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Exploring the educational significance of science fairs for high school science teachers

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Ethical clearance certificate

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Abstract

In this study, the researcher sought to understand why teachers of Physical Sciences participate in the South African 'Eskom Expo for Young Scientists'. This was analysed in terms of the educational significance that they perceive the science fair to offer, what sustains their participation over a long period of time, and the extent to which Expo participation provides an opportunity for professional development. The educational significance of the Expo was established in terms of its contribution to the Professional Identity of teachers, and was related to the roles (organiser, mentor and judge) of participation in science fairs.

The sampling employed in the study was both purposive and convenience-based in nature. Only schools participating regularly (at least five times in the past ten years) in the long running (since 1980) of the 'Expo for Young Scientists' (Northern Gauteng Region) were selected. Five urban public high schools and ten teachers of the school subject "Physical Sciences" were identified to participate in this study. Face-to-face semi-structured interviews were conducted with two teachers from each school in this QUAL-quan research approach. The interview transcripts were subjected to a thematic analysis, where after the points raised by the teachers were clustered into categories and related to sub-themes and themes according to the educational significance for teachers, the benefits and drawbacks for learners, teachers' Professional Identity, and reasons for sustained participation.

Many researchers regard science fairs as one of the better ways to enhance science education. Globally, science fairs have been taking place for more than 30 years and are thought to have educational value for both science teachers and learners. These science fairs provide a context for the development and application of scientific investigation and research skills. This research employed the model of Beijaard, Meijer and Verloop (2004) to characterise teachers' Professional Identity (professional knowledge, attitudes, beliefs, norms and values, and emotions). The researcher also employed Ajzen's (1991) Theory of Planned Behaviour to understand why teachers take part and sustain their involvement in the Expo, be it at school or regional level. The major focus was thus on the benefits for teachers as perceived by them, with some contextualisation of the educational benefits and potential drawbacks for learners, while the literature to date has largely reported on the benefits for learners.

This study has found that expos provide sustainable educational significance in terms of professional development for teachers, and enhance aspects of their Professional Identity, such as contributing to pedagogical knowledge, pedagogical content knowledge, as well as scientific procedural and declarative or factual knowledge. Their self-efficacy beliefs are strengthened, positive attitudes are developed, and strategies of inquiry based learning and effective methodological instructions in science education, which contributes to their teaching. Learners gain knowledge of science through reading and investigations, and also learn more of the nature of science. Teachers' values (and those of their schools) are reflected when their emotions are lifted in sharing learners' achievements in the science Expo. Teachers learn both from their engagement with learners, but also through networking opportunities with fellow teachers. The consequent enhancement of Professional Identity contributes to the sustainability of their participation in the Expo.

Although this research focused on teachers of Physical Sciences, learners in the Expo are guided on projects ranging from biology and environmental sciences, engineering and design, information technology to psychology, and various social sciences beyond the physical sciences. The teachers who guide the subjects related to these fields possibly have similar experiences, thus extending investigations to such teachers would surely provide a richer set of insights. Teachers who do not sustain their participation did not form part of the research, but their experiences and perceptions were included to further enrich the nature of the findings. It is recommended that the opportunity for professional development that is provided by teachers' participation in such *school level investigation science fairs* be acknowledged and promoted by schools and fair organisers. They can do this by continuing to extend the range of teachers who are encouraged to be involved in such science fairs.

Key words: educational significance, Expo, inquiry based learning, physical science teachers, Professional Identity, Professional Development, science fair, Theory of Planned Behaviour.

Declaration of originality

I, **Clement Kapase Mbowane**, Student Number **98321732** declare that this dissertation is my own original work.

I understand what plagiarism is and am aware of the University's policy in this regard.

Where other people's work has been used either from a printed source, internet or any other sources, this has been properly acknowledged and referenced in accordance with departmental requirements.

I have not used work previously produced by another student or any other person to hand in as my own.

I have not allowed and will not allow anyone to copy my work with the intention of passing it off as his or her own work.

Signature of student:

Date: 24. 11. 2016

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List of Acronyms and Abbreviations

ACE: Advanced certificate in education

CAPS: Curriculum assessment policy summative

CK: Content knowledge (also known as SMK, subject matter knowledge)

DBE: Department of Basic Education

DST: Department of Science and Technology

EPGBU: Education program for gifted student bridge with university

IBL: Inquiry based learning (also written as inquiry-based learning)

MST: Mathematics, science and technology

NOS: Nature of science

PBC: Perceived behavioural control

PCK: Pedagogical content knowledge (also used as TSPCK)

PD: Professional development

PK: Pedagogical knowledge

PROFILES: Professional reflection oriented focus on inquiry-based learning and education through science

SCIFEST: Science festival office organisation in South Africa

SMK: Subject matter knowledge (also known as CK, content knowledge)

STEM: Science, technology, engineering and mathematics

STENCIL: Science teaching European network for creativity and innovation in learning

TK: Technological knowledge (or knowledge of teaching technology)

TPACK: Technological pedagogical and content knowledge

TPB: Theory of Planned Behaviour

TPCK: Technological pedagogical content knowledge (also known as TPACK)

TSPCK: Topic specific and pedagogical content knowledge

List of Appendices

Definitions of Terms

The following terms are operationally defined in this study:

Beliefs: This refers to beliefs in relation to the effective teaching and learning of mathematics, science and technology (regarding classroom practices and learners' achievement). This has the potential to inform the development of learning experiences within science subjects, as well as to promote self-efficacy and commitment (van Putten, 2011: 269-271, 281).

Content knowledge (**CK**)**:** This refers to knowledge of the subject matter or disciplinary field, which includes the content to be taught in a specific subject, as well as knowledge beyond what is required to be taught. This is also abbreviated as SMK (Hauk *et al.*, 2014).

Educational significance: Educational significance comprises the practical skills and experiences that help teachers to improve their professional practice and academic performance, beliefs and self-actualisation (Beijaard *et al.*, 2004).

Expo: This term is used specifically for the South African school science fair, known as the Eskom Expo for Young Scientists, as well as generically to refer to science fairs in which school level learners engage in studies and projects in various fields of science and technology, which are then presented and judged. The Expo is held at schools, at regional level, and in a national final, which draws some participants from neighbouring countries in Southern Africa (Gray, 2014).

Inquiry based learning (IBL): is defined as a process that explores the world and engages learners in activities to develop a broad knowledge and understanding (Department of Science and Technology (DST), 2012). This is also known as enquiry based learning.

Physical Sciences (capitalised): This is a specific school subject in the South African national curriculum for high schools, and consists of generally non-calculus components of physics and chemistry. The non-capitalised "physical sciences" refers to the broad fields of physics, chemistry, astronomy etc. and as in common usage are differentiated from the fields of life or biological sciences.

Professional Identity (PI): This is a teacher's knowledge, beliefs, values, and commitments and intentions that influence the individual's participation in societal practices associated with professional practice, mathematics, science and technology (MST) knowledge, pedagogical content knowledge, and skills. Attitudes and emotions are additional concepts that form part of Professional Identity (Beijaard *et al.*, 2004; van Putten, 2011: 22-24).

Professional knowledge: Teachers' professional knowledge can be explained in terms of: 'Content Knowledge' (CK), 'Pedagogical Knowledge', 'Pedagogical Content Knowledge' (PCK) (Shulman, 1986, 1987), 'Technological Knowledge' (TK), and 'Technological Pedagogical (and) Content Knowledge' (TPCK or TPACK) (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

Pedagogical knowledge (PK): is defined as knowledge that concerns the processes and practices of teaching and learning. It also involves purposes, values and aims, classroom management, lesson plan preparation and implementation (Koehler & Mishra, 2009).

Pedagogical content knowledge (PCK): Is a form of knowledge related to practice as a teacher, which integrates the knowledge of subject, teaching strategies, and learners' conceptions (Shulman, 1986, 1987; Carlson, Schneider, Berry & van Driel, 2014) in a dynamic fashion (Hauk *et al.*, 2014). As this study involved teachers of Physical Sciences specifically engaging learners in science projects, this was used synonymously with "Topic Specific PCK" (Mavhunga & Rollnick, 2013a; Rollnick & Davidowitz, 2015).

Technological pedagogical (and) content knowledge (TPCK or TPACK): This involves different strategies for the enhancement of knowledge in relation to content, pedagogy, technology (most usually information technology, but also including various teaching and subject-specific technology) and the specific context of function (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

Professional development: refers to the acquisition of new knowledge in the area of professional knowledge through the sharing of experiences with other teachers, and the development of skills, professional competence, and research and practical work (Zivkovic, 2013).

CHAPTER 1

Introduction

1.1 Research context

The purpose of this research was to examine the educational significance, as perceived by teachers of Physical Sciences, of their involvement in the Expo, and the related practical skills and experiences that have helped them to improve in their professional and academic performance, beliefs and self-actualisation. The focus was particularly on the sustainability of the participation of these teachers, who enact various roles in the science fairs that are organised in South Africa.

In South Africa, academic performance and the improved skills of mathematics and science learners are priorities that the government supports through the Department of Basic Education (DBE) and the Department of Science and Technology (DST, 2012). The DST supports science fair events, which fall under the umbrella of the Eskom Expo for Young Scientists. It is thought that science fairs help learners to improve in both mathematics and science (Fisanick, 2010; Molefe, 2011: p. 17). Science fairs rely on teachers to motivate and assist learners to identify potential projects, and to help them to present their projects. The roles of teachers in science fairs include mentoring, organising, collaborating, networking and judging (Molefe, 2011: pp. 68, 104). While teachers participate in science fairs in various roles, it is not that clear why they do it. What sustains them in carrying out these potentially time-consuming tasks for several years?

The South African electricity provider, Eskom, together with the Department of Science and Technology (DST), sponsors the science fair known as the *Eskom Expo for Young Scientists* annually (DST, 2012). This series of science fairs has taken place at schools, at regional and at national levels for several decades, having begun with leading high schools participating in 1980 (Gray, 2014; DST, 2012). The vision of the Eskom Expo for Young Scientists (which we refer to simply as the Expo) is to encourage the participation of the most innovative and gifted learners across South Africa's rural and urban areas (Alant, 2010; DST, 2012).

It has been reported that teachers believe that science fairs enhance the skills, attitudes and knowledge of learners, and encourage future careers in scientifically oriented professions (Czerniak, 1996; Fisanick, 2010: 96, 121). They also believe that science fair projects have educational significance, in particular that science fairs challenge learners with academic rigour, establish useful skills, and complement other efforts to address the science achievement gap (Abernathy & Vineyard, 2001; Fisanick, 2010, p. 132; Molefe, 2011, pp. 106, 240). In the United States of America, participation in science fairs is recommended by the American Association for the Advancement of Science and the National Science Teachers Association (Schneider & Lumpe, 1996; Yasar & Baker, 2003). Bencze and Bowen (2009), McComas (2011), Ngcoza, Sewry, Chikudu and Kahenge (2016), and Taylor (2016) recommend that science fairs benefit learners through science inquiry and provide an advantage in science literacy. Gibson and Chase (2002) argue that many teachers who take part in science fairs are stimulated to use a hands-on approach in their classroom practices, therefore participation in science fairs is claimed to benefit the classroom practices of teachers.

The researcher sought to understand why teachers of Physical Sciences participate in the South African 'Eskom Expo for Young Scientists', what educational significance they perceive the Expo to offer, and what sustains their participation over a long period. The role of the Expo in teachers' professional development is a further aspect that was investigated.

1.2 Problem statement

Many teachers perceive science fairs as beneficial to the learners who are involved (Abernathy & Vineyard, 2001; Czerniak & Lumpe, 1996 b; Fisanick, 2010: 96, 121, 132). However, what are the benefits for teachers?

Science fairs are competitions that may be local, regional or country-wide where learners have an opportunity to perform and understand science inquiry, as well as to experience the process of scientific investigation (Bencze, Bowen & Arsenault, 2008; Kahenge, 2013, pp. II, 6, 13; McComas, 2011; Ndlovu, 2014). Several benefits to the participating learners have been identified: learners gain communication skills, make project discoveries, and are awarded with medals and scholarships (Villas-Boas, 2010). Bigler and Hanegan (2011), Dionne, Reis, Trudel, Guillet, Kleine and Hancian (2012), O'Kennedy, Burke, Van Kampen, James, Cotter, Browne, O'Fagain and

McGlynn (2005), as well as Wirt (2011, pp. III, 26, 175) report that many learners who participate in science fairs show improvement in their scientific skills, content knowledge, understanding, and interests. However, in what way do science fairs benefit the science teachers who are involved?

Teachers play a crucial role in attracting learners to participate in science fairs (Tortop, 2013; Kahenge, 2013, p. 95; Schachter, 2011). I sought to investigate the educational significance of science fairs as perceived by high school science teachers who are mentors, organisers, administrators and judges of learners' projects at science fairs. I sought to identify why some science teachers perceive science fairs as beneficial for learners, as well as why they take part while others do not.

The study also explored teachers' views on the educational significance of science fairs in terms of their Professional Identity. The critical reflections of the participating teachers may reveal substantial information regarding the importance of science fairs to teachers. As part of this study, I sought to examine the willingness of school teachers to establish, administer or participate in school, regional or national science fairs, and also why they sustained their participation, often over several years.

1.3 Rationale of the study

I was introduced to science fairs as a student at the University of Pretoria in 2001. Several researchers (Fisanick, 2010, p. III, 129-130; Grote, 1995; Hanifee, 2013; Kotwani, 2013) report that science fairs may be worthwhile for teachers; in fact, several schools have incorporated science fair projects into their science curriculum (Egenrieder, 2010; Molefe, 2011: p. 220; Prytula & Weiman, 2012).

The knowledge gained in this study about teachers' beliefs may be beneficial in the recruitment of other teachers to participation in science fairs. The knowledge gained from this research may also prove useful to teachers who have not been involved in science fairs, and it may help those who have taken part to improve their activities.

The literature that was reviewed generally explored the benefits to learners who participate in science fairs, however, what teachers find of value or significance educationally will contribute to understanding science fairs from the point of view of teachers.

1.4 Aim and objectives

The aim of the study was to explore the educational significance of science fairs from the viewpoint of teachers of Physical Sciences. The educational significance was measured in terms of the contribution of participation to the Professional Identity of teachers, and the consequent role of participation in science fairs in their professional development.

More specifically, the objectives of the study were to determine the educational significance as perceived by the participating teachers, who had sustained their participation in the Expo as organisers, mentors and judges over a period of several years.

1.5 Research questions

The main research question, which expresses the focus of this study, is:

> *From their point of view, what is the educational significance of science fairs (if any, in terms of Professional Identity and Professional Development) to teachers of high school Physical Sciences, and why did they sustain their participation over many years?*

To explore this question, several sub-questions are presented. These are:

i. *What is the perceived educational significance of teacher participation in science fairs to their Professional Identity and Professional Development?*

ii. *What is the educational significance of science fairs in the opinion of the teachers who participate as organisers, mentors and judges?*

iii. *If teachers' participation in science fairs is sustained for several years, what are the possible factors that support this sustained participation?*

The questions presented in this study address the teachers' perception of the significance of participation in terms of Professional Identity, the reasons for their participation in these fairs, what motivated them, and what attitudes and beliefs they possessed that motivated them to continue to be involved (for several years in many cases). Therefore, a conceptual framework was required that could describe the teachers (in terms of Professional Identity), explain their choice to participate in various roles in science fairs, and explain why those who participate for an extended period sustain their participation.

1.6 Conceptual framework: Professional Identity and roles in the Expo

1.6.1 Overview of the conceptual framework

The conceptual framework proposed for this study consisted of two aspects, forming a simple systems model, which is represented in Figure 1.1. The major elements of this model are the teacher's Professional Identity with elements, as given by Beijaard, Meijer and Verloop (2004), of the roles that teachers play in science fairs, and a postulated link between teachers' professional identities and choice of role. In order to address the question of sustainability, teachers' perceptions of the effect of their roles in science fairs on the elements of their Professional Identity are included in the framework as an influence that is directed from the roles towards their Professional Identity. It is postulated that a teacher's participation contributes to and benefits the teacher in terms of their professional development, which encourages further or sustained involvement.

