (Kaplan & Flum, 2012). Lederman and Zeidler (1987) argue that there is a direct and positive relationship between teachers' conceptions and positive conceptual change in learners. Lyons and Quinn (2010) argue that a teacher's positive attitude and scientific literacy results in successful classroom practices and successful learner outcomes.

The scarcity and low quality of science teachers in a developing country such as South Africa are still a reality, as the low quality of science results may be due to the shortage of well-motivated science teachers who are qualified and competent to teach science (Departments of Basic Education and Higher Education and Training, 2011; McCarthy & Bernstein, 2011). The quality and scope of science teaching do not meet the national needs of the South African society, especially regarding the development of scientists and engineers. The Engineering Council of SA (ECSA) has stated that South Africa has one engineer for every 3 100 citizens, Germany one for every 200 and Japan, Korea and the US hold a ratio of one to 310 (Gotthardt, 2014). This paints a bleak picture for the economy of South Africa, especially in the light of large scientific initiatives and projects such as the Square Kilometre Array (SKA) Telescope Project, the discovery of vast shale gas resources in the Karoo, and the fast developing alternative energy industry (Alfreds, 2012). Producing scientists and engineers is not an easy feat, as the poor science results in the South African National Senior Certificate statistics show.

The overall pass rate for Physical Science has increased from 61.3% in 2012 to 67.4% in 2013 and Life Sciences from 69.5% in 2012 to 73.7% in 2013 in South Africa. However, statistics show that 73.7% of

Life Sciences learners and 67.4% of Physical Science learners achieved less than 40% in the National Senior Certificate exam (Basic Department of Education, 2013). These statistics indicate that learners are not achieving the required science results to gain access into higher education institutions and will not be able to apply for science-related degrees at higher education institutions. This is not very encouraging, as South Africa urgently needs quality science teachers to ensure improved learner outcomes which could contribute towards developing more scientists and engineers for the 21st century in response to global challenges (Zeidler, Walker, Ackett & Simmons, 2002).

There is an urgency for the South African education system and higher education institutions to focus not only on preparing new science teachers but also particularly on supporting in-service teachers to produce high-quality science teaching. In-service CPTD is necessary as 70% of the teacher population is younger than 50, which implies that many teachers will still be teaching for at least another decade or more (OECD, 2009a). Furthermore, many teachers still teach the way they were taught. Kereluik, Mishra, Fahnoe and Terry (2013) point to a "disjuncture" between centuries, where a gap is evident between how teachers taught in the past and how they should teach science in the 21st century. Resnick (1987) suggests "bridging apprenticeships" to reintroduce the key elements of teaching and learning. Science teachers need continuing professional development to reinvigorate their teaching practices in order to enthuse learners, motivating them to achieve better results and choose science as a subject in the pursuit of career as a scientist or engineer.

A serious concern in South Africa is that only 35% of the few qualified science teachers mentioned above are employed at previously disadvantaged schools (Departments of Basic Education and Higher Education and Training, 2011:36). Many of these teachers would rather teach a different subject in an ex-model C (previously whites only) or a private school than their specialised subject such as science in a township or rural school. Hence, a qualified science teacher may teach geography or maths in a privileged school, while teachers qualified in English may teach science at a disadvantaged school. This worsens the problem as South Africa does not have enough teachers in specialised scientific fields, yet many of these qualified science teachers are not teaching in their field of expertise and many teachers not qualified in the field of science are teaching science. This results in poor science teaching in some classes and intensifies the problem of enhancing scientifically literate teachers offering quality teaching in all schools, not only in the more privileged schools.

The National Department of Education (DoE) embarked on the Dinaledi schools project in 2001, focusing specifically on improving science teaching and learning in previously disadvantaged schools. This project was established with corporate support and aimed to increase the number of students entering university with mathematics and science (USAID, 2009). It started with 102 historically disadvantaged, mainly rural and township schools and has increased to more than 500 schools. Yet, the Parliamentary Monitoring Group (2013) recently reported that these schools still face the challenge of teachers with poor science teaching skills. Most of the funds (R61.5 million) were spent on infrastructure development and resources such as science textbooks and equipment. Subsequently, these schools only achieved on average 10% higher than non-project schools during 2011/12. This revealed the "transversal expenditure framework" which revealed that professional teacher development was often compromised for resources, equipment and infrastructure (Wildeman, 2008:163). The DoE spent more money rectifying the physical injustices of the apartheid regime and not much on the actual desperately needed development of the teachers as human capital. The teaching resources are only mediating tools, a "kit of good activities", which will only prove to be worthwhile if teachers know how to use and adapt these to suit their contextual needs informed by their pedagogical reasoning behind a particular approach or strategy (Loughran, Berry & Mulhall, 2012).