Professional Identity describes the process of interaction between a person and the context, and may be characterised by professional knowledge, attitudes, emotions, norms and values, beliefs (Beijaard *et al.*, 2004; Beauchamp & Thomas, 2009; Flores & Day, 2006) and agency (Beijaard *et al.*, 2004). Botha (2012:170,174), and Botha and Onwu (2013) define Professional Identity in mathematics, science and technology (MST) as an incorporation of internal and external factors such as technical knowledge, beliefs, and an understanding of the nature of MST, which involve actions and a knowledge of curriculum processes in a given school context. Botha (2012:167-168) perceives Professional Identity development in MST teaching as a continuously changing educational process that affects and is affected by teachers' perceptions, acquired knowledge, and their professional environment. The development of Professional Identity is seen as versatile, dynamic and active (Beijaard *et al.*, 2004; Vandenbroeck, 1999; Botha, 2012; 167, 172).

Van Putten (2011: 22-25; 31-34) has described Professional Identity as an interaction between a person and context, which is not rigid or unique, but keeps on changing in a complex process and thus is formed through multiple contexts. Van Putten (2011) further contends that Professional Identity involves subject matter knowledge (conceptual knowledge and skills), didactics (teaching and learning skills), and pedagogical expertise (knowledge and skills for emotional caring and nurturing), and is associated with beliefs and emotions. The concept of Professional Identity is used to characterise the dynamic aspects of science teachers in the professional context that frames their professional activities. This process of decision making and the resulting choices link Professional Identity (who they are) to their roles (what they do), and hence is placed in the forward component of the "process" element of the simple systems model.

It is supposed that participation in science fairs strengthens or influences aspects of the teacher's Professional Identity (an assumption supported by Botha (2012) and van Putten (2011)), and this postulated link is shown as the feedback component of the framework. Linked to this is the question of how or why the participation is sustained, and thus aspects of personal identity that lead to the resilience of the teacher are implicitly included in the conceptual framework. A diagrammatic representation of the framework is presented in Figure 1.1.

The model shown in Figure 1.1 describes the dependence of the teacher's role on Professional Identity. It is expected that teachers sustain their participation in science fairs because it brings enhancement in some way to their Professional Identity. This postulated effect is shown as the arrow to the left in Figure 1.1.

1.6.2 The Input: Professional Identity of the teacher

According to Beijaard *et al.* (2004), Botha (2012:174), and van Putten (2011, p. 31), Professional Identity is viewed as the interaction between a person and the environment (school context). School contexts involve joint activities, mutual cooperation, and a shared repertoire of resources, both in material and in shared experiences (van Putten, 2011, p. 28). Furthermore, Flores and Day (2006) propose that, in education, Professional Identity is influenced by school culture, as well as consequent cognitive and emotional responses. Teachers' professional knowledge comprises subject matter (content and process skills), didactic (teaching and assessment skills), and pedagogical (caring and fostering) knowledge respectively (Beijaard *et al.*, 2000). Moreover, Professional Identity is influenced by both intrinsic and extrinsic factors (Beauchamp & Thomas, 2009; Botha, 2012, p. 170; Day, Kington, Storbart & Sammons, 2006; Flores & Day, 2006). Professional Identity is also influenced by self-efficacy, motivation, commitment, job-satisfaction, and effectiveness (Canrinus, Helms-Lorenz, Beijaard, Buitink & Hofman, 2012; Day *et al*., 2006). These aspects may be identified with the beliefs, attitudes, emotions, and norms and values, and agency elements of the earlier model (Beijaard *et al.*, 2004). Professional development has a significant impact on agency, as Beauchamp and Thomas (2011) find that the absence of agency-related experiences in other professional contexts, as well as experiences, notions, and strategies are enhanced by educational courses.

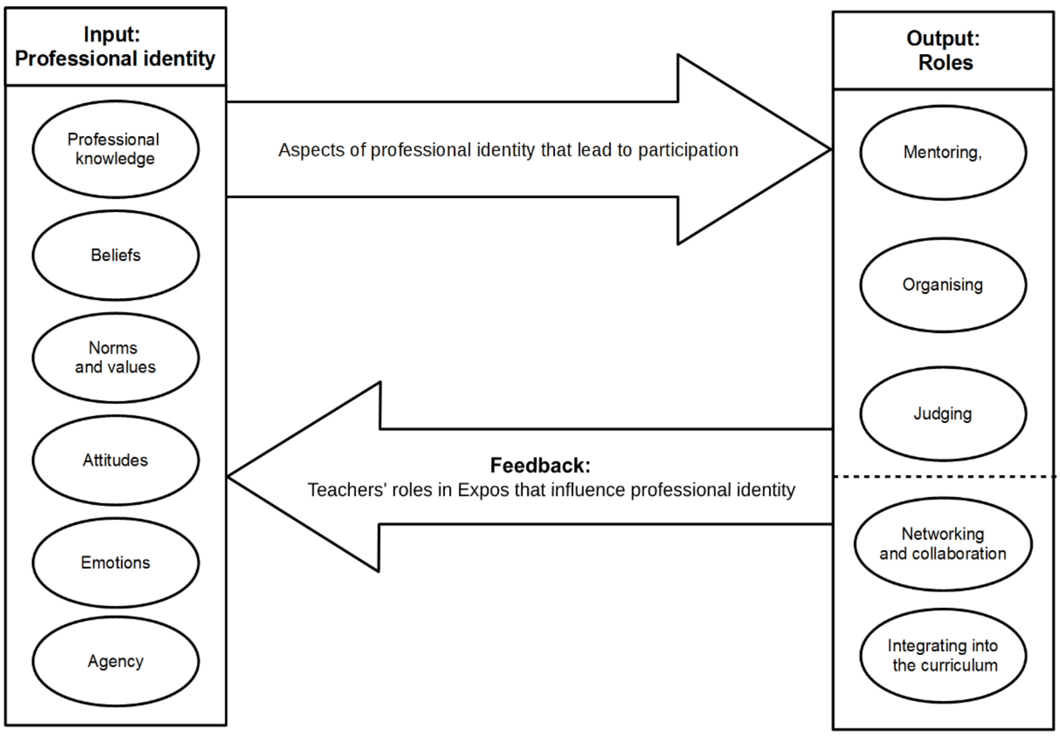

Figure 1.1: A model that links the Professional Identity of teachers (Beijaard *et al.*, 2004) to teachers' roles in science fairs.

Secondary roles are separated from the primary roles by the dashed line.

Several researchers view Professional Identity as an ongoing, continuous and twisting incorporation of personal aspects (Ibarra, 1999; Weiner & Torres, 2016), and personal roles, relatively stable traits, beliefs, values, motives, and experiences through which teachers explain their career and professional roles (Ibarra, 1999). Professional Identity is seemingly a continuously changing and complex process that is influenced by both personal and social factors (Beijaard *et al.*, 2004; Beauchamp & Thomas, 2009). Identity is seen as both process (interaction in the context) and product (influences on teachers) (Beauchamp & Thomas, 2009). In some studies, Beijaard *et al.* (2004) relate Professional Identity to teachers' images of self, while in other studies, they emphasise teachers' role identity. Philipp (2011) views identity as the embodiment of a person's knowledge, beliefs, values, commitments, and intentions. These affect an individual's participation in particular societal practices, as well as the way he or she has discovered to think, act, and interact.

In this study we relate benefits (to themselves, their learners, any disadvantages and as a profession) that teachers identify that they gain from Expo participation to professional identity, and interpret changes to professional identity as professional development.

- ***Professional knowledge***

Teachers' *professional knowledge* can be explained in terms of: content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological knowledge (TK), and technological pedagogical content knowledge (TPCK) (Beijaard *et al.*, 2000).

Basic knowledge types: Content knowledge (CK) concerns subject matter, which comprises facts, concepts, theories, and procedures (Shulman, 1986, 1987). Pedagogical knowledge (PK) is broadly known as knowledge that concerns the processes and practices of teaching and learning, and involves purposes, values and aims, classroom management, and lesson plan preparation and implementation (Mishra & Koehler, 2006). Various syntheses of the basic forms of teacher knowledge CK and PK yield the latter forms.

Pedagogical content knowledge (PCK) has been described as an integration of several elements, including, knowledge of the subject; knowledge of effective and proactive teaching strategies, teaching orientation (beliefs about the nature of science and science literacy), representations of subject matter knowledge (SMK or CK), and knowledge of learners' conceptions (Shulman, 1986; Sibuyi, 2012, pp. xii-xiii; Carlson, Schneider, Berry & van Driel, 2014). PCK includes the knowledge of teaching and teaching approaches in specific subject content topics and learner contexts (Mavhunga & Rollnick, 2013a, 2013b). Anderson (2015) contends that the PCK model entails knowledge of reasoning and preparing a particular subject to accomplish outcomes in relation to a specific goal for a particular group of learners.

This is a definition that is shared by Rollnick and Mavhunga (2014). They further contend that PCK is constituted by the following factors: learners' prior knowledge or misconceptions, curriculum saliency or ability to decide what is crucial for teaching in a sequential manner, what makes a topic complex or easy to understand, representations of the topic, analogies made through the use of examples, as well as methodological conceptual teaching strategies.

Topic Specific PCK: Rollnick and Mavhunga (2014) emphasise the relationship of PCK to specific topics by differentiating between PCK (in general as an encompassing term) and 'Topic Specific PCK' (TSPCK). In this study, the context of the study was science fairs and the involvement of teachers, and specifically the project nature of science investigations. Therefore, this research does not differentiate between TSPCK and PCK, essentially using them interchangeably. Hauk, Toney, Jackson, Nair and Tsay (2014) report on efforts to develop a comprehensive and unified model of PCK, which has influenced other researchers such as Rollnick and Davidowitz (2015), amongst others. In this study, the terms and discussions that the participating teachers provided were associated with PCK based on these definitions.

Evens, Elen and Depaepe (2015) contend that experiences in teaching practices and contact with other supportive school teachers are beneficial for PCK development. This may be expected to be gained through networking at science fairs, for example.

Technological knowledge (TK) involves the standard technology used in teaching, such as books, chalk and blackboard, and Internet and digital video (Koehler & Mishra, 2009). 'Technological Pedagogical (and) Content Knowledge' (TPCK or TPACK) comprises different strategies that involve the enhancement of knowledge of the complex work in relation to content, pedagogy, technology and the specific context of function (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

- ***Beliefs***

Beliefs are defined in a variety of different ways, and are utilised interchangeably with a variety of other concepts such as attitudes, values, judgements, opinions, ideology, perceptions, conceptions, a conceptual system, dispositions, implicit and explicit theories, action strategies, internal processes, rules of practice, and perspectives (Pajares, 1992, Savasci-Acikalin, 2009). Pajares (1992) asserts that certain subjective beliefs are the foundation of societal cognitive philosophy. Moreover, Intelligent nature, knowledge and inspiration, as well beliefs are said to be static and have a major impact on a person's self-efficacy. Here, *beliefs* refer to knowledge about the world that is thought to be true beliefs. Beliefs in this study are also held to be more cognitive than attitudes and emotions, encountered less extremely, and are more difficult to change than attitudes (Philipp, 2011).

Additionally, Kagan (1992) and Anderson (2015) describe beliefs as the process of filtering most of the new information that an individual gains; this is then used to interpret new experiences. Beliefs influence pedagogical strategies and content knowledge (Anderson, 2015; Savasci-Acikalin, 2009), and may be a source of resistance to change (Anderson, 2015; Botha, 2012, pp. 172-173; Crosswell, 2006, pp. 218, 49, 98-99; Philipp, 2011; Savasci-Acikalin, 2009). The concept of beliefs is seen in teaching and learning science to involve both personal and professional commitment (Crosswell, 2006, p. 218). Anderson (2015) and Savasci-Acikalin (2009) explain that quality content is effectively presented when it is combined with learner-centred beliefs and the nature of science through the implementation of inquiry-based activities. Beliefs and emotions are interrelated with motivations, as contended by Canrinus *et al.* (2012). Beliefs consist of three contributions: cognitive (personal knowledge), affective (ability to discuss the centre of object in a debate at various intensities) and behavioural (about action when activated) (Rokeach, 1972; Savasci-Acikalin, 2009).

Anderson (2015) argues that teachers' beliefs about the goals of science education and the nature of science (NOS) have been discovered to have a strong impact on classroom practice. Beliefs further influence the development of pedagogical content knowledge (PCK) for science teaching and learning, subject matter knowledge, and learning opportunities for learners, especially through the implementation of inquiry-based practices in the classroom. Beliefs focus on pedagogical strategies and content knowledge, which enhances teaching through the integration of inquiry-based teaching as this is believed to be effective in the teaching process, and helps in addressing complex questions.

- ***Attitudes and Norms and values***

Collaboration, commitment and context are also some of the elements that enhance teachers' *attitudes* (Flores & Day, 2006), while *norms and values* are manifested in facilitation, contextual interaction and conceptual knowledge (Beijaard *et al.*, 2000). In addition, norms and values involve caring attitudes, as explained by O'Connor (2008).

- ***Emotions***

Emotions are explained as being complementary to beliefs as they are interrelated (Canrinus *et al.*, 2012). While some researchers clarify that the collaboration and acceptance of values manifest as emotions (Pillen, den Brok & Beijaard, 2013; O'Connor, 2008), others explain that emotions concern caring attitudes (Botha, 2012, pp.168-169; van Putten, 2011, pp. 22-23; Den Brok, Van der Want, Beijaard & Wubbels, 2011). O'Connor (2008) also relates emotions to caring attitudes, which include performance (pedagogical), profession (management and retention), as well as norms and values (code of ethics). Den Brok *et al.* (2011) further contend that emotions involve elements such as: commitment, appraisal of situations, effectiveness (self-efficacy, competence), content and pedagogical expertise, as well as tension and dilemmas.

- ***Agency***

Agency is the ability to pursue one's goals, and concerns an individual's capability to pursue a goal that benefits him or her, and that he or she values (Beijaard *et al.*, 2004; Beauchamp & Thomas, 2009; Coldron & Smith, 1999; Day *et al.*, 2006). Beauchamp and Thomas (2009), and Day *et al.* (2006) contend that agency is the process of shaping, retaining and enhancing one's identity through interaction with various educational environments. Agency is found to be closely related to valuing resources (Beijaard *et al.*, 2004; Beauchamp & Thomas, 2009; Day *et al.*, 2006). You and Craig (2013) add collaboration to Professional Identity as the voluntary process of interacting and sharing experiences, resources and methodological practices, which can be seen as another aspect of agency. Professional Identity, and its factors, provides the setting for participation in various roles in science fairs, which is considered in this study to be a consequence of personal and environmental factors.

1.6.3 Output: the roles of teachers in the Expo

The roles described in the conceptual framework were derived from various literature sources. These roles may be summarised as mentoring, organising, and judging, supported by networking and collaboration, with the integration of subject matter into and from the curriculum.

- ***Mentoring***

In *mentoring* learners during projects, an opportunity arises for teachers to engage learners in inquiry based learning (Cowen, 2013; Ndlovu, 2014). This provides teachers with different strategies for learning and teaching, such as content knowledge, pedagogical knowledge and various other approaches (Egenrieder, 2010; Grant, Yerrick, Smith, Nargund-Joshi & Chowdhary, 2013; McComas, 2011; Molefe, 2011, pp. 260-261; Schachter, 2011). Opportunities to experience inquiry activities in terms of CK, PCK, PTK and TK also occur. Sahin (2013) reports that teachers' roles and tasks in science fairs expedite and create cooperative team study for learners through inquiry based learning (IBL) instruction projects.