In addition to the Dinaledi project, the national DoE and many donors embarked on CPTD training in content knowledge in an attempt to familiarise teachers with the content of curriculum changes since 1994. The Outcomes-based Education (OBE) curriculum, the National Curriculum Statement

(NCS), the Revised National Curriculum Statement (RNCS) and most recently the Curriculum Assessment Policy Statement (CAPS) required content knowledge training, but the need for pedagogy was often compromised (Taylor, Fleisch & Shindler, 2008; Kriek & Grayson, 2009; Crouch, 2011; McCarthy & Bernstein, 2011; Schleicher; 2011; Bantwini, 2012; Department of Education, 2012). This limited the impact of the interventions and emphasised Shulman's (1986:8) claim that, "Mere content knowledge is likely to be as useless pedagogically as content-free skill" and gave rise to the term pedagogical content knowledge (PCK). Shulman (1986) argues that the content knowledge of a subject is extended by matching specific content knowledge to particular ways of communication and teaching strategies in order to create optimal learning experiences for learners. Similarly, Loughran (2011:290) argues that teachers need to be "experts in the knowledge generation, dissemination and practice of the discipline of teaching".

Another reason for the limited impact of these CPTD interventions could be that the interventions were "either too basic or too advanced for the different of levels of teachers" given the history of education in South Africa (Department of Higher Education and Training, 2010; Bantwini, 2012; Parliamentary Monitoring Group, 2013). The "one size fits all" approach, which only provides resources and content knowledge to teachers, is not sufficient in South Africa, due to the legacy of different education systems. Furthermore, the national INSET programmes offered short workshops, despite teachers requiring district officials to ensure ongoing quality engagement and guidance.

District officials are fundamental in scaffolding and supporting teachers, and should be experts in their respective fields (Bantwini & King-McKenzie, 2011; Bantwini, 2012). Thus, the actions of district officials, school managers and even unions can contribute to teacher development and the improved conduct of teachers (McCarthy & Bernstein, 2011). Teachers and their teaching are at the front line of improving the quality of science education, but require multiple levels of support to achieve real change and success (Edwards, 2011; Roth & Lee, 2007).

The DoE acknowledges the continuing dilemma of science teachers and teaching in many South African schools. The OECD (2008), reports that progress has been made as education reform has been a priority since 1994. While the government and the DoE have excellent policies and strategies for CPTD in place, the actual focus on teachers and the implementation of the interventions seems to be a concern (Departments of Basic Education and Higher Education and Training, 2011). Consequently, the current professional development interventions in South Africa do not address teachers' needs or result in improved student outcomes in science, although these interventions have many factors that contribute to limited success.

4. THE A-TEAM HYBRID ECOLOGY OF LEARNING PRACTICE

The University of Johannesburg's Department of Education adopts an approach to CPTD that introduces science teachers to new (and exciting) experiences as professionals. Its A-Team project draws on the success stories of the Amandla development using non-governmental organisations (NGOs) to improve science teachers and teaching. They contend that in education "equitable opportunity development is complex and needs a multifaceted approach to achieve sustainability" (Amandla Development, 2009:1). The NGO LEAP (Leadership, Effectiveness, Accountability and Professionalism) initiative was established in 2005 and achieved excellent science results. Moreover, 72% of LEAP's matriculants are currently pursuing tertiary studies. One of their claims to success is their acknowledgement that both emotional and cognitive issues influence teaching and learning.

A recent report by the Centre for Development and Enterprise (CDE) (2011) found that while there are good teachers in the public schooling system, there are many teachers who are not teaching well or are poorly utilised especially in subjects such as maths and science (McCarthy & Bernstein, 2011; Departments of Basic Education and Higher Education and Training, 2011). We need to tap into the human capital of good experienced teachers, to build the social capital of the entire science teacher community in all schools.

CPTD has evolved on the international front and recent international studies yielded successful outcomes. Many of these successful CPTD interventions were led by higher education institutions. Examples of successful CPTD interventions are: the Ohio Public Schools Project called *Target Inquiry* (TI), which focuses on inquiry-based teaching approaches in a laboratory setting (Yezierski & Herrington, 2011); the FINNABLE project using ICTs in education (Niemi, 2012); the Annenberg Institute for School Reform aimed at tapping into social capital (Kronley & Ucelli-Kashyap, 2010); and the Japanese Lesson Study using model lessons (Crockett, 2007; Makinae, 2010).

However, CPTD is the "worst problem and the best solution" and it is never easy, as this requires of teachers to change" (Fullan, 1998:2).

5. THE BIRTH OF THE A-TEAM PROJECT

The Faculty of Education at the University of Johannesburg was the first to initiate an intervention similar to the *TI* intervention and includes elements from the Finnish, Annenberg and Japanese lesson study examples. It has a unique comprehensive approach specifically aimed at improving the quality of science teachers and teaching in the South African context and addressing the needs of South Africa's diverse teachers.

The A-team CPTD intervention follows a design-based method. It is formative and the iterative cycles allow the project's developers to adapt and improve the programme as new insights evolved from the programme's implementation (Reeves, 2000; McKenney & Reeves, 2013). The A-team project is longitudinal in nature and the participating science teachers are asked to commit for a period of five years. This project is also systemic as it involves not only science teachers but also school principals, expert scientists and other role-players from the University of Johannesburg and various international partners. George Dawson, a retired professor from Florida State University, and Joel Dawson, a retired school principal, were invited to participate as mentors in the programme. The study follows an empirical qualitative approach of observing the lived experiences of the science teachers in the project. The socio-cultural approach used in the A-team project focuses mainly on developing the technological pedagogical content knowledge of science teachers using a hands-on inquiry-based learning approach. The data collection methods include observations, interviews, questionnaires, teacher reflections, visual data (such as photographs and videos), and other artefacts The artefacts included lesson plans, shared teacher ideas and resources and physical products such as solar cookers made during actual contact sessions. The need for visual data was emphasised as a recommendation for ethnographic research and numerous photographs and videos were included as evidence. In addition to this the interviews and online reflections posted by teachers also provided evidence of improved teacher motivation and the implementation of hands on –inquiry based activities in classrooms. It also indicated the importance of validity in the data analysis phase, which prompted the use of both emic and etic approaches (Hoare, Buetow, Mills & Francis, 2013). The emic approach is threefold. Firstly, in understanding science teaching in a SA school context, secondly the daily lives of science teachers, their motivation for teaching science alongside their language and culture and thirdly their behaviours within the intervention. The etic perspective is more deductive in nature as it involves an investigation of collective cultures, also known as meta-cultures of science teaching. This is evident from using the literature, not only locally, but also international perspectives of science teaching and interventions alongside theoretical perspectives. This study also adheres to the six general principles for high quality Scientific Research in Education (SRE) (Towne, & Shavelson, 2002). In addition to this, an autobiographical approach ensured that the researcher bias was limited as far as possible. The data was analysed using both Microsoft Excel and Atlas.ti. Furthermore, the third-generation cultural historical activity theory (CHAT) is used as a heuristic tool to identify the contradictions, tensions and opportunities arising from the intervention.

6. CHOOSING A THEORY OF ACTION

The biggest problem the programme's developers faced was in selecting the most appropriate action theory of change to create a comprehensive CPTD A-team intervention. Using communities of practice (CoP) was the first option. Wenger (2006:1) defines a CoP as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly”. Wenger and Snyder (2000:141) argue that “studies have shown that apprentices learn as much from journeymen and more advanced apprentices as they do from master craftsman.” This theory is related to the purpose of the A-team to create interactive opportunities for science teachers to improve their teaching of science. Following a socio-cultural approach, the underlying belief of the programme is that teachers can learn much from each other by sharing their ideas in a science domain and that this exchange could promote best practices. This was the first consideration as the human capital of expert teachers and scientists could result in social capital shared among diverse science teachers.