Mentoring learners as they carry out projects enhances and facilitates collaboration between teachers and universities. It also promotes sharing information and resources, and heightens caring attitudes and commitment (You & Craig, 2013). Teachers who are mentors create positive attitudes towards teaching, and let learners engage with projects and participate in science fair competitions. It is argued that these science fairs promote learners' interest in science (Fisanick, 2010: 132; Kotwani, 2013; Tortop, 2013) through interaction with their mentor teachers. Teachers' roles in science fairs are to encourage, support, and advise learners in order to develop creative, innovative and thinking minds (Barry & Kanematsu, 2006; Nath, 2007). Many teachers have taken on mentoring roles and have developed positive attitudes in their learners towards science fair activities through the incorporation of inquiry-based approaches in the science classroom. This is done in order to promote STEM education for their learners (Molefe, 2011, pp. 80-81; Schachter, 2011). The mentoring attitude adopted by teachers as science fair participants offers an opportunity for teachers to disseminate their Expo knowledge and experiences.

- ***Organising***

The *organising* role enacted by teachers in science fairs offers opportunities for teachers to organise and collaborate with other science institutions to obtain resources and find judges for the learners' STEM projects (Cowen, 2013). Carrier (2006) argues that as a participant of science fairs, she organises the resources for learners' projects and also communicates with parents through newsletters to update them about learners' science fairs and ask for some extra resources, and in return she also receives volunteer mentors as well. Teachers benefit by gaining organisational and prompting skills as Expo participants (Taylor, 2016). Declue (2000), Kahenge (2013, p. II, 48) and Ngcoza et al. (2016) contend that teachers in science fairs organise and collaborate with nearby tertiary institutions (universities) for project resources, judges, professors and mentors for their school's projects. Some teachers organise and arrange workshops for learners' science Expo projects in order to motivate learners to get involved (Kahenge, 2013, p. 48, Ngcoza et al., 2016).

- ***Judging***

Judges are drawn from several scientific organisations for science fairs (Cowen, 2013). It is argued that teachers are enhanced with intuitive judging experience and skills for projects (Molefe, 2011, pp. 80-81; Taylor, 2016). The judges of the learners' projects at the Expo include teachers, scientists and professors (Eskom Development Foundation, 2015; Kahenge, 2013, p. 105-106). Teachers in science fairs judge, guide, and help learners to complete their scientific projects (Fisanick, 2010, p. 128; Molefe, 2011, pp. 96-97).

Participation in any of the three primary roles (mentoring, organising and judging) creates opportunities for the secondary roles. These are shown in figure 1.1 as networking and collaboration, and integrating [activities, experiences, knowledge etc.] into the curriuculum.

- ***Secondary activities***

Collaboration promotes *networking*, which gives teachers content knowledge, effective pedagogy, and new teaching strategies, and also increases inquiry implementation (Grant *et al.*, 2013; Hardre, Ling, Shehab, Nanny, Nollert, Refai, Ramseyer, Herron & Wollega, 2013). Grant *et al.* (2013), and You and Craig (2013) contend that collaboration facilitates partnership between schools and universities, which provides greater access to science, technology, engineering and mathematics resources. Collaboration amongst teachers in mentoring learners to carry out projects at science fairs enhances teachers' content knowledge (CK) through the use of more pedagogical techniques (TK and TPCK), and provides great access to STEM resources. Teachers experience new ways of teaching and learning science in a collaborative culture (Grant *et al*., 2013). Molefe (2011, p. 204) explains that through collaboration with various teachers from other schools, and researchers from universities through the process of inquiring, effective teaching is encouraged.

Teachers gain knowledge and opportunities for reflection through networking (Beauchamp & Thomas, 2009). Hardre *et al.* (2013) view networking as a connection between people in and across organisations and communities, social structures, and relationships. This connection influences teachers in learning and changing, as well as knowledge, which improves their emotional attitudes. Hardre *et al.* (2013) argue that social networking creates and sustains the connection of professional development activities into long term relationships and support communities for transformative development. Science fairs provide teachers with the opportunity to network with other teachers from different schools and experts from other tertiary institutions. In networking, teachers exchange experiences with one another and learn from each other. They are also able to discuss and learn instructional strategies from one another.

Instructional strategies should actively engage learners, helping them to use their prior knowledge and skills to solve problems in subjects like mathematics. Moreover, their learning environment should be conducive to and supportive of their learning (Tanner, Bottoms & Bearman, 2003). Molefe (2011, pp. 220, 230) supports the view that an environment that is conducive to learning enhances effective learning, as the ethos of the school has the power to enable teachers to initiate and conduct science fair activities.

Sibuyi (2012, p. 80) posits that productive teaching approaches maximise learners' time and actively engage them in their tasks. Productive teaching also helps learners to use prior knowledge, and enables them to learn skills to solve problems related to learning situations. Egenrieder (2010), as well as Gilmore, Hurst and Maher (2009) argue that effective and productive teaching and learning within the subject of science includes the integration of inquiry-based activities and the use of technological tools (TPCK). Sumrall and Schillinger (2004) find that the integration of science fair tasks in the school curriculum through the implementation of inquiry-based strategies offers science teachers an opportunity to collaborate with their peers. This collaboration progressively enhances teaching using IBL knowledge, which creates innovative and authentic science investigation skills in learners.

- ***Potential benefits of science fair participation by teachers***

Teachers participate in the science Expo as organisers, judges and mentors (Gray, 2014; Molefe, 2011, pp. 97-99; Taylor, 2016). Expos offer the opportunity for teachers to interact and collaborate with their learners in terms of the various Expo roles of judging, mentoring and organising (Cowen, 2013, Ngcoza et al., 2016). Further than this, teachers and parents generally are mentors to learners undertaking science fairs projects (Abernathy & Vineyard, 2001; Kahenge, 2013, pp. 20, 53; Molefe, 2011, pp. 97-99).

In summary, Hardre *et al.* (2013), Prytula and Weiman (2012), and Zivkovic (2013) find that the collaboration and networking of teachers with other science communities (professors) or other science fields through the implementation of IBL strategies enhances their content knowledge. It also extends resources for learners' projects, and thus benefits them by providing teachers with resources, professional knowledge and scientific ideas as they exchange science experiences.

1.6.4 Feedback

It is posited that teachers' experiences through their roles in science fairs affect their Professional Identity, for example, professional knowledge may be strengthened by the incorporation of resources and opportunities for those teachers who are involved in science fairs.

Teachers often voluntarily support and encourage their learners to enter their projects into science fairs (Fisanick, 2010, p. 122). Science fairs improve both teachers and learners psychologically, mentally and through the development of healthy attitudes (Kotwani, 2013). Ozturk and Debelak (2008) argue that health-wise, learners are also taught resilience. It has further been shown that science fair projects provide teachers with positive attitudes as facilitators of learning (Egenrieder, 2010; Molefe, pp. 201, 97-99; Nath, 2007; Sahin, 2013). Lin (2013) argues that teachers' experiences and attitudes towards taking part in science fairs are developed by collaboration and networking through science fair activities. Hardre *et al.* (2013) argue that social networking creates and sustains the connection formed through professional development activities into long term relationships and support communities for transformative development. Teachers integrate inquiry-based activities from science fairs into their science curriculum and build a repertoire of what they can and cannot do (Egenrieder, 2010; Prytula & Wieman, 2012), thus it influences their professional beliefs.

Al-Khatib (2013, 42) perceives Professional Identity development as a continuous process that involves both personal and contextual factors as the development of knowledge in professional performances and skills in collaboration teams. This involves emotions, power, agency, status and content knowledge.

Additionally, Professional Identity is seen as an aspect that develops in society and influences the school environment and class practices, beliefs, as well as personal knowledge, which are ever-changing contributions (Beijaard *et al.*, 2004; Botha, 2012, p. 174; Flores & Day, 2006). It is posited that activities that produce changes in a teacher's professional identity are a form of professional development, and that the path to these changes is shown in the feedback arrow in Figure 1.1.

Professional identity (which describes the teacher), the roles that science teachers take on when participating in science fairs, and the experiences and professional development that teachers gain though their participation can be related to the systems model, as presented in Figure 1.1.

1.6.5 The model

It is evident that the conceptual systems model includes aspects that are considered to be properties of the Professional Identity of teachers and the roles that are played by teachers in science fairs. The feedback of this study thus provides a link between the roles and environment of science fairs and the Professional Identity of teachers.

This investigation sought to establish which of the various roles and properties of these fairs are linked by teachers themselves. This study also aimed to map these teachers' explanations according to the elements of the model provided in the conceptual framework. Some aspects reflected in the model have proven to be more important than others, which provides insight into the major factors that lead to the initial and sustained participation of teachers in science fairs.

1.7 Layout of the dissertation

Chapter 1 briefly explains the history and background of the science Expo, which is a forum to help science learners conceive and experience investigations. It touches on the rationale and purpose of the enquiry regarding the science Expo, as well as the its aim and objectives. In this chapter, the conceptual framework that was used to structure the research questions was also explained in terms of a systems model that relates the Professional Identity of the teacher to the roles that they take on in science fairs. A hypothesis was also formulated regarding the educational significance of science fairs from the point of view of teachers, and how this may lead to sustained participation in fairs by teachers. The model of Professional Identity used here was that provided by Beijaard *et al.* (2000) and Beijaard *et al.* (2004) as it is considered sufficiently detailed for the purposes of this investigation.

Chapter 2 reviews the literature that is pertinent to the study. It also gives a basic recount of the fundamental aspects of Expos, the educational significance, and the methodological instructions used by teachers.

Chapter 3 outlines the research design, sampling methods, data gathering instruments and data analysis that were used in the study.

Chapter 4 summarises and discusses the data and its analysis based on the approaches that are outlined in Chapter 3. The research questions listed in Chapter 1 are then provided again in terms of how the data were coded, grouped, and how themes were formulated to provide a structure for interpreting the data. Thereafter, the findings are presented and discussed in detail.

Chapter 5 provides a summary of the main findings and conclusions of the study, which is encompassed and bound by the research questions. The study is then discussed retrospectively, and the limitations are presented. Finally, based on the findings and the limitations of the study, recommendations and proposals for future research are given.

CHAPTER 2

Literature review

2.1 Introduction

This chapter provides a review of articles that focus on science fairs, the effects of and opportunities in science fairs, as well as the educational significance of science fairs as professional development, which describes the benefits of professional development projects. It is argued that science fairs have characteristics of professional development. The articles mainly refer to the benefits of science fairs for learners, including providing opportunities for inquiry based learning (IBL), and the consequent development of deeper understanding of the nature of science by both learners and teachers. The reported effects of science fair participation on instructional strategies in classroom practice are also discussed. Finally, the theory used in this study, Ajzen's Theory of Planned behaviour is discussed, which contributed to gaining an understanding of why teachers begin and sustain their participation in science fairs.

Learners who participate in science fairs with authentic scientific investigations are reported to develop scientific skills and are able to interpret, draw conclusions and discuss their findings with teachers (Smasal, Molohon, Huynh, Huynh, Burtness, Burtness & Moore, 2006). Learners learn about the nature of science (NOS) in scientific classroom activities that enhance learners' science literacy, which meets the required educational standards (Schneider & Lumpe, 1996). However, it has been found that some science teachers lack knowledge on how to teach scientific inquiry-based activities, and have limited PCK (Anderson, 2015; Ramnarain, 2014; Ramnarain & Fortus, 2013; Smasal *et al.*, 2006).

It is reported that science fairs provide learning opportunities for both learners and teachers. In the case of teachers, this learning could be viewed as professional development.

2.2 The effects of and opportunities within science fairs

Science fairs have existed for many years in the history of science education (Bencze & Bowen, 2009; Bencze *et al.*, 2008; Dionne *et al.*, 2012; Molefe, 2008; 2011, p. 34; Gray, 2014). Dionne *et al.* (2012), Fisanick (2010, p. 132), O'Neille (2016), Welsh (2008, p. 34-35), and Wirt (2011, p.14) argue that science fairs advance academic achievement. An important goal of these fairs is to encourage learners to become involved in science and consequently to pursue careers in science and engineering (Anderson, 2015; Dionne *et al.*, 2012; Gray, 2014; Molefe, 2008; O'Neille, 2016; Taylor, 2011; Taylor, 2016; Welsh, 2008, pp. 4, 39; Wirt, 2011, pp. III, 26, 45, 175). Globally, there are several science competitions that attempt to encourage learners to learn about science (O'Kennedy *et al.*, 2005) and are considered educationally worthwhile (Bencze & Bowen, 2013).

Abernathy and Vineyard (2001), the Eskom Development Foundation (2015), Smasal *et al.* (2006) and Urban Advantage (2015) refer to science fairs as an event in which learners share their research investigations and findings with their peers, teachers, scientists, parents, and others, and present interpretations regarding their findings and experiences. Science fairs offer an opportunity for learners to collaborate with professors and scientists who are role models to them (Kahenge, 2013, p. 106; Molefe, 2011, p. 119; Science Fair Foundation, 2015; Smasal *et al.*, 2006). It is maintained that the main rationale of science fairs is to assist learners to learn scientific methods while designing and conducting experiments to enhance their school program. These authors further maintain that learners who carry out a study learn to identify a problem, investigate a solution, conduct tests, analyse data, and present their findings and conclusions.

Allchin, Andersen, and Nielsen (2014) find that inquiry based learning (IBL) through conducting scientific investigations enables learners to learn about the nature of science (NOS). They also assert that through learning the NOS, IBL is a better way to meet the main objectives of the required educational standards. They claim that as NOS understanding is fostered, learners grow in epistemic understanding and increase their scientific practical skills and scientific literacy. Smasal *et al.* (2006) also explain that inquiry-based instruction encourages a deepening of understanding of science content knowledge, as well as enhancing science literacy development through authentic research experiences and learning.

Learners in science fairs gain many benefits, including scientific knowledge (Abernathy & Vineyard, 2001; Bencze *et al.*, 2008; Czerniak & Lumpe, 1996 b, Schneider & Lumpe, 1996). The learning outcomes covered in science fairs include widened or deepened subject matter knowledge, an appreciation of the NOS, and professional practices (Bencze *et al.*, 2008). The professional practices of the scientific inquiry-based strategies in science fairs motivate learners with self-confidence as they emulate professional scientists. Learners who participate in science fairs also gain scientific and research skills (Betts, 2014, pp. 87-88; Grote, 1995; Fisanick, 2010, pp. 23, 136; Molefe, 2011, pp. 119-220; Smasal *et al.*, 2006; Urban Advantage, 2015). Additionally, science fairs further endow learners with curiosity and interest in science related careers (Dionne *et al.*, 2012; Eskom Development Foundation, 2015; Molefe, 2011, p. 109; Smasal *et al.*, 2006).

In South Africa, the annual national science fair is known as the 'Eskom Expo for Young Scientists' (simplified as the Expo), and participants are drawn from several countries within Southern Africa. When science fairs are presented at schools, they are generally known as a *Mini Expo*. The Expo has been presented since 1980 (Gray, 2014), and its mission is to identify the most innovative and gifted school-level science learners across South Africa's rural and urban areas (Alant, 2010; Science Expo Project Guide, 2016; Eskom Development Foundation, 2015). According to Ndlovu (2014) and Kahenge (2013, p. II), the Expo offers opportunities for learners to understand scientific investigations that follow the principles of scientific inquiry. These projects enable learners to participate at a regional or national level depending on the level of the projects' merits (Bencze & Bowen, 2009; Kahenge, 2013, pp. 83-85; Molefe, 2011, p. 111).

At the regional and national levels, the Expo in South Africa currently allows projects to be entered in 24 categories, ranging from Agricultural Sciences, Animal and Veterinary Science, to Social and Psychological Sciences. Sustainable Development, Recycling and Recycled materials, several topics in energy technologies, as well as environmental studies are examples of modern technological studies (see Appendix 5). In this research, the focus is on the Physical Sciences whose topics of physics and chemistry, in basic and applied contexts, have been represented at the Expo since its inception.

Science fairs have specific rubrics and rules that guide the judging (Abernathy & Vineyard, 2001; Eskom Development Foundation, 2015; Molefe, 2011, p. 105; Science fair foundation, 2015). Learners who participate in science fairs can win bronze, silver and gold medals (Kahenge, 2013, pp. 84-90; Molefe, 2011, pp. 105-106; Ndlovu, 2014), as well as being awarded bursaries for tertiary studies (Kahenge, 2013, p. 104; Gray 2014). The points given during the judging process are awarded for problem solving, proposal of solutions, conducting of fair tests of hypotheses, the analysis of data, and drawing conclusions (Bellipanni & Lilly, 1999). The judges of the learners' projects comprise teachers, scientists, and university lecturers and professors (Abernathy & Vineyard, 2001; Eskom Development Foundation, 2015; Kahenge, 2013, pp. 54-56, 100, 152, 156). Often, these judges have rudimentary training in judging (Tortop, 2014a; Grote, 1995).

Scientific process skills are seen as a cornerstone in learners' consequential and lifelong education because they become proficient in searching for information, and interpreting and judging the evidence of a specific context (Bilgin, 2006). Liu (2009) explains that science fair competitions promote science literacy within the community. Betts (2014, pp. 15-16), and Bigler and Hanegan (2011) posit that hands-on activities enhance learners' scientific content knowledge, as well as promoting science literacy in a form other than traditional teaching. Abernathy and Vineyard (2001) state that learners who participate in science fairs explore and excel in the interested subject. In addition, Tuan, Chin, Tsai and Cheng (2005) assert that inquiry-based activities stimulate learners' interest and ability in learning science in contrast to traditional science teaching methods.

The Expo offers opportunities for learners to acquire scientific process skills and scientific knowledge simultaneously (Bencze *et al.*, 2008; Betts, 2014, p. 88; Molefe, 2007; 2008; 2011, pp. 119-220; Taylor, 2011). Researchers add that science fairs enhance learners' attitudes towards science education (Bencze *et al.*, 2008; Bencze & Bowen, 2009; Dionne *et al.*, 2012; Molefe, 2007; Ndlovu, 2014; Ozturk & Debelak, 2008; Tuan, Chin & Shieh, 2005; Tuan *et al*., 2005). In addition, learners who participate in science fairs develop creative and innovative minds (Barry & Kanematsu, 2006).

Science fairs offer opportunities for the involved learners to improve their academic performance and gain access to careers in science, mathematics, technology and engineering (SMTE). Learners who participate in the Expo have the opportunity to collaborate and share their findings with scientists (professors), teachers, parents, and others. It has also been found that learners taking part in science fairs develop scientific investigation skills, gain an understanding of the NOS, have enhanced scientific literacy, and gain subject matter knowledge. Innovation and creativity are further skills that learners gain from science fairs and are enhanced with self-confidence, curiosity, and interest while they emulate professional scientists.

While learners who take part in science fairs improve their scientific skills, knowledge and attitudes, there should be educational value for teachers who fill the roles of mentors, judges and organisers.

2.3 The educational significance of science fairs as professional development

Roberts and Allen (2013) contend that educational value lies in the practical skills that an individual gains as a consequence of being engaged in activities such as research. According to Dede (2006), educational value is encompassed by the enhancement of teachers' and learners' experiences. The term "value" is used as an element of the model of Professional Identity that was developed by Beijaard, Meijer and Verloop (2004). I thus use the term 'educational significance' rather than 'educational value' to mean the practical skills and experiences that help teachers to improve their professional knowledge, academic performance, beliefs, values, and self-actualisation.

2.3.1 The benefits of professional development projects

Zivkovic (2013) defines professional development (PD) as the development of professional competence that includes the achievement of new knowledge in teaching methodology, preparation for the attainment of new knowledge, supervision of the process of developing new knowledge, the sharing of views and experiences in different professional fields, active and effective participation in training, and educational change. Professional development also involves gaining new knowledge in psychology, didactics, and pedagogy, training in the application of newly acquired knowledge, monitoring new developments in the profession, and sharing and exchanging experiences with other teachers (Hardre *et al.*, 2013; Zivkovic, 2013). These authors further clarify that PD involves intrinsic and extrinsic factors in professional competence and readiness for professional development, which is correlated to Professional Identity. Professional Identity is associated with teachers' professional development and self-actualisation that is obtained through individual learning, and self-developmental professional training (Prytula & Wieman, 2012; Zivkovic 2013). Professional Identity is fundamental to practices, attitudes or behaviour, as well as competencies that are demonstrated in teaching practices (Beijaard *et al.*, 2004; Walkington, 2005).

Professional development interventions are effective and productive whenever cooperating teachers share their experiences, educational learning practices, and reflections (Evens *et al.*, 2015; Hardre *et al.*, 2013; Haney, Czerniak & Lumpe, 1996; Prytula & Wieman, 2013). The benefits that teachers gain from professional development include innovation, resources and collaboration, as well as networking (Hardre *et al.*, 2013; Prytula & Wieman, 2013).

Carlson *et al.* (2014) contend that improved pedagogical content knowledge leads to a productive professional development trajectory. PD benefits teachers by developing IBL approaches, PCK teaching strategies (Carlson *et al.*, 2014), and subject content knowledge.

In Europe, the *Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science* (PROFILES) is an organisation that organises science teacher workshops for professional development (Rauch & Dulle, 2014). The researchers report that these workshops improve science teachers' inquiry-based teaching and learning skills (Rauch & Dulle, 2014). Metljak, Glažar, Juriševič, Pavlin, Slapničar, Vogrinc and Devetak (2014) have found that PROFILES projects assist teachers to develop their professional identities. Metljak *et al.* (2014) explain that the projects help teachers to motivate and teach learners to become scientifically literate, which assists them with their daily scientific challenges. These projects also help teachers to improve learners' science competency, which involves a deeper knowledge of scientific concepts, scientific research skills, and knowledge of NOS (Metljak *et al.*, 2014).

The project, *Science Teaching European Network for Creativity and Innovation in Learning* (STENCIL), contributes to teachers' development in science teaching through the promotion of innovative methodology and creative solutions that draw more learners to science (Magrefi-Amitie, 2014). STENCIL also offers teachers opportunities to share their scientific ideas. Urban Advantage (2015) and Wheeler, Bell, Whitworth and Maeng (2015) report that professional development of teachers includes science curriculum content and practical teaching practices as well as teaching and promoting high quality of science inquiry orientation through the emphasis on learners' scientific investigations in the science classroom.

Zhang, Parker, Koehler and Eberhardt (2015) argue that professional development (PD) for science teachers is most effective if teachers consciously perceive the need for development. Specifically, teachers have expressed the need for developmental support in classroom pedagogical practices, subject content knowledge, creating engagement in learning opportunities, and coherence or collaboration. Zhang *et al.* (2015) further assert that PD is most requested for content-based support, and that effectiveness depends on the intervention being sustained for a long period of time. PCK, which is believed by many education authorities to be necessary for improved classroom practices, should be presented within specific topics rather than using a generic approach. The researchers found that most teachers battle with implementing IBL approaches in science education and they conclude that elementary teachers need professional development for IBL.

Professional development is linked to Professional Identity in both its effect and in teachers' readiness for professional development. Professional Identity is the context of this readiness to change. For example, teachers who do not believe in the changes required, whose values do not include changed practice according to an external measure that they do not accept, or do not have the will or capacity to develop needed resources (agency) may enter the professional development programme with resistance and probably will not implement the intended change. Alternatively, if development programmes are perceived to be needed by teachers themselves and are sustained over time, the likelihood of these programmes being successful in actually bringing improved classroom practice is high. This study therefore sought to identify opportunities for professional development that are accepted by teachers.

2.3.2 Science fairs as professional development

The Science Fair Foundation (2015) reports that in Canada, workshops for teacher professional development are offered and involve themes around teaching of science, mentoring, scientific research, and innovation. In the workshops, teachers network with other teachers and share and exchange science teaching experiences. Teachers who are involved in organising and operating science fairs gain enhanced effectiveness and efficiency in their teaching. The effect of this is that learners are able to learn in-depth in the classroom, and teachers are better able to extend science learning beyond classroom activities (Science Fairs Foundation, 2015).

Nath (2007), the Science Fair Foundation (2015) and Urban Advantage (2015) argue that science fairs develop teachers' attitude towards facilitation. Wheeler *et al.* (2015) find that inquiry-based strategies promote teachers' professional development, particularly scientific instructional practices. Such practices include debating, and gathering and analysing data respectively through the application of evidence to solve problems, which are all important in the implementation of IBL approaches. The implementation of research-based instructional strategies have an impact on the new experiences and knowledge that may be developed through the process (Wheeler *et al.*, 2015).

Anderson (2015) reports that science fairs provide teachers with knowledge in science education through the engagement of learners in a range of scientific investigation disciplines. Teachers also learn a variety ways to manage and help learners to learn from them by providing opportunities to carry out authentic scientific investigations, thus teachers' Pedagogical content knowledge is also improved.

Teachers who participate in the science Expo not only benefit through the development of knowledge, but are also advantaged with resources needed for the science curriculum (Expo Eskom Development Foundation, 2015; Urban Advantage, 2015). Teachers who mentor, judge and organise learners' projects learn more about scientific investigations and develop skills that are essential for their own classroom inquiry-based investigations (Anderson, 2015; Kahenge, 2013, pp. 51, 59). Anderson (2015), Hanifee (2013), and Molefe (2011, pp. 98, 220) explain that teachers have the opportunity to incorporate several aspects of the school curriculum while learners work on projects and learn about, or create new innovations.

There is clearly some common ground in the arguments for workshops and science fairs as both provide aspects of professional development, workshops in scheduled activities, while science fairs achieve their professional development in a less formal setting. This justifies establishing teachers' own narratives of any gains in Professional Identity that they perceive as educationally significant.

2.4 Benefits of science fairs for learners

2.4.1 General

Benzce and Bowen (2009), as well as Yasar and Baker (2003) explain that most science fair participants are learners from well-resourced schools and privileged backgrounds in the United States of America. However, learners from all backgrounds take part in science fairs in South Africa (Alant, 2010; Department of Science and Technology (DST), 2012; Eskom Development Foundation, 2015; Tay, 2011). Science fairs (exhibitions) offer wide, authentic opportunities for both teachers and learners to disseminate knowledge and to experience different new innovations and inventions (Metljak *et al.*, 2014; Nath, 2007). In addition, Kahenge's (2013, p. II) findings show that the science Expo offers chances for both teachers and learners to experience a broad diversity of scientific investigations and skills needed in classroom-based scientific investigations. Metljak *et al.* (2014) and Nath (2007) further assert that the crucial importance of the competition is that it fosters achievement of a variety of process skills that may lead to the development of numerous abilities in a social environment.

Learners who participate in science fairs are motivated by several factors. These include prior interest, where learners are interested in the subject content; intelligence and self-efficacy, which may be achieved through inquiry-based tasks; a passion for science education; science learning values and performance goals; collaboration with peers; and the opportunity to gain a variety of strategies, scientific knowledge, and methods (Dionne *et al.*, 2012). Participating learners are stimulated in their academic achievement at expo competitions (Czerniak & Lumpe, 1996b; Eskom Development Foundation, 2015; Molefe, 2011, pp. 121, 229; Smasal *et al.*, 2006). In addition, Kahenge (2013, pp. II, 2, 13), Molefe (2011, pp. 127-128), Grote (1995), and Tortop's (2014b) findings demonstrate that learners learn about scientific methods at science fairs. Kahenge (2013, p. 67) further argues that scientific methods help learners to solve possible problems that they come across in their environments through exploring and carrying out scientific investigations.

The participating teachers commented that science fairs promote learners' interest in and passion for science, and they also get an opportunity to interact with other learners who are curious about science. They also learn about other learners' research (Fisanick, 2010, pp. 44, 47; Grote, 1995).

2.4.2 Inquiry based learning (IBL) and the nature of science (NOS)

The main objective of science education is to develop learners' scientific knowledge, science literacy, and knowledge of the nature of science (NOS), as well as the relationship between science and technology in reality (Betts, 2014, p. 14; Tuan, Chin & Shieh 2005; Tuan *et al.*, 2005). In addition, science fairs develop learners' communication skills (Abernathy & Vineyard, 2001; Czerniak & Lumpe, 1996b; Fisanick, 2010, p. 132; Grote, 1995; Smasal *et al.*, 2006), and they also learn about NOS (Abernathy & Vineyard, 2001; Ndlovu, 2014).

Learners who are involved in science fair projects experience academic improvement (Czerniak, 1996; Smasal *et al.*, 2006; Taylor, 2011). Dionne *et al.* (2012) and Taylor (2011) argue that science fairs strengthen learners' self-efficacy and science literacy. The Eskom Development Foundation (2015), and Kahenge (2013, pp. 66-67, 73) report that teachers claim that since learners who are involved in science Expo broaden their scientific horizons, and their curiosity in science is stimulated, this sometimes results in learners furthering their studies towards science careers. Additionally, participating learners develop an attitude of inquiry (Carrier, 2006; Fisanick, 2010, pp. 132, 136; Nath, 2007; Ndlovu, 2014), and gain an understanding of academic thoroughness (Fisanick, 2010, p. 132).

2.5 Science fairs and inquiry based learning (IBL) and teaching

Inquiry based learning (IBL) in science pedagogy is defined as a process that explores the world and engages learners in activities to develop broad knowledge and understanding (Bencze *et al.*, 2008; DST, 2012). Gilmore, Hurst and Maher (2009), and Wheeler *et al.* (2015) posit that inquiry-based education is the process of engaging learners in authentic science practices, namely: forming hypotheses, gathering, analysing, discussing, and interpreting data. The Inter-Academy Panel (2012, as cited in Ramnarain, 2014) asserts that the Science Education Programme promotes IBL in its science education approach. It also permits learners to develop scientific ideas through learning how to investigate, and it builds their knowledge and understanding of the world through the use of scientific skills such as questioning, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions, and discussing their findings. Allchin, Andersen and Nielsen (2014) argue that IBL in a variety of approaches fosters education regarding

NOS. Urban Advantage (2015) articulates that IBL in the science classroom is characterised by scientifically orientated questions, giving priority to evidence, expressing descriptions of evidence, evaluating justifications in the light of alternative explanations, and representing and justifying proposed explanations.

Smasal *et al.* (2006) find that science fair participation is one of the better ways to teach learners about NOS and improve their science literacy through scientific investigations and methods. In addition, it is argued that in IBL, one of the basic objectives is to offer opportunities for learners to engage in hands-on experiences (Czerniak & Lumpe, 1996b). Betts (2014, pp. 15-16), and Ramnarain's (2014) studies further showed that IBL promotes and supports science literacy, which is one of the fundamental goals of science education worldwide. Betts (2014, p. 14) furthermore claims that science education's objectives for learners are: to gain knowledge of science concepts, to heighten curiosity and motivation, improve scientific practical skills and problem solving skills, as well as to learn about the nature of science. The educational outcomes of IBL, according to various researchers, are worthwhile, which led this study to focus on pedagogical content knowledge.

In addition, Botha's (2012, p. 175) findings show that mathematics, science and technology (MST) teaching and learning have to focus on problem solving, reasoning, hands-on activities, as well as creative inquiry-based teaching strategies that could provide fundamental MST knowledge, concepts, and skills. Curriculum developers in South Africa agree with this as Physical Sciences explores physical and chemical occurrences and takes place through inquiry-based science teaching (Department of Basic Education, 2012; Gauteng Province Education, 2014). Ndlovu (2014) finds that science fairs offer opportunities for learners to experience quality levels of scientific inquiry and investigations. IBL is supported by several researchers as they argue that learners start to enjoy the courses once they have knowledge of the subject and its processes (Abernathy & Vineyard, 2001; Bencze & Bowen, 2009; Dionne *et al.*, 2012; Molefe, 2007; Tuan, Chin & Shieh, 2005; Tuan *et al.*, 2005; Villas-Boas, 2010). Anderson and Clark (2012), Philpot (2007, pp. VII, 7, 116), and Welsh (2008, pp. 28, 34, 129-130) suggest that inquiry based learning enhances learners' understanding of NOS and subject content. Ramnarain (2014) posits that IBL enhances learners' knowledge of science concepts, encourages academic improvement, and helps learners to be independent when it comes to scientific investigation. It is further argued that learners may be drawn to scientific careers once they are able to apply theory to solving real life problems (Ergul, Simsekli, Calis, Ozdilek, Gocmencelebi & Sanli, 2011; Villa-Boas, 2010).