The second option of a professional learning communityalthough similar to CoP focuses on school-based staff development programmes. This is a good theory of action for some schools, but is not viable in the South African context, as many schools have only one science teacher while others do not have any qualified science teachers at all. It was the programme’s aim to use expert teachers from diverse schools to build the capacity of less experienced teachers, thus not focusing on individual schools.

The third option was networked learning communities. Steeples and Jones (2002) in De Laat (2006:149) define networked learning as “learning in which information and communication technologies are deliberately used to promote connections between learners in a community, their tutors and learning resources”. This was also an action theory to consider. However, the limited access to technology and the Internet in South Africa, together with the limited technological skills of many teachers, would not allow equal opportunities for all teachers to participate optimally in such a venture. Many features of the three theories are essential for effective CPTD and the A-team project included elements from all of these theories. However, the researchers chose to use the term “hybrid ecologies of learning practice” (HELP) as an action theory, as it was better suited to the purpose of this intervention.

This A-team intervention aimed to develop philosophically and scientifically literate teachers. The Centre for Unified Science Education at the Ohio State University had already defined scientific literacy in 1974, a definition which included the following seven elements:

The scientifically literate person:

1. understands the nature of scientific knowledge;
2. accurately applies appropriate science concepts, principles, laws, and theories in interacting with his universe;
3. uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe;
4. interacts with the various aspects of his universe in a way that is consistent with the values that underlie science;
5. understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each other and with other aspects of society;
6. has developed a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life; and
7. has developed numerous manipulative skills associated with science and technology (Rubba & Andersen, 1978:450).

The A-team project aimed to achieve all of the above, but it was not an easy feat for teachers to achieve. Lederman (1992) mentions that researchers have been concerned that the teachers’ classroom practices are influenced by complex factors such as their beliefs and attitudes, the curriculum, their content knowledge and other school-related factors such as the school environment and administrative responsibilities. Similarly, Hargreaves (1994) argues that good teaching is a complex process, requiring motivation, expertise, insight and moral purpose alongside competence and technical skills. Hence, developing real scientific literacy requires adherence to the long-standing call from experts such as Lederman and Zeidler (1987), Matthews (1992), Lyons and Quinn (2010) and Nikkhah (2011) to reinstate the NoS into classrooms. Lederman and Zeidler (1987:3) argue that NoS incorporates "the values and assumptions inherent to the development of scientific knowledge" and "facilitates the understanding of science subject matter" (Lederman, 2006:3). The main tenets of the nature of science are:

1. Science is empirically based.
2. Scientific knowledge is tentative.
3. There is a difference between observation and inference.
4. Scientific knowledge is theory laden, yet partly subjective.
5. Imagination and creativity play a role in science.
6. There is no single scientific method.
7. There is a difference between law and theory. (Vhurumuku, 2010:28)

The A-team believes that philosophically literate science teachers will reinstate NoS in classrooms. The incorporation of NoS will facilitate deep learning, as well as citizenship, enhancing the learners' social responsibility towards global challenges and working towards a sustainable future for all (OECD, 1996). The notion of incorporating NoS into classrooms will prepare learners by building accountability for participation in a globalised 21st century society (Sahlberg, 2010; Elliott, 2012). Hence, the importance of developing philosophically literate teachers guides the choice of using HELP as a theory of action in this A-team intervention.

7. THE A-TEAM AS A HYBRID ECOLOGY OF LEARNING PRACTICE

> The ecology of human development is the scientific study of the progressive, **mutual accommodation**, throughout the life span, between a **growing human organism** and the **changing immediate environments** in which it lives, as this process is affected by **relations obtaining within and between these immediate settings**, as well as the **larger social contexts, both formal and informal,** in which the settings are embedded. (Bronfenbrenner, 1977:514)

The term "ecology" was proposed by Ernst Haeckel in 1869 as "the study of the natural environment including the relations of organisms to one another and their surroundings" (Odum & Barrett, 1971:3). Odum and Barrett (1971:2) simplified it as the study of "life at home", emphasising "the totality or patterns of relations between organisms and their environment". These definitions are particularly relevant to the A-team project as multi-cultural and multi-skilled teachers will interact socially in a scientific laboratory environment, the natural home of science.