According to Anderson and Clark (2012), and Betts (2014, p. I), inquiry based learning and teaching is one of the most effective ways of teaching science productively, and is possible through involvement in science fair activities. Anderson (2015), and Czerniak and Lumpe (1996b) assert that science fairs sufficiently sustain the educational objectives of science. Anderson and Clark (2012) further explain that an effective way to teach science is through the integration of pedagogical and content knowledge into teaching as this uses and works with prior conceptions and misconceptions that teachers may have. Anderson and Clark (2012) find that subject matter knowledge consists of a knowledge of science (knowledge produced by science), and knowledge about science (NOS), while both are strengthened through participation in science fairs. Kahenge (2013, p. II) explains that when participating in science fairs, both learners and teachers are exposed to a broad diversity of scientific investigations and skills that are needed for classroom-based investigations.

Scientific IBL is the driving force behind the benefits that learners who participate in science fairs gain (IBL), as viewed by many researchers, it also inspires learners to have a positive attitude towards science, and it improves their process skills, critical thinking, and problem solving skills (Ergul *et al*., 2011; Science Fair Foundation (2015); Rambuda & Fraser, 2004; Taylor, 2011). Scientific IBL could help schools with discipline as learners are more engaged with activities (Ergul *et al.*, 2011). Anderson's (2015) study shows that when teachers believe in the goals and purposes of science education, these beliefs strongly influence the nature of learning opportunities for learners through inquiry-based classroom practices. Anderson (2015) further claims that teachers develop substantial content knowledge about learning and teaching science through participation in authentic scientific investigation projects with learners. Teachers also gain an improved understanding and common knowledge of learners' difficulties, assessment skills, and pedagogical content knowledge (PCK).

Researchers state that IBL instructions facilitate and enhance learners' understanding of the practical nature of science, and science literacy. Science fairs are seen as a better way to enhance teachers' IBL strategies, which is considered to stimulate and have an influence on the PCK strategies of teachers.

2.6 Instructional strategies in classroom practice

Bencze and Bowen (2009), Bigler and Hanegan (2011), Botha and Onwu (2013), Ergul *et al.* (2011), Mathumbu, Rauscher and Braun (2014), Molefe (2007), as well as Villa-Boas (2010) point out that, problematically, most teachers lack the relevant content knowledge to introduce inquiry-based science teaching in schools. In addition, Ramnarain (2014), and Zhang *et al*. (2015) find that several teachers lack competence in the implementation of the inquiry-based approach, and teachers have limited knowledge on how to implement pedagogical content knowledge strategies in the classroom (Sibuyi, 2012, pp. 66-67, 80; Ramnarain, 2014). Because teachers lack the necessary knowledge for inquiry-based teaching, they deprive learners of the opportunity to better understand science (Bencze & Bowen, 2009). Bosman (2006, pp. 171, 175-176, 222-226) and Ramnarain and Fortus (2013) explain that many teachers lack both specific pedagogic and content knowledge. Philpot (2007, p. 113) goes further to state that many teachers have limited knowledge of the nature of science.

In the same vein, according to Karisan, Senay and Ubuz (2013), and Ramnarain and Fortus (2013), as well as Rollnick and Davidowitz (2015), many teachers lack specific content knowledge. Ramnarain and Fortus (2013) also found that teachers are unenthusiastic to putting inquiry-based teaching into practice in their classrooms, which would strengthen their PCK. PCK consists of five factors for teachers, these include direction towards science education, knowledge about the science syllabus, knowledge of learners' understanding of a particular science topic, science assessment knowledge, and knowledge about the instructional approaches to teaching science as a subject (Magnusson, Krajcik & Borko, 1999).

PCK is perceived as necessary for effective science learning and teaching (Anderson & Clark, 2012). Science fair activities offer opportunities for teachers to collaborate in terms of organising, judging, and networking with teachers from other schools and researchers from universities (Molefe, 2011, pp. 98, 106). Rambuda and Fraser (2004) posit that as their inquiry-based capabilities increase, teachers and learners may be able to use process skills. You and Craig (2013) contend that collaboration is about voluntarily sharing visions for teaching and learning, endurance and commitment, and the interaction between teachers, university lecturers, and other scientists. Flores and Day (2006) assert that such collaboration improves teachers' attitudes towards teaching and learning. In Molefe's (2011, pp. 98, 106-108) study, the findings from interviews with the teachers show that when the ethos of a school is good, it facilitates collaboration. Participation in science fairs is said to provide teachers with opportunities for networking and collaboration (Egenrieder, 2010; Hardre *et al*., 2013; Meltjak *et al.*, 2014; Prytul & Wieman, 2012). Science fairs are also said to improve teachers' mentoring attitudes, and provide collaboration opportunities (You & Craig, 2013).

It should be noted that several studies (Abernathy & Vineyard, 2001; Czerniak, 1996; Czerniak & Lumpe, 1996b; Fisanick, 2010, pp. III, 96, 121; Kahenge, 2013, pp. 51-53; Kotwani, 2013; Tortop, 2013) have shown that most teachers who are involved in science fairs have positive attitudes towards science fair competitions and learners' projects. Abernathy and Vineyard's (2001) findings corroborate this and they claim that teachers want to integrate science fair activities into their science curriculum back in the classroom. Furthermore, Fisanick (2010: 137) supports the positive perceptions of teachers regarding science fair activities. This leads to the integration of learner-conducted experimental science fair activities into the school science curriculum; teachers enjoying being administrators of learners' projects, the practice of scientific skills and the knowledge achieved by the learners who are involved in science fairs, mentoring for standardised science curriculum assessments, and science fair competitions on the nature of science. In addition, Molefe's (2011, pp. 98, 220, 230) findings demonstrate that several schools in the Western Cape Province in South Africa have already incorporated science fair projects into their school science curriculum, and those teachers claim that is effective in improving learners' academic work; learners also work hard and strive to be successful in the Expo competitions.

To strengthen teachers' positive attitudes towards science fairs, there are schools that organise workshops to motivate learners to get involved in science fair projects; there are also workshops to train teachers on how to work with learners on their projects (Kahenge, 2013; Tortop, 2014b). Betts' (2014, pp. 16, 63) findings corroborate that teachers' attitudes about participation in science fair competitions are overwhelmingly positive because participation achieves science education objectives, and the learners who participate in science fairs improve in their overall skills of presentation and understanding of science concepts.

Numerous teachers believe that participation in science fairs enhances learners' attitudes, basic skills and knowledge, and enables them to be comfortable and successful in the scientific and technological community (Czerniak, 1996; Czerniak & Lumpe, 1996b); they also gain problem solving skills (Czerniak & Lumpe, 1996b). Several schools have experienced an upturn in learners' positive attitudes, better attendance, and improved academic performance through parental support and involvement in schools (Czerniak, 1996). Teachers are motivated to voluntarily sponsor learners' projects because it allows them to conduct experiments related to the science curriculum, to prepare for standardised science assessments, it allows the chance to practice the skills and knowledge acquired by learners, as well as providing the chance to be administrators in a competitive and information rich environment (Fisanick, 2010, pp. 136-137).

The Science Festival (SCIFEST) office in South African organises workshops for science teachers whereby they demonstrate to teachers how the Eskom Expo teaches scientific methods related to their science curriculum activities (Khahenge, 2013). This is in contrast to teachers' training programmes and workshops, which Karisan, Senay and Ubuz (2013) claim do not serve as a basis for contribution to teachers' professional development, for example, PCK. They further elaborate that PCK can be shaped in classroom practices. However, Grote (1995) cautions that poor judgement procedures at science fairs may discourage gifted learners to further their studies in science-based careers.

According to Anderson (2015), Molefe (2011, pp. 119-220), and Taylor (2011), science fairs enhance learners' critical-thinking skills, use these skills across the various subject topics, develop effective communication skills, engage learners in questioning, increase learners' self-confidence, enhance social skills, and enable learners to become successful students. Bencze *et al.* (2008), and Abernathy and Vineyard (2001) assert that learners are more engaged and encouraged when they collaborate with their peers. Various scholars also argue that learners who take part in science fairs improve their scientific skills greatly.

The same scholars find that teachers have positive attitudes towards science fairs because these enable learners to improve in their academic performance, and become knowledgeable about science content; science fairs also assist teachers to achieve the required educational outcomes. If teachers have a positive attitude towards science fairs, it points to the fact that they also benefit something as well. Scientific methods help learners to develop scientific process skills, which help them to solve daily challenges (Kahenge, 2013, p. 1; Molefe, 2011, pp. 127-128), thus they eventually become scientifically literate. The scientific method is seen as one of the key processes of IBL and teaching in science education (Kahenge, 2013, pp. 11-12, 15, 51-52; Molefe, 2011, pp. 126-128; Smasal *et al.*, 2006). This is argued to be the case as it meets the national standards and goals of science education (Smasal *et al.*, 2006).

According to Anderson (2015), teachers' beliefs about the objectives of science education have been found to be influenced by the development of teacher knowledge, and the development of both PCK and subject matter knowledge. However, Lotter, Harwood and Bonner (2007) find that there are four sets of beliefs that guide high school science teachers to use inquiry-based teaching and learning in their classroom practices: conceptions of science, their learners, effective teaching practices, and the purpose of education. Anderson (2015) further explains that teachers' beliefs regarding knowledge development are pertinent to their PCK development, and this occurs effectively through the process of carrying out scientific investigations, which provides an authentic opportunity for both teachers and learners.

Furthermore, it is postulated that science fairs meet educational goals because they engage inquiry based learning activities (Betts, 2014, pp. I, 80, 88; Kahenge, 2013, pp. 13, 61, 118; Molefe, 2011, pp. 125-128), improve learners' academic performance, and increase their success in competitions (Betts, 2014, pp. 11, 15-16; Molefe, 2011, p. 105). Several scholars find that the better way to teach science is through the implementation of IBL, which involves the integration of PCK teaching. They further posit that it covers the goals and purposes of science education (Anderson, 2015; Anderson & Clark, 2012; Ramnarain & Fortus, 2013). It is again emphasised that teachers' beliefs play a crucial role (Anderson, 2015). Allchin, Andersen and Nielsen (2014) explicate that when IBL is well implemented, it is worthwhile as it develops fundamental skills in the process of science, and maintains an understanding of the epistemic principles involved. However, I was interested in the educational significance of teachers' professional development and Professional Identity in this research.

Fisanick (2010, p. 96) posits that many teachers have a positive perception of science fairs and thus volunteer to sponsor learners' projects. Molefe's (2011, p. 97) findings indicate that most science teachers, as well as learners who take science subjects (Physical Sciences and Life Sciences), are involved in science fairs. Das and Sinha (2000) claim that hands-on, problem-based discussions enhance both teachers and learners' innovation. In addition, Molefe (2011, pp. 29, 259) claims that the involvement of schools in science fairs stimulates learners to excel academically, which often leads to being successful in science fair competitions. Learners learn scientific process skills, inquiry, problem solving, and critical thinking skills (Kahenge, 2013, pp. 13, 17, 20; Molefe, 2011, pp. 268-269; Taylor, 2011). Much has been researched and written on the advantages of learners participating in science fairs, hence, this research sought to discover what the benefits are, in terms of professional development, for teachers who are involved in these fairs.

In spite of the fact that some science teachers are perceived to have limited knowledge of how to facilitate and implement IBL and PCK strategies, they nevertheless have positive attitudes towards science fairs. It has been documented that science fair tasks are a better way to stimulate science education because these enable learners to improve their academic performances in a fun and hands-on way. Moreover, as stated previously, science fairs offer an opportunity for teachers to collaborate and network with teachers from other schools, as well as other scientists.

2.7 The explanatory theory

Ajzen's (1991) Theory of Planned Behavioural (TPB) was used in this study, specifically to answer the third research sub-question, which sought possible explanatory factors for sustained participation in science fairs. Ajzen's theory links reasons and the factors that lead to an intention to participate in a task, and thus to a decision to actually perform the task.

The theory postulates three self-determinant variables that contribute to intention, namely, *attitude towards the behaviour* (which refers to the degree to which an individual evaluates the possible favourable condition for a behaviour), *subjective norms* (which refers to the degree to which an individual is expected to perform in the community (school)), and *perceived behavioural control* (which includes self-efficacy and refers to a person’s perceived ability to perform the behaviour). Prior experiences and anticipated impediments may also play a role in perceived behavioural control (PBC). When attitudes and subjective norms are favourable with respect to the particular behaviour, and the PBC is favourable, the person’s intention to perform the considered behaviour will be strengthened. Armitage and Conner (2001) provide evidence that a strong PBC is sufficient to enable the prediction of a behaviour.

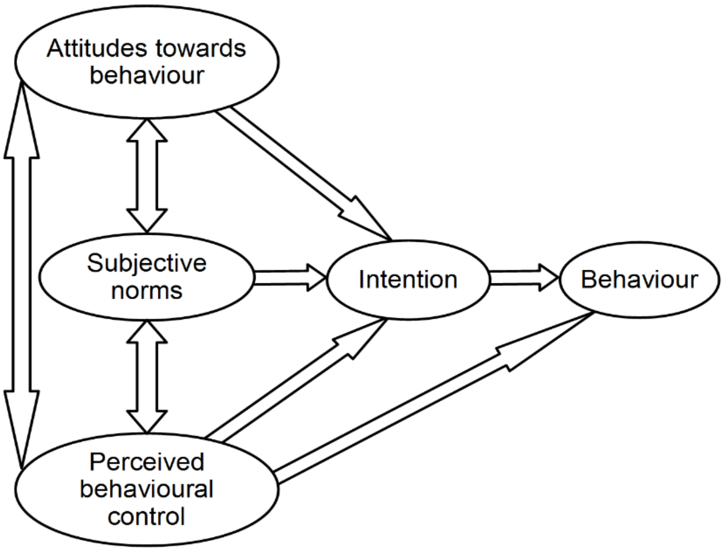

Figure 2.1: Diagram of Ajzen's Theory of Planned Behaviour (TPB) (Ajzen, 1991, p. 182)

In relation to the prediction of intentions (motivations), attitudes, subjective norms, and perceived behavioural control are anticipated to vary across behaviour and conditions. All three variables may independently contribute to intentions.

The theory asserts that perceived behavioural control may be used together with intentions to predict behaviour. However, variations in intentions and perceived behavioural control together account for inconsistency in the actual behaviour.

The central element in the Theory of Planned Behaviour describes a person's intention to perform a specific behaviour. Intentions are believed to depend on the motivational factors that have an influence on behaviour; thus, these capture why a person is willing to put effort into the performance of a specific behaviour. Performance depends on elements such as the requisite opportunity and resources (time, money, skills), and collaboration with others (Ajzen, 1991). Action depends on intentions, as well as ability and opportunity (control).

This theory also emphasises the development of self-efficacy, or PBC, with respect to beliefs, attitudes, and intentions. Salient beliefs are considered to be influential on a person's intention and actions. Salient beliefs have three aspects, namely: behavioural beliefs that influence attitudes, normative beliefs with underlying subjective beliefs, and control beliefs that are fundamental to the perception of behavioural control (Ajzen, 1991).

Perceived behavioural control contains the psychological construct of self-efficacy (Bandura, 1982, 1991, 2012; Stajkovic & Luthans, 1998), as well as perceptions of the availability of environmental and social resources. Self-efficacy beliefs can influence choice of tasks, the effort expended during performance, and emotional reactions (Ajzen, 1991). It is furthermore perceived as the ability to deal with new situations effectively for personal success (Crosswell, 2006, p. 100). Stajkovic and Luthans (1998, p. 2) expand this concept:

> *Self-efficacy is a construct that deals specifically with how people's beliefs in their capabilities to affect the environment control their actions in ways that produce desired outcomes. Unless employees believe that they can gather up necessary behavioural, cognitive, and motivational resources to successfully execute the task in question, they will most likely dwell on the formidable aspects of the project, exert insufficient effort, and, as a result, fail.*

Positive beliefs about self-efficacy support motivation, commitment, behaviour, effectiveness and collaboration, and, in the case of teachers, are strengthened through learners' successes (Canrinus *et al.*, 2012; Crosswell, 2006, pp. 100, 228, 232). This also affects behaviour, performance, competence and beliefs in terms of teachers' professional responsibilities (Canrinus *et al.*, 2012).

Czerniak and Lumpe (1996a) offer support for the use of Ajzen's (1991) variables through their finding that teachers' beliefs have a major influence in predicting their thoughts, motivation, intentions and behaviours. On the one hand, Van Aalderen-Smeets, Van der Molen and Asma (2012) state that beliefs can range from positive to negative, guide evaluation processes, involve emotions, and yield behaviour patterns.

On the other hand, attitudes can be measured in terms of the productive teaching of science as a subject (Van Aalderen-Smeets et al., 2012) (and hence the teacher's actions). Elements of attitude may include cognition, intention, thoughts, beliefs, self-efficacy and affective factors, which themselves can be related to the teacher's Professional Identity.

Ajzen's (1991) Theory of Planned Behaviour (TPB) has been applied successfully by several authors to examine the predictors of TPB's elements in order to explain and predict the transition from intention to behaviour (Armitage & Conner, 2001; Cooke, Dahdah, Norman & French, 2014; Egmond, Bruel & Novem, 2007; Fisanic, 2010, pp. 124-125; Taylor, 2014; Teo & Lee, 2010; Zint, 2002). Armitage and Conner (2001), and Taylor (2014) indicate that TPB constructs successfully correlate with the change from intentions (self-prediction) to behaviour. According to Armitage and Conner (2001), PBC independently indicates anticipated intentions and behaviour. Taylor (2014) reports that both attitudes and subjective norms have been found to have a positive influence on intention and anticipation. In using Ajzen's (1991) Theory of Planned Behaviour to predict and interpret teachers' behaviour and attitudes towards science fairs, Fisanic (2010, pp. 124-125) supports these findings. Zint (2002) argues that to predict and ensure teachers' performance, elements of TPB must be developed and amended, where-after the theory may then be applied to improve professional development. Haney *et al.* (1996) find that the beliefs element of PBC has majorly contributed and strengthened the development of teachers' opportunities in inquiry-based teaching, as well as innovation in the use of available resources.

Cooke *et al.* (2014) reason that attitudes, subjective norms and self-efficacy strongly correlate with an individual's intention to perform a certain task. Teo and Lee (2010) regard attitudes toward usage and subjective norms as crucial in predicting behavioural intention. Edmond *et al.* (2007) argue that awareness, knowledge, norms and values, and attitudes result in the intention to make decisions and to apply solutions. However, Egmond *et al.* (2007) point out that intention requires the necessary resources and skills to be available to overcome any obstacles to implementation. Values and norms act as a stimulating factor towards intention. Egmond *et al.* (2007) further suggest that intention has intrinsic and extrinsic sources, where the intrinsic aspect involves attitudes, beliefs and motivations, and the extrinsic element consists of constraints, haste and the absence or presence of incentives.

The concepts of attitude towards behaviour and perceived behavioural control (PBC) are linked directly, as well as through subjective norms whereby attitudes and PBC may influence intentions, and thus behaviour (the roles of teachers in science fairs). In the input element of the conceptual framework, aspects of teachers' Professional Identity can be linked to the constructs of Ajzen's theory.

Ajzen's theory (as the process element) potentially establishes an explanatory association between elements of Professional Identity (as input towards an intention to participate) and teachers' roles (as output/behaviours) in science fairs. The relationships in the theory's constructs were used in this study to order themes, sub-themes and categories in the teacher interviews to yield an understanding of teachers' sustained participation in science fairs.

2.8 Synthesis

This literature review provides the basic context of the science Expo and the reported significance thereof to science teachers and learners, both within and in addition to the science curriculum.

This chapter has reported that the learners who participate in science fairs gain scientific investigation skills; professional practices or authentic research skills; academic improvement; innovative, critical thinking; and invention skills. Moreover, it has been shown in this chapter that learners who are involved in the Expo experience growth in their understanding of the nature of science (NOS) and scientific literacy. They further gain an opportunity to interact with scientists, their peers, teachers, professors, parents and others and in return many pursue careers in science, mathematics, technology and engineering (SMTE).

It was posited in this chapter and in this study, that teachers may gain professional development from science fairs, as well as scientific resources, innovation skills, and networking opportunities. Additionally, the collaborative or networking opportunities provided by science fairs may contribute positively to the Professional Identity of teachers.

Ajzen's (1991) Theory of Planned Behaviour is presented in this chapter as it was used to analyse the reasons and decisions that led to the participating teachers taking active roles in Expo and sustaining their participation in the Expo (Czerniak & Lumpe, 1996a; Zint, 2002).

The purpose of this study was to understand the educational significance of science fairs (if any, in terms of Professional Identity and professional development) for high school teachers of Physical Sciences, from their point of view. This study also sought to establish why they sustained their participation over many years. The next chapter discusses the processes that were followed to obtain and analyse the views and explanations provided by the teachers themselves regarding their participation in the Expo.

CHAPTER 3

Research methodology

3.1 Introduction

This research concerned the educational significance perceived by high school teachers of Physical Sciences who were involved in the science Expo as mentors, judges and organisers in relation to science education. This chapter presents a description of the worldview and philosophy that underpinned the research design and method that was employed in the data planning, collection and analysis of this research.

An explanation of the research design and method is provided, followed by the sampling procedure and a description of the data collection, as well as an analysis within an interpretive paradigm. The quality assurance is then discussed, which included attention to trustworthiness, reliability and validity. The ethical considerations of this study are then, lastly, described.

3.2 Research design

The QUAL-quan research design and approach of this study was situated within the interpretive and descriptive paradigm, which was used in order to develop an understanding of the experiences and perceptions of high school teachers of Physical Sciences with regard to their involvement in the science Expo as mentors, judges and organisers. The research involved an in-depth examination to obtain intensive knowledge and information. This was obtained through semi-structured interviews with the teachers regarding their experiences and perceptions according to the roles they played in the science Expo. The interpretive paradigm was intended to assist in understanding the phenomenon of human experiences as it relates to the teachers' actions and/or interpretations during their involvement in the science Expo as they played their various roles (Creswell, 2013, p. 187; Creswell, 2014, p. 200).

The purpose of this study was to explore the educational significance of science fairs (if any, in terms of Professional Identity and professional development) in the view of high school Physical Sciences teachers, and to understand why they sustained their participation over many years.

3.3 The sample

Sampling refers to the process of choosing part of the population for a research study (Nieuwenhuis, 2010b, p. 79). Sampling considerations should be considered in the research planning in order to accommodate elements such as time, expenses and accessibility, which often might be an obstacle to the researcher in terms of obtaining information from the determined size of the population (Maree & Pietersen, 2010, p. 172). For this research, both purposive and convenient sampling were employed in the study because the participants were chosen according to the prior selected criteria as appropriate to the research questions (Maree & Pietersen, 2010, pp. 177-178). The reason for using purposive sampling was that the school principals and Heads of Department in the science departments decided which of the teachers should be interviewed. Convenient sampling refers to the chosen participants who are easily and conveniently accessible (Maree & Pietersen, 2010, p. 177) to the researchers. The teachers and researcher were based in the same area, namely, Pretoria, thus it was convenient for the researcher to stay in contact with them as they were not located far away. Only schools participating regularly (at least five times in the past ten years) in the Expo for Young Scientists (Northern Gauteng Region) were selected. Five urban public high schools and ten teachers (two from each school) were identified to participate in this study.

The teachers were required to have taken part in the Expo more than once in order for them to be selected. Those teachers were the main source of data collection to support the research questions. Most of the interviewed teachers were experts in the science Expo, thus it was expected that they would be able to provide deeply descriptive data for the purposes of this study.

3.4 Data collection strategies

Data gathering strategies refer to the research instruments or tools that were employed to collect the necessary data. Semi-structured interviews (see Appendix 4) were the main data collection tool that was used in this QUAL-quan research approach (Creswell, 2014, p. 209; Leedy & Ormrod, 2010). The interview with each teacher was scheduled at their own convenience. The data collection process was carried out through face-to-face, semi-structured interviews, which assisted the researcher to keep an open mind to any unexpected ideas that he may have encountered. As the researcher strove to sustain the role of being a good interviewer and careful listener, what emerged in the participants' responses could not be anticipated (Creswell, 2008, pp. 225-226). With the permission of the participants, the researcher used an audio recorder to capture the interviews, which were then transcribed (Creswell, 2014, p. 96; Nieuwenhuis, 2010b, p. 89). Written notes were also taken during the interview process (Lincoln & Guba, 1985). The selected teachers had already indicated that they would voluntarily participate, but they were again reassured that they were free to withdraw at any time if they felt either uncomfortable or inconvenienced. The semi-structured interviews allowed the participants to answer predetermined interview questions, as well as allowing for further probing (Nieuwenhuis, 2010b, pp. 87, 94).

Individual interviews were conducted with ten high school teachers of Physical Sciences from the five selected urban public schools, with two teachers per school. Personal interviews are believed to have the potential to produce a great deal of crucial information because the researcher can ask questions concerning beliefs, perceptions, facts, feelings, reasons, views, motivations and knowledge about a specific topic (Leedy & Ormrod, 2010).

The interview schedule was divided into two sections, A and B. Section A sought to establish the biographical data of the teachers, while Section B consisted of open and closed questions seeking to determine the teachers' opinions on the significance of the science Expo to teachers. Table 3.1 was used to guide the process of collecting and analysing data.

3.5 Data analysis strategy

Ten teachers from five urban high schools were interviewed. The chosen teachers were all from schools that had participated in the regional and national science Expo at least five times in the past 10 years.

In terms of Section A, the teachers' biographical information consisted of their age, gender and language diversities, which included both their home and official teaching languages. The teachers were also asked questions regarding their qualifications, the current grades that they taught and the number of years' teaching they had, as well as their teaching experiences. Questions about the teachers' roles as organisers, judges and mentors at the science Expo were included in the biographical questions, and specific open-ended questions related to these roles were then asked in the open interview section.

Table 3.1: Summary of data collection methods and instruments used related to the research questions

Sub-research questions	Data collection	Data sources	Data analysis
What is the perceived educational significance of teacher participation in science fairs to their Professional Identity and professional development?	Semi-structured interviews	Teachers (10)	Closed coding Open coding Classification Categorisation [Beijaard *et al.*'s (2004) professional identity] Linking of categories to the themes: Professional Identity and indications of change to professional identity identified as professional development
What is the educational significance of science fairs in the opinion of the teachers who participate as organisers, mentors and judges?	Semi-structured interviews	Teachers (10)	Closed coding Open coding Classification Categorisation Linking of categories to themes of advantages and disadvantages to teachers and learners; Linking of categories to roles
If teachers' participation is sustained for several years, what are the possible factors that support this sustained participation?	Semi-structured interviews	Teachers (10)	Closed coding Open coding Classification Categorisation [Ajzen's (1991) TPB] Linking of categories obtained from both an interview question directed to sustained participation and the overall interviews to the constructs in the TPB

The transcripts of the interviews were analysed through encoding the responses by identifying key words or phrases, which were later organised into sub-categories and categories. The number of answers in which each key word or phrase was found were counted and the counts were expressed as a frequency. In each question asked, a particular key word or phrase was counted only once, and further mentions of the same word or phrase in the answer to the particular question were not counted. The tabulated and categorised data from the respondents is attached as Appendix 7.

The encoding and tabulation allowed for themes to be identified, ordered according to the response frequency, and enabled the researcher to make the most important themes identifiable. These themes were then ordered according to the concepts that had been developed in the conceptual framework provided in Chapter 1 (Section 1.6) (linked to Professional Identity), as well as to the themes appropriate for each of the research sub-questions.

Ajzen's (1991) Theory of Planned Behaviour (TPB) (refer to Section 2.7) was introduced, used and implemented in order to interpret and predict answers based on research sub-question iii. This theory has been recommended by several researchers (Czerniak & Lumpe, 1996a; Fisanic, 2010; Taylor, 2014) as a suitable model to predict and interpret teachers' attitudes towards and decisions regarding various activities. The theory provided an organising theme towards understanding teachers' participation in the Expo.

Content analysis was employed in this research because the researcher was analysing the information gained from the transcripts of the teacher interviews (Nieuwenhuis, 2010a, p. 101). This was done in order to identify common categories that the teachers had mentioned frequently, ultimately leading to sub-themes that were arranged according to the main themes (Braun & Clarke, 2006). In order to allow the ranking of themes or categories, the number of teachers out of the sample of 10 who mentioned a theme or category were considered the most important parameter. If the number of teachers mentioning a theme or category was the same for more than one category, the secondary parameter was the aggregated total count of mentions by unique teachers, as described above. This is the limit of the use of any quantitative counts: the quantities themselves had no particular importance beyond ranking the themes or categories that arose from a careful inductive process of analysis. The qualitative information obtained was the component of the analysis that was important.

Inductive analysis assisted in identifying the multiple realities and potential themes derived from the data (Creswell, 2014; Leedy & Ormrod, 2010; Nieuwenhuis, 2010a, p. 107). The data analysis process was a continuous and iterative process, which included data collection, processing, and analysis and reporting, which were all intertwined. Data collecting, the process of reflecting on the data, and observing gaps in the data was considered, which enhanced the credibility of the data.

The researcher ordered the data, read and reread the data, made meaning of it, put the data together, and broke the data up in searching for considerations, patterns and new meanings. The identified themes and concepts were then further categorised according to the research questions (see Section 1.5), which allowed for the most detailed interpretation possible.

The responses from the teachers' interviews were grouped mostly into the sub-categories, then further collected into categories; the categories in the thematic diagrams were then used to identity sub-themes. Thematic analysis is the process of identifying and analysing themes within the data (Braun & Clarke, 2006). Braun and Clarke also argue that a thematic analysis offers an accessible and hypothetically flexible methodological approach to QUAL-quan data. Braun and Clarke (2006) further state that themes usually capture crucial information that is relevant to the research questions. The responses to the open-ended questions in this study were analysed qualitatively through the use of open coding. However, the responses to the closed questions were only analysed quantitatively.

Coding, in the general sense, is perceived as the process of reading attentively and carefully through the transcribed data line-by-line, and categorising it into meaningful analytical components. Specifically, open coding is the process whereby meaningful segments transcribed as data are quickly retrieved and gathered according to thematic ideas, and sorted out (Creswell, 2012; Nieuwenhuis, 2010a, p. 105). Alternatively, closed coding engages the process of examining the data inductively as well as deciding on a process to use a set of existing codes of data. Closed coding also includes categorising which of these codes require ordering and structuring of the data, and carefully examining the data during the analysis process, linking conflicting themes, as well as classification or grouping of the data (Nieuwenhuis, 2010a, p. 105).

During analysis, the researcher looked for contradictions, resemblances and trends. The interview data sources were worked through several times to discover and verify the data by making sure that the initial transcripts were read and reread. Duplications were also avoided by going back to the categories in order to make sure that there was no repetition of the data, hence the fact that key words and sub-categories were assigned to only a single category, and thus not assigned (or counted) twice. The researcher grouped the emerging similar categories from the interviews, identified the linkages between the categories, and eventually linked the categories to build sub-themes. These sub-themes were then linked to the themes provided by the analysis of the research questions and the conceptual framework (Professional Identity and roles). Furthermore, it was ensured that all relevant information that emerged from the data through coding and grouping was captured.

3.6 Quality assurance

It is absolutely crucial to ensure that data collection is consistent, true, authentic, convincing, and reliable. The replication of study findings in QUAL-quan research is difficult because human nature is never static (Maree, 2010, p. 262). Additionally, the criteria for the quality of qualitative research remains a matter for theoretical development, see for example Lincoln (1995, 2002). Thus, the application of the criteria that was chosen for this study is discussed.