The programme developers chose not to host a homogeneous group as it is essential that the conflicts, tensions and opportunities develop in order to inform and improve the design of the intervention. Furthermore, ecology also refers to "biodiversity", where the community and non-living elements function together in their natural environment (Odum & Barrett, 1971; Savard, Clergeau & Mennechez, 2000). It could be described as a symbiotic relationship, as the programme developers attempted to create interactive mutualistic science environments for diverse multi-cultural teachers, encourage enquiry-based teaching and the inclusion of socio-scientific issues (The impact of sociological theory on empirical research, 2002).

7.1 The hybrid nature of the A-team

(mutual accommodation)

The Merriam Webster dictionary describes "hybrid" as something that has two different types of components performing essentially the same function. In this scenario, hybrid firstly relates to the A-team intervention, which offers a spectrum of activities for teachers.

Figure 1 shows the integration of the different activities of the programme which the teachers participated in:

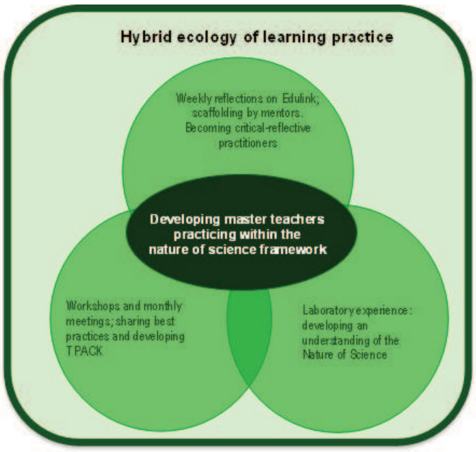

Figure 1: The A-Team Concept: A three-tier programme

In this intervention the science teachers shared experiences at short monthly workshops and two longer workshops of between three and five days per annum. In addition to this, teachers could collaborate with and support each other in online communities and write online reflections.

The first cycle of this intervention hosted 31 teachers during a week-long programme during the school holidays. The Natural Sciences, Life Sciences and Physical Sciences teachers participated in a variety of hands-on activities, which included among others *Gardner's theory of multiple intelligence*s, *Edward de Bono*'s *Six Thinking Hats, making solar cookers* and computer skills sessions in a computer laboratory on the Soweto Campus.

7.2 Monthly workshop sharing experiences
(larger social contexts, both formal and informal settings)

The monthly workshops hosted teachers' modelling and sharing their best practices and resources. These sessions included some features similar to the Japanese lesson study, as the teachers offered positive criticism, which led to improved lessons. These lessons demonstrated best practices in topics such as human anatomy, constructing a real life skeleton, chemical reaction in the process of making soap, highlighting and sharing technological resources such as Internet sites and PowerPoint slides. Some sessions were facilitated by lecturing staff and post graduate students at the University of Johannesburg. A physics lecturer presented a lesson on the solar system and a botany lecturer offered a session on plant reproduction, the aromatic world of flowers. One teacher commented, "This is exactly what I am teaching now. I cannot tell you how much this means to me." These sessions produced enriched and motivated teachers, especially as less privileged schools gained physical resources and the skills of integrating technologies into the classrooms.

7.3 Attending two longer workshops per annum
(changing immediate settings)

The science teachers once more gave up their school holidays to participate in real-life laboratory experiences, gaining hands-on experience with real scientists. The teachers experienced DNA Barcoding and extracting their own DNA in the Botany laboratories, heart dissection in the Zoology laboratories and electroplating in the Physics laboratories. These laboratory experiences revealed the real world of science to teachers and inspired them to use inquiry-based learning in their classrooms.

Inquiry-based teaching and learning is not new as evidence of this is found in the 1960s to 1980s in the works of Robert Gagne, a very influential learning theorist (Matthews, 1992). Rubba and Andersen (1978 in Lederman, 1992:348) found that:

> the classes of the most effective teachers were typified by frequent inquiry-oriented questioning, active participation by learners in problem-solving activities, frequent teacher-student interactions, infrequent use of independent seat work, and little emphasis on rote memory/recall.

Inquiry-based teaching and learning is central to science teaching and success stories advocating improvement in the learners' understanding of science have been reported widely (Matson & Parsons, 2002; Anderson, 2002). However, a large and growing body of literature reveals that using inquiry-based teaching strategies resulted in teachers' misconceptions in their attempts to simplify science and revert to "cookbook" laboratory experiments (Matthews, 1994; Bencze & Hodson, 1999; Matson & Parsons, 2002; McComas, 2002; Herman, Clough & Olson, 2013). These cookbook inquiry-based activities may include scientific processes, but are still aimed at reaching pre-determined outcomes that defy the purpose of authentic scientific investigations (Bencze & Hodson, 1999). Thus, teachers need to understand, not only the science processes involved, but also the nature of science and develop the skills to conduct a scientific inquiry (Matson & Parsons, 2002). Teachers need to portray the nature of science in the classroom, and mediate learners' understanding that science is empirically based, that scientific knowledge is tentative, yet durable, that scientific knowledge is theory-laden, yet partly subjective, that imagination and creativity play a role in science, and that there is no single scientific method (Vhurumuku, 2010). Teachers need to understand, think and work like real scientists in order to develop the learners problem-solving skills, thus promoting the notion of innovative and creative knowledge creation (McComas, 2002). Meichtry, (2002: 239) argues that real science should include:

> a way of thinking about problems and curiosities, a method of discovery, an organized process in which ideas are tested, conducting an experiment to test a hypothesis, science is ever-changing and growing with new information, systematic approach to obtain knowledge, involves repeated trials, science is an ever-changing experience, discovery-inquiry-exploration, and going through a process that involves thinking and may involve attitudes and values.

Hence, real-world experiences in laboratories are important for the development of philosophically literate science teachers. Dewey's statement of "learning is learning to think" implies that the thinking process is about the brain's processing of information received by the senses and the context in which the learning takes place (Van Lier, 2000). Ecology specifically deals with the interaction of people with their environment and the environment holds much potential for learning and practice to think and making meaning. Furthermore, in ecology, the term "population" represents a group of people and a community is a group within a population occupying a specific area. Science teachers represent such a community within the teacher population as they are specialising in the area of science teaching.

In addition to the laboratory experiences, teachers developed their computer skills using Blackboard and open source software for integration into their classrooms and to ease the burden of administrative tasks. Furthermore, an excursion to the Sterkfontein Caves and the Cradle of Human Kind also offered the teachers enriching socio-scientific experiences.

7.4 The A-team's online experiences

(larger social contexts, both formal and informal settings)

The University of Johannesburg uses the Blackboard learning management system. Teachers used this system to communicate asynchronously, to share resources and to post regular reflections on their classroom practices and their A-team experiences. In addition to this, teachers received support from the programme's international partners, George and Joel Dawson, to improve lessons and planning. Another session which impacted greatly on the teachers and their teaching was an interactive Skype session, with Walter Lewin, Professor Emeritus of Physics at the Massachusetts Institute of Technology. Professor Lewin demonstrated the moment of inertia and hosted a question and answer session after the demonstration.

All of the above-mentioned activities convey the hybrid nature of the intervention as all the components of the project performed essentially the same function of enhancing the quality of the science teachers and their teaching by following a socio-cultural inquiry approach. It is clear that

":hybrid" was the correct name for this project as the Merriam Webster dictionary also describes hybrid as "a person whose background is a blend of diverse cultures or traditions".

The A team participants are a diverse multi-cultural, -lingual and -skilled science teachers, also reflecting the hybrid nature of the programme. This heterogeneous hybrid group involved teachers from two privileged private schools, four ex-model C schools and five previously disadvantaged schools in the greater Johannesburg area. A total of 31 science teachers from 11 schools in the greater Johannesburg area attended the first week-long workshop during the October school break. After the first intervention, teachers already expressed their delight with the approach: "We sacrificed a September holiday in 2010 and came back to school invigorated! Far better than any holiday!"

The idea of snowball sampling was evident as the number of participants varied between 24 and 42 science teachers from multiple schools throughout the intervention (Heckathorn, 2011). At one session teachers from Mpumalanga travelled to Johannesburg to participate in the programme. However, only 24 teachers of the original October 2010 A-team remained, alongside the new entrants. The exit interviews of the original teachers who no longer participated in the A-team revealed that they were allocated different subjects to teach. This is very worrying for the teaching of science, as we lose expert science teachers to teaching English, Geography or Mathematics, thus draining the pool of expert science teachers. This is also mentioned in the 2011 CDE report above (McCarthy & Bernstein, 2011). This emphasised the distress experienced by teachers, who cannot become expert teachers if they are required to teach different subjects every year.