My task as the researcher was to provide a rich and sufficient description of the data, as well as working assumptions within another context, and meeting the criteria of transferability. The interviews were crucial because this was the main data source for meaningful interpretation. The theoretical literature supports this study in providing plausible interpretations and descriptions of the data. Thus, the theory and the derived conceptual framework enriched and confirmed the crystallization embodied in this study.

Trustworthiness involves credibility, of which there are four elements (Marland, 2014; Nieuwenhuis, 2010b, p. 80), namely: credibility, applicability, dependability and conformability. These construct internal and external validity using data from interviews and, in line with the findings of the literature that was studied, assisted in analysing the findings. The researcher verified the gathered data with the participants to check for errors, maintaining confidentiality and anonymity, as well as controlling for bias with the participants. The researcher's supervisors also checked the selected extracts against the transcripts to further strengthen the trustworthiness of the findings.

Validation is very important and necessary in research. It refers to the accuracy and truthfulness of the data's findings. The core idea of validation is that the instrument actually measures what it is supposed to measure (Pietersen & Maree, 2010, p. 216). The participating teachers were asked interview questions according to a single interview protocol (except for follow-up questions) to ensure the consistency of the interview process. The interview protocol was piloted with two teachers from one school to verify validity first before the interviews with the other participants at the different schools were conducted. The aim of piloting the study was to ensure the duration of the interviews, to establish if any question was ambiguous, to indicate any shortcomings, and also to gather some recommendations and suggestions with regard to the final interview questions. In addition, the researcher's supervisors also checked the data collection instruments. The transcriptions were then sent to all of the participants to check, and positive confirmation of the acceptability of the record was obtained from all.

Key phrases that led to the identification of sub-categories and categories and their counts were checked by the supervisors (as co-researchers) to ensure that (i) there was no untoward influence from the interviewer on the teachers – and if so, the data thereof were not included, and (ii) repetition of the same key phrases was not counted through the mechanism of unique counts (as described in Section 3.5).

3.7 Ethical considerations

To ensure confidentiality and privacy in this study, the schools' names and teachers' names were replaced with pseudonyms and at no point were their actual names revealed (Maree, 2010, p. 299; Annice, 2014).

Ethical approval to proceed with the study was requested from the Faculty of Education at the University of Pretoria. Permission was also requested from the Gauteng Department of Basic Education (see Appendix 1) to visit teachers for interview purposes. The school principals of the participating teachers provided permission to conduct the semi-structured interviews with the teachers (see Appendix 2).

The prospective participating teachers were informed about the objectives of the study and the researcher assured them of their confidentiality and right to privacy. The teachers were further assured that they would be protected as individuals and that there would be no damage to the schools' reputations due to their participation. The teachers were furthermore informed that the study would rely on their voluntary participation and that they might withdraw at any point if they wished to do so. The researcher had prepared consent letters for all interviewees (see Appendix 3). In the consent forms, the participants' confidentiality and anonymity were assured and explained, it was again emphasised that the teachers' participation was voluntary and they were free to withdraw from the research at any given time. They were then asked to complete and sign the consent forms to confirm their willingness to take part in this study. The researcher outlined the ethical procedure issues to all interviewed teachers prior to the commencement of the semi-structured interviews, and the issue of confidentiality and anonymity were restated in every interview.

The co-researchers (supervisor and co-supervisor) were also committed to the obligation to maintain confidentiality and abide by the ethical requirements.

3.8 Conclusion

This chapter outlined the various aspects of this QUAL-quan study, and explained the case study design that was implemented. The interview procedures and data gathering methods that were used to collect and analyse the data, as well as the ethical procedure issues were discussed. The research design, sampling, and data gathering procedures were also explained and justified. Lastly, the study's quality assurance was described in detail.

The next chapter presents the analysis and interpretation of the information obtained from the teachers during their semi-structured interviews.

CHAPTER 4

Results and Analysis

4.0 Introduction

This chapter contains the results of the investigations; and the characteristics of the participating schools and teachers are described. The schools were characterised according to their predominant teaching language and curriculum focus (English or Afrikaans, general academic, or technical), and the teachers in terms of their level of experience, highest qualifications, gender, and number of years that they had been associated with the science Expo, as well as further biographical measures. An analysis of the interview responses are presented herein in terms of the stated benefits or challenges for teachers and learners, the relationship of these to the teachers' Professional Identity, their roles in the science Expo, and what sustained their involvement with the Expo. The results are then linked to the research questions.

Further detailed discussions and reflections on the findings in terms of the research questions are provided in the next chapter, Chapter 5.

4.1 Biographical data of the teachers

The scene was set for the analysis by providing a description of the participating teachers through a summary of their biographical information.

Each of the ten teachers (drawn from five well-resourced schools, with 2 teachers per school) who were interviewed provided information regarding age, gender, diversity of languages spoken during their upbringing, official languages during teaching, qualifications, grades taught and the number of years' experience they had of teaching Physical Sciences in high schools. The teachers were also asked questions based on their roles as organisers, judges and mentors at the Expo, as well as the number of years they had been involved in each role at a range of expos, from the school-based mini-Expo to the regional and national level science Expos. The biographical information is summarised in Tables 4.1, 4.2 and 4.3.

Table 4.1: Biographical information of the teachers

Biographical information	Category	Teachers' codes	Frequency
Age	24-29	T1; T6; T7; T9; T10	5
	30-39		0
	40-49	T3; T4	2
	50-59	T2; T5; T8	3
Gender	Females	T1; T2; T3; T4; T6; T7; T8; T9; T10	9
	Male	T5	1
Languages they are able to speak	Afrikaans and English	T1; T3; T4; T5; T6; T7; T8; T9; T10;	9
	Afrikaans	T2	1
Home language	Afrikaans	T1; T2; T3; T4; T5; T8; T9	7
	Afrikaans and English	T7; T10	2
	English	T6	1
Official languages during teaching	Afrikaans	T1; T2; T3; T5; T7; T10	6
	Afrikaans and English	T8; T9	2
	English	T4; T6	2
Qualifications	BEd	T1; T6; T9; T10	4
	BEd (Hons)	T1; T6	2
	BEd (post graduate)	T3; T8	2
	BSc	T2; T3; T4; T5; T7	5
	BSc (Hons)	T8	1
	MEd	T6	1
	HED	T1; T3; T4; T5	4
	PGCE	T7	1
	ACE	T5	1
Grade currently teaching	12	T3; T4; T5; T6; T7	5
	11	T1; T2; T3; T4; T6; T7; T8	7
	10	T1; T3; T4; T5; T6; T9; T10	7
	9	T3; T10	2
	8	T8; T10	2
No of years that the teacher has taught Physical Sciences	1-4	T10; T9	2
	5-10	T1; T6; T7	3
	20-30	T2; T3; T5; T4; T8	5

Of the ten teachers with ages ranging from 24 to 59, nine were female, one was male, and their experience of teaching the subject ranged between one and 30 years. All of them had obtained a Bachelors' degree in BEd or BSc, and one had a Master's degree in Education (MEd). In Table 4.1, and thereafter, the teachers are indicated by the code "T" together with an identifying number, with the number assigned according to the order in which the interviews were conducted, for example, T1 to T10.

Table 4.2: Teachers' pseudonyms and their school codes

School code	Language of instruction	Teacher	Pseudonym	Gender
School A	Afrikaans	T1	Annlin	Female
		T7	Glory	Female
School B	Afrikaans	T2	Bernie	Female
		T5	Jacob	Male
School C	Afrikaans	T3	Carla	Female
		T10	Jade	Female
School D	English	T4	Danielle	Female
		T6	Fransie	Female
School E	English and Afrikaans	T8	Harmony	Female
		T9	Ina	Female

For this and subsequent discussions, the teachers have been given pseudonyms to maintain anonymity. The schools in which the teachers were employed at the time of this study were labelled as Schools A, B, C, D and E.

4.2 Nature of the schools and contributions of the teachers

Schools A, B and C had predominantly Afrikaans speaking learners, with only a few African learners. To a large extent, the racial profile of the learners was affected by the languages offered. School D had mixed learners from all racial groups, while School E had 70% Afrikaans speaking learners, while the other 30% were English speaking learners who included Africans, Indians, and Coloureds. The five schools were known to be amongst the top academically performing schools in the Gauteng Province, with one of these schools being a top performer in South Africa when measured using the Grade 12 performance of their learners in recent national examinations.

- **School A**

Annlin was from School A. Her teaching experience was in the 5-10 year range, and she was teaching Grade 10 and 11 learners at the time of this study. With her Bachelor of Education and Bachelor of Education Honours qualifications, Annlin was involved in science expos as an organiser, mentor, and a regional coordinator and judge of the mini-Expo for seven years in each case.

Glory was also a teacher at School A, and taught Grade 11 and 12 at the time of this study. She had a Bachelor of Science in Animal Science and a Post Graduate

Certificate for senior phase. Her teaching experience was in the 5-10 year category. She had also mentored and judged at the mini-Expo for three and two years respectively.

School A was an elite school in the Gauteng Province; the school's learners consistently did well in the regional Expo. Afrikaans was the medium of instruction in this school, which was the second biggest school in the sample, accommodating over 1 000 learners at the time of this study.

- **School B**

School B was a technical high school for boys, and its teaching language was Afrikaans. The school was also involved with the Tshwane University of Technology in relation to science competitions.

Bernie, who had a Bachelor of Science degree, was a teacher of Physical Sciences at School B. Her teaching experience was in the 20-30 year range and she was teaching Grade 11 learners at the time of the interviews. She had been organising school level mini-expos for two years, and had mentored and judged for three. She had also mentored at the regional level competition for three years.

Jacob, who was a Grade 10 and 12 teacher at the time of this study, was the only male participant of the ten teachers interviewed. He held a Bachelor of Science degree and an Advanced Certificate in Education. He had 20-30 years' teaching experience and had been a mentor, judge and organiser from school to regional expos for eight years. The Electronics and Mechanics teachers at his school further assisted him in performing experiments.

- **School C**

The medium of instruction at this school was Afrikaans. School C was a big school and had about two thousands learners enrolled. Ten learners from this school received gold medals at the provincial level in 2014; the school was also one of the top academic performers in the Gauteng Province and had top achievers in the South African Expo over the years. Several of the school's learners had participated in science fairs at an international level.

Carla from School C had a Bachelor's degree in science and additional teaching qualifications, and her teaching experience lay in the range of 20-30 years. Carla had been involved in expos as an organiser for ten years at both school and regional level, and had been a mentor to learners whose projects had been presented at both school science Expo and international fairs for fifteen years. She was a judge at the mini-Expo for fifteen years, and was a five year judge at regional level. She was also involved with the Mining Technology Company-MINTEK, the Hip to Be Square competitions (HIP2Bsq), and the Olympiads for fifteen years.

Jade is one of the youngest participating teachers in this study. Her teaching experience ranged between 1-4 years and she was qualified with a Bachelor's degree in Education. At the time of this study, she taught Grade 10 learners and had been mentoring, organising and judging for two years at mini-expos and regionals, respectively.

- **School D**

This high school was the only school of the sample where English was the single medium of instruction. School D was a prominent boys' school that has a history of annually achieving exceptional academic performance, and typically excels at Expo competitions.

Danielle had 20-30 years' teaching experience within Grades 10-12. Her highest qualifications were a Bachelor's degree in Science and a Higher Education Diploma. She had been involved in both mentoring and judging for more than twenty years at mini-expos at school level, and ten years as a regional mentor.

Fransie's qualifications included a Master's degree in Education, a Bachelor of Honours, and a Bachelor of Education, and she was in the process of obtaining a doctoral degree in technology supported education at the time of this study. Her teaching experiences fell within the range of 5-10 years, and she taught Grades 10-12. She had been mentoring, organising and judging science Expo projects at her school mini-expos for four years. Fransie had been a mentor and organiser for two years and a judge for a year at the regional level.

- **School E**

School E was the only interviewed school that had both English and Afrikaans as the medium of instructions. The school had a history of performing well academically within their cluster in the district of the Gauteng Province.

Harmony taught Grade 8 and 11 learners at the time of this study, and had 20-30 years' experience in the field. Her qualifications were a Bachelor of Science honours and a Bachelor's of Education degree. Harmony's role in the regional science Expo as a mentor had occurred for seven years. She also divulged that she used to work as a professional researcher in an agricultural science company before entering the teaching profession.

Ina, also from School E, had a Bachelor of Education degree. Her teaching experience was in the 1-4 year range and she taught Grade 10 Physical Sciences and Grade 11 Life Sciences at the time of this study. Ina had started to organise, mentor and judge expos while she was still a student at the University of Pretoria. She played these roles at mini-expos for four years respectively, and had two years' of experience at the national level as an organiser and mentor. She had been a mentor, an organiser, as well as a judge of science Expo at regional level for the past four years.

4.3 Analysis of the interviews

This section comprises an analysis of the responses given by participants in the semi-structured interviews. In the interviews, the participating teachers were asked 23 questions, which were divided into three sections, namely: educational significance, significance according to roles, and reasons for sustained participation (as shown in Appendix 4). The responses are presented according to the question groups, and the categories are derived from codes that were assigned to key words. A count of the number of teachers who gave closely related responses was allocated categories. The categories were ultimately collected into sub-themes and themes that arose naturally from the analysis. These were grouped according to the advantages for teachers (Section 4.4), advantages for learners (Section 4.5), and disadvantages for learners (Section 4.6). The categories were further gathered and analysed according to the conceptual framework, which links the responses of the participants to aspects of Professional Identity, as proposed by Beijaard *et al.* (2004), as subthemes (professional knowledge, attitudes, beliefs, values and norms, emotions, and agency).

This was linked to the roles (as organisers, judges and/or mentors) that these teachers played in the science Expo (Sections 4.7 and 4.8 respectively).

Table 4.3: Teachers' involvement in science fairs

Teachers and roles	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	No of unique teachers*
Organiser											
School mini-Expo	7	2	10		8	4			4	2	7
Regional Expo	7		10		8	2			4	2	6
National Expo									2		1
Judge											
School mini-Expo	7	3	15	20		4	2		4	2	8
Regional Expo	7		5			1			2	2	5
National Expo											
Mentor											
School mini science Expo	7	3	15	20	8	4	3		4	2	9
Regional Expo	7	3	15	10	8	2		7	4	2	9
National Expo			15						2		2
MINTEK, HIP2BSq and Olympiads			15							2	2
Totals:	42	11	100	50	32	17	5	7	26	14	

* The category "unique teachers" is used to prevent repetition in the counting of teachers mentioning the same concept multiple times in reply to a specific question. Thus, only one response is counted per question, per teacher. If a teacher does not mention a concept at all, this means that fewer than ten teachers mentioned this concept. As one moves from sub-categories to categories and sub-themes, the unique teachers involved are followed in the process of analysis.

Answers regarding sustained participation in the Expo were sought in two ways. Firstly, through an analysis of replies to the direct questions of Section 3 of the interview (see Section 4.9). Secondly, the entire transcripts were analysed once more according to Ajzen's (1991) Theory of Planned Behaviour. This linked the responses to the aspects of Professional Identity that the teachers reported to be affected by participation (see Section 4.10). In Section 4.11, a systems model is proposed in terms of which professional development as change (or enhancement) of Professional Identity can be analysed. The implications of these findings will be further explored in Chapter 5.

In this case, frequency represents the total number of unique teachers (UT) who provided data per question during the semi-structured interviews.

Where statements made by the teachers are mentioned, the teacher's code and the line numbers in their transcripts are given in brackets to enable the reader to refer to the detailed contexts, for example, a statement by Jade is referenced as [T10, 622-631].

4.4 Benefits for participating teachers as they play their roles

The benefits gained by the participating teachers are represented in Table 4.4. The theme 'Benefits of science Expos for teachers' has been associated with three sub-themes, five categories, and seven sub-categories.

Table 4.4: Benefits of science Expos for teachers

Sub-theme	Categories	Sub-categories	Responses as unique teachers, total count: count according to the general questions and according to roles, expressed as UT (T): [G, O, J, M]*
Professional knowledge	Subject content knowledge (CK)	Procedural content knowledge	10 (94): [65; 14; 15; 0]
		Declarative content knowledge	10 (41): [25; 6; 10; 0]
		Knowledge in the curriculum	10 (33): [27; 6; 0; 0]
	Pedagogical knowledge(PK)	Methodological integration, critical thinking skills, assessment skills, self-enhanced teaching skills	10 (106): [58; 14; 20; 14]
	Pedagogical content knowledge (PCK)	Judging skills, Discovering, misconceptions	9 (41): [19; 4; 18; 0]
Norms and values	Norms and values	Gained enjoyment by interacting with learners, Collaboration of teachers with the schools, school ethos, administration and time management, organising skills, mentoring skills	10 (175): [70; 47; 25;33]
Networking as resource	Networking as resource	Networking as resource	9 (23): [17; 6; 0; 0]

*(UT) refers to the number of teachers from the sample of 10 who provided a response (at least once) that is classified into a group referred to as "unique teacher"; (T): refers to the total number of times a similar response was identified in the teachers' statements, at least once in a particular question (whilst repetitions are not counted). (G) refers to the response-count, (to direct questions on educational significance and their reasons for sustained participations), while (O), (J), and (M) refer to the response-count of the various role-based questions - teachers as organisers, judges and mentors, respectively. This convention and order also applies to all tables from Table 4.4 to 4.9.

Three sub-themes emerged from the total number of responses from the teachers, namely 'Professional Knowledge', 'Norms and values' and 'Networking as a resource'. These have been classified and ordered according to the number of "unique teachers" contributing to a category and the response-counts. The thematic figures

(Figures 4.1-4.7) show the responses for sub-themes, and further assist interpretation through a visual representation of the responses in terms of categories and sub-themes and their relationships, as recommended by Braun and Clarke (2006).

The total responses for 'professional knowledge' as a sub-theme are 10 (315): [194; 44; 63; 14]. This shows that all of the teachers said that they valued the effect of participation in the Expo as providing a positive contribution to their professional knowledge. Of these, only one teacher did not mention improvement in 'Pedagogical content knowledge' as a benefit.

The total responses for 'Subject Content Knowledge' as a category are 10 (168): [119; 26; 25; 0]. Despite the fact that all of the teachers agreed that their subject content knowledge was developed, none of them assigned this benefit to the role of mentoring.

4.4.1 Professional knowledge

The teachers (UT) provided 317 responses in total regarding professional knowledge. The general questions (G) included interview questions addressing educational significance and sustained participation; this provided 195 responses. The benefits gained from the various roles that contributed to professional knowledge are reflected separately as organisers (O), judges (J) and mentors (M), with 44, 63 and 14 obtained respectively from the teachers. The teachers benefitted from mentoring the least often in comparison to other roles, but generally explained that learners benefitted the most from mentoring. This may be because mentoring is often done within schools in mini-expo projects, which are more curriculum based.

In comparison to the other two identified sub-themes, the professional knowledge sub-theme aspect showed an overwhelming response from the teachers. 'Professional knowledge' consists of the following categories, which are arranged in descending order, namely, 'Subject content knowledge' (CK), followed by 'Pedagogical knowledge' (PK), and 'Pedagogical content knowledge' (PCK) with 168, 106 and 41 responses respectively.

(a) Subject content knowledge

'Subject Content Knowledge' is the category of benefits most identified by each of the ten teachers interviewed under the 'professional knowledge' sub-theme. Three sub-categories were grouped together under the category, namely: ‘Procedural Content Knowledge’, ‘Declarative Content Knowledge’ and ‘Knowledge in the curriculum’.

The ten teachers agreed that activities in the science Expo could form part of the school curriculum, for example, doing a research project is required by the science curriculum. In relation to this topic, Glory explained:

> *Science fair activities, no, but according to CAPS we must include science activities, investigations, research as part of our assessments, yes. ... Yes, we have a research project for Grade 11 and they do a research project as part of formal assessment* [T7, 132-134, 138-139].

However, Glory did point out that for high school learners, the Expo themes were expected to be open, and not necessarily part of the curriculum:

> *For seniors, we usually give an open investigation, do anything* [T7, 153].

- **Procedural content knowledge**

Carla, Ina and Jade agreed that science Expo activities taught them more about investigation and research skills in terms of the scientific method processes. Ina mentioned:

> *I got to see what importance is of a scientific report and of investigation, and also about innovation* [T9, 100-101].

As Jade came from a rural area, she only started learning about investigation and research skills (which also include scientific process skills) when she began participating in Expo activities as a professional teacher, she explained:

> *So for me as a science teacher, I just learned that the practicality of science is so much more important than just teaching pure content* [T10, 630-631].

Carla and Bernie acknowledged that they had learned from what their learners had discovered during their science Expo project activities. Annlin, Carla and Danielle argued that through the research investigations taking place in their school science fairs, they gained science knowledge. They also reported that the competitions were educationally worthwhile for them as teachers.

Ina had gained knowledge about scientific investigations as she played her different roles in the Expo, and affirmed with similar sentiments that she had started to learn about investigation processes as a school teacher and as a student at the university respectively:

> *I know what's important, to focus on in the class… especially writing reports and practical, investigate* [T9, 499, 503].

Ina further discussed her experience of the Expo:

> *Yes well, for instance my love for science fair actually started way back, when I was a student and I had to do my … practical teaching* [T9, 299-300, 303].

Carla elaborated on the benefits gained by her and her learners when participating in the Expo. This included appreciating correct investigational procedures, and consequently feeling like a better teacher, which shows improved a belief in self-efficacy (Bandura, 2012):

> *I think I'm more aware of how important it is for a child to do research in the correct way …. So my involvement in science expos really bettered me as a teacher* [T3, 673-774, 719-720].

In discussing the benefits further, Glory said:

> *I'm a scientist as well, so I also enjoy the developmental part thereof* [T7, 84-85].

- **Declarative content knowledge**

'Declarative (content) knowledge' is also known as science factual knowledge, and includes new knowledge on the horizon of science. Bernie, Carla, Jacob, Ina and Jade argued that they had learnt a lot about science in general. Jacob enhanced his knowledge of science through the application of scientific investigations based on his experiences in the science Expo as he played his roles. Jade corroborated this by saying:

> *I come from a small town, and we didn't have these opportunities. For me as a science teacher I learned that science is so much more than just standing in a class and teaching content. I learned that doing a project isn't just sitting and*

> *reading things and writing down. I learned that doing a project involves creativity.* [T10, 622-626].

Carla further described that knowledge gained from the Expo environment improved daily life:

> *The practical aspect of applying the knowledge to everyday situations increases tremendously* [T3, 121-122].

- **Knowledge in the curriculum**

Eight teachers narrated that while they were carrying out their various Expo roles, they gained scientific knowledge during learners' investigations through the application of scientific processes. Annlin, Carla, Ina and Glory found that their science content knowledge of topics improved through taking part as Expo organisers, mentors and judges. Carla, Bernie and Jade asserted that they had improved their science content knowledge whilst they were helping, encouraging and supporting learners with their investigative projects.

Carla elaborated by saying that she had learned from one of her learners' projects about the production of electricity through the application of Faraday's Principle by using bacteria. She normally used every possible and practical daily example in her Physical Sciences class as methodological presentation and teaching in order to make it easy for her learners to understand certain scientific concepts. In light of this, Carla described how her knowledge as a teacher advanced:

> *Oh, a lot, because there are certain topics of which you aren't a master of, and through expos you learn so much more in depth of a certain topic* [T3, 66-68].

Five of the ten teachers (Fransie, Annlin, Carla, Jacob and Jade) were of the opinion that investigation and research skills in terms of scientific method processes were not being taught and emphasised in detail within the school curriculum. However, they felt that through their involvement in science fairs, the school curriculum was complemented. Annlin, Bernie, Carla, Jade and Fransie said that they had gained new knowledge of science topics and that they were integrating these into their teaching in order to improve learners' science knowledge.

Jade explained:

> *Yes, as a teacher I definitely learn how important projects are for children. I understand now why projects are part of the curriculum…. As a science teacher it just showed me another part, an extra part of the curriculum* [T10, 458-459].

One can therefore deduce that science Expo activities significantly supplement the science curriculum for both teachers and learners.

(b) Pedagogical knowledge

Most teachers (9) argued that, together with the participating learners in science fairs, they developed critical thinking skills, which resulted in them being innovative and inquisitive in their learners' investigative projects. Carla stated:

> *So it helps with critical thinking. I think it's a very, very important role in critical thinking, because of my involvement with science fair expo. I constantly think, hey that's funny, that will be a great science Expo. I wonder why that's happening, that will be a great science Expo. So it ensures that you start wondering about things. You get an inquisitive mind* [T3, 132-136].

While these teachers were teaching and helping learners with their science Expo projects, they also themselves benefited significantly. They integrated aspects of inquiry into their teaching, which involves practical experiments and lab work, technological teaching tools (such as teaching via You Tube videos), assessment skills, learners' misconceptions that were discovered by the teachers, and other methodological incorporation of science activities into the school curriculum. Thus, the experience gained by the teachers improved their Professional Identity as their professional knowledge of science as a subject had been developed.

A majority of the interviewed teachers (9) explained that they taught their learners to think critically in their investigations and to be innovative with their outcomes. Ina, Bernie, Fransie and Jade found that their scientific assessment skills had improved as they learned scientific assessment procedures while evaluating learners' projects. They did this by using the same rubric that was being used at the science Expo centres.

Jade elaborated that, as she carried out her various science Expo roles, she learnt to teach and emphasise topics that are related to daily challenges, which also enabled her learners to be critical in their thinking:

> *Out of this project this learner taught me this that was new…. I think yes definitely it's kind of a thing that you apply every day* [T10, 203-204, 206].

Bernie, Danielle, Fransie, Glory, Jade, Ina and Jacob argued that other than their roles in the Expo, they also benefitted from experimental tasks and pedagogical strategies, such as better ways of teaching and conducting practical experiments in their schools. Ina also said that she learnt more about the interpretation of data as an organiser in the science Expo. Ina and Jade further stated that their scientific assessment skills were enhanced in working with learners who participated in the science Expo.

Jade mentioned that she learnt more about logical skills in the Expo, stating:

> *I learnt that doing a project involves creativity. It involves developing your investigation skills, your interviewing skills* [T10, 625-627].

Glory said that in spite of an overloaded curriculum, work, and time constraints, they as teachers had to be creative, particularly with new ideas:

> *We get caught up in 'I have this curriculum to teach and I have to teach it in that amount of time'. A science fair brings you new ideas, so you must keep an open mind for that new ideas. … I used that example in class, when you add baking soda to vinegar, it's a practical thing they have done or they can do at home, which you can use in class* [T7, 307-309, 320-322].

Carla and Fransie learnt a variety of ways to present science topics in their classes. They also mentioned that they were constantly trying to find better ways of preparing learners for future presentations in science Expo projects. Carla said:

> *You see I think in the process, I am trying to inspire because I'm inspired. I try to inspire learners too, wow this is amazing. … Wow, this is amazing, it's what I often like to do, and I like to use videos like 'You've Been Warned'. Do you know 'You've Been Warned? … It must be compulsory. If you want to be a good science teacher you have to do a science fair. You have to, you're not inspiring children if you don't do that* [T3, 701-702, 704-706, 787-789].

Jade concluded by saying that through providing learners with opportunities to present their research projects, they are developing future scientists.

(c) Pedagogical content knowledge

The teachers explained that collaboration opportunities enhanced their judging skills, and enabled them to discover learners' misconceptions and difficulties. Glory mentioned that, as a judge, she learnt that her learners were confused by variables during their scientific investigations. Jacob and Ina further affirmed that they had gained and improved in the judgemental skills from their learners' projects in the science Expo. Glory recounted that she discovered that learners struggled with procedural knowledge (identifying variables in experiments):

> *When we do the judging for the science fairs, we see that there are definitely learners who struggle with identifying the variables* [T7, 224-225].

Carla emphasised that, as a judge, she had gained PCK by recognising new misconceptions that her learners experienced:

> *Yes, you see their misconception* [T3, 543].

Jacob also reported that scientific method process skills were also some of the advantages they had gained from the expos:

> *I was informed about their research and their projects, so that's how I learned quite a lot* [T5, 72-73].

Glory found that, as a judge in the Expo, she had developed a knowledge of adjudication skills:

> *When we do the judging for the science fairs, we see that there are definitely learners who struggle with identifying the variables* [T7, 224-225].

To add more detail on the skills she had gained through judging, Danielle reported that her assessment skills had improved:

> *Yes, maybe it helped me with putting together assessment rubrics or how to put together a, yes that's what I said, assessment rubric or how to assess class activities* [T4, 316-318].

Danielle also indicated that, by participating in the Expo, she found out how difficult learners found investigations to be, and she learnt how to teach these learners:

> *I would say it enhanced my perception of how difficult learners find the investigation process. So, you understand what I'm saying? I actually understand more how you actually need to guide them through the process ... Yes, I learn about how to teach the learners* [T4, 102-105, 110].

Pedagogical content knowledge was strengthened by the teachers' participation, whether through learning to understand their learners, or learning how to guide their learners to develop the necessary investigational skills.

4.4.2 Norms and values

These teachers were motivated in gaining enjoyment when interacting with the learners. This was followed by the enhancement of the school ethos, and the gaining of organising and mentoring skills. Thus, the interviewed teachers were passionate and eager to support and interact with the learners who were involved in the Expo. The school ethos is an institutional support to the learners because it is compulsory for all science teachers to be involved in expos in these participating schools. This was mentioned by all of the teachers.

All of the teachers who were interviewed assessed learners' science Expo project tasks, and thereby showed internalisation and the enactment of their schools' ethos. Bernie, Jacob and Harmony asserted that they were involved in science fairs because all of the science teachers in their schools were involved. Bernie and Harmony further clarified that science Expo tasks were part of their extramural activities. All ten of the participating teachers confirmed that all of the science teachers at their schools had to be involved in science fairs as part of their school science cultural activities. Danielle elaborated:

> *Well, all the science teachers at the school must be judges ... So, it's just basically all the teachers are involved* [T4, 253-254, 255].

Danielle also emphasised that Expo activities were compulsory for Grade 10 learners in her school:

> *And it's part of our Grade 10 curriculum* [T4, 550].

The teachers explained that they had learnt a lot from participating in the science Expo as they carried out their various roles. This was especially the case when helping learners with project investigations that were conducted through the use of scientific research processes. Carla, Jacob, Jade and Ina narrated that they usually motivated and encouraged learners to be critical and creative in whatever research they were carrying out. Six teachers (Annlin, Carla, Fransie, Glory, Jade and Ina) said that they had a passion to help, encourage and support learners to do well in Expo competitions.

Passion, interacting with the learners, and providing support are factors that contributed to the enjoyment gained by these teachers, for example, Ina, who was a passionate science teacher, positively exclaimed:

> *Well, I enjoy helping learners, to discover new ideas, and get new opportunities and to help learners to perhaps; they can win a bursary if they went through to the Northern Gauteng expo. It's part of teaching that I love. It's, yes … I like it and I enjoy it when I can help learners to reach their maximum potential* [T9, 556-560].

In conclusion, based on the norms and values concerning the teachers' professions, Carla, who was passionate about the Expo, declared:

> *I have passion for expo. I love expo, and usually when you give these expo tasks to the children they are, ah I have to be expo, and what I usually tell them is, if you're not forced to be inventful* [sic.], *you seldom are. So once you are being forced to think about a solution, you are able to come up with a solution, but if you're not forced to do it you seldom think of it, because you don't need to. ... I wonder why that's happening, that will be a great science Expo. So it ensures that you start wondering about things. You get an inquisitive mind. Why is this thing different to that thing, and if you start wondering about it you're starting to investigate and then you notice more and more about the subject* [T3, 127-132, 135-138].

4.4.3 Networking as a resource

This sub-theme comprises networking as a resource. The teachers commented that their involvement in the Expo gained them resources that helped them during their teaching.

Six teachers reported that, as science Expo organisers, they had a chance to network with other school teachers. As a result, they gained science content knowledge, which they could thereafter integrate into the school science curriculum, particularly practical teaching