The participants in the A-team intervention varied throughout the duration of the programme as participation was voluntary and thus flexible. This also added to the dynamics of the interactions as new participants complemented the intervention by adding new views and insights to the A-team. Consequently, the mix of activities and Natural-, Life- and Physical- Science teachers could result in hybrid science teachers and leaders embracing and dispersing quality science teaching practices. Hence, the co-evolution of a new hybrid teacher leader is possible within the framework of an ecological perspective.

However, science teaching does not occur in a vacuum and is embedded within a particular national education system and school context and climate. Bandura (2001: 14) argues that "human functioning is rooted in social systems". Consequently, the different levels in education such as the department of education, the district, the particular schools and classroom factors have a definitive influence on the quality of teaching and learning (Deakin Crick, McCombs, Haddon, Broadfoot & Tew, 2007). Figure 2 offers a view of the different interdependent levels of the education system in South Africa (Rogan & Grayson, 2003).

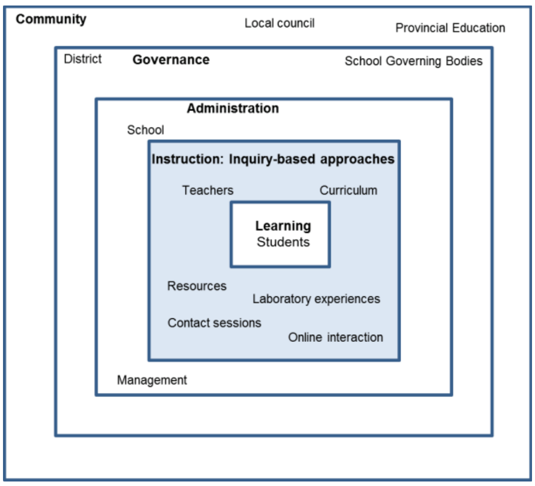

Figure 2: The various interdependent levels of education as organised in SA (Adapted from Rogan & Grayson, 2003:1180)

The A-team teachers and their teaching are influenced by the interdependent hierarchical levels and, for this reason, school principals were also included in this study, thus making it systemic in nature. Edwards (2009:211) mentions "collaborative intentionality capital" as "an emerging form of organisational asset". Personal agency, as mentioned in Bandura's social cognitive theory above, is embedded in the collaborative intentionality capital as it includes diverse science teachers with different beliefs and teaching practices collaboratively working towards quality science teaching practices (Bandura, 1989; Bandura, 2006). Also, as the project progressed we tapped into the overwhelming social capital resources of scientists, professors and the teachers themselves, sharing a wealth of experience and information.

7.5 Mutualism within the A-team

(growing human organism)

The term "mutualism" refers to the "cooperative interactions between pairs of species" (Jones, Bronstein & Ferrière, 2012:66) and can be defined as "an interaction between species that is beneficial to both, since it has both historical priority and general currency" (Boucher, James & Keeler, 1982:315). This is particularly relevant to the A-team intervention as the project aimed to create an environment where diverse science teachers are able to cooperate and interact. This environment could allow for the cross-pollination and diffusion of best practices alongside the expertise of scientists, adding to the sustainability and dynamics of the intervention (Margolis, 2012; Jones, Bronstein & Ferrière, 2012). Teachers could share, combine, develop and grow their teaching practices alongside their peers and experts, which resulted in a hybrid species of teacher leaders able to enhance science teaching in all communities (Margolis, 2012). Thus, the A-team teachers as participants in a scientific environment could offer a keystone specie of hybrid science teacher leaders.

7.6 The A-team members as keystone species

(growing human organism relations obtaining within and between these immediate environments)

The Oxford online dictionary defines "keystone species" as "a species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically" (Oxford online). Quality science teaching depends on quality science teachers as keystone species. These teachers could have a dynamic influence at any level, producing a cascade effect in improving the quality of science teaching in South Africa (Paine, 1995; Petersen & De Beer, 2012). The A-team hoped to develop the participants as keystone species, characterising them as expert science teachers in the system.

7.7 The A-team members as flagship species

(larger social contexts, both formal and informal settings)

Cristancho and Vining (2004:153) claim that "those species that can be considered most important to the structure and function of a community deserve the keystone species label." The keystone science teachers of the A-team could evolve towards becoming a flagship species. These science teachers are charismatic in nature, and have the ability to become ambassadors for science in schools (Cristancho & Vining, 2004; Savard, et al., 2000; Paine, 1995). Moreover, the A-team teachers could become ambassadors for inquiry-based science teaching not only within their own schools but also in entire districts and even on a national level.

8. FINDINGS AND CONCLUDING REMARKS

The nature of the concept "ecology" and the link with the social sciences gave rise to the term "hybrid ecology of learning practice" (HELP). The HELP model includes all of the above-mentioned theories and theories of action and is most relevant to the purpose of the A-team intervention.

I contend that combining learning and practice in a hybrid ecology of learning practice is essential for the professional development of science teachers.

Findings of this study revealed that hands-on professional development activities in the continuing professional development of science teachers, not only improved their technological pedagogical content knowledge but also motivated teachers to include inquiry-based teaching strategies in their classroom practices. The hands-on experiments with scientists in the UJ laboratories, that emphasized the true nature of science, proved to be the greatest motivating feature of the entire intervention. These activities included DNA barcoding, electroplating, heart dissections and extracting DNA from strawberries and even their personal DNA. The main aim of these sessions was to develop the teachers' science process skills and to enhance the teachers' perceptions of the true nature of science. This proved to be successful in that the teachers' online reflections revealed the successful transfer of these activities into classrooms. Moreover, these inquiry-based A-team teacher experiences transferred into classrooms ignited the learners' interest in science as a subject and could also entice students towards taking science as a subject. A group of Life Science learners from a participating A-team school were also hosted for a DNA barcoding session. One teacher's response after this learner experience was that "a few new scientists were born." In addition to this these hands-on inquiry-based activities positively affected the learners' attitude and behaviour in the science classroom. Furthermore, the data also revealed that some teachers teaching science in SA schools have never been exposed to real science experiences in laboratories, which is of grave concern.

Successful outcomes are already evident from of the A-team project. One teacher was in the process of leaving the teaching profession. However, the support and the guidance of the A-team members resulted in her becoming a facilitator for many provincial programmes offered in science. Two more of our teachers (as flagstone species) were approached to present at a CAPS training session. The Life Science A-team teacher presenter used her A-team experience to present an inquiry-based hands-on session, resulting in a positive and motivating CPTD experience for the teacher attendees. Another A-team teacher was invited as a guest lecturer for a group of first year science teachers. In addition to this, some of these teachers made time to embark on further studies to improve their teaching of science. These are but a few outcomes of the A-team project – Excelling in Science Education as a hybrid ecology of learning practice.

Hybrid ecologies of learning practice provide support to teachers in challenging the status quo, offering opportunities to address larger and more difficult issues (Hargreaves, 1999). It allows for cultivating creative spaces and conditions for information sharing and knowledge generation, not only within a specific school but also between different schools, often referred to as "lateral capacity building" (Chapman, 2003). Hargreaves (1999:127, 139) contends that networks connect people, groups and communities, resulting "in combination, [in] a process of systemising and elaborating explicit knowledge by combining different bodies of knowledge" and that "networks within and between schools could promote professional knowledge creation within the individual school and in the education service as a whole". These wider circles embrace not only systemic change but also the impact of globalisation and rapid change, thus applying new ways to teaching and learning, by participating in global hybrid ecologies of learning practice (Stoll, 2006).

I conclude by advocating hybrid ecologies of learning practice as an outcome of the social cognitive, social constructivism and situated learning theories which is considered to be most effective, as collective action tends to create energy within a group that could promote positive behaviour, create a sense of belonging and enhance motivation (Kritsonis, 2005). By working together these science teachers could become a force for change to bring about new system beliefs and practices in the field of science teaching and learning. The A-team could fulfil the role of change agent within the system as "human agency gains unusual powers when future-oriented activity-level envisioning and consequential action-level decision-making, come together in close interplay" (Engeström, 2005:313). For this reason, I believe that the A-team as a hybrid ecology of learning practice offers HELP on demand for distressed science teachers and their teaching, as similar CPTD interventions could bring about an entirely new approach to science teaching in a South African context.

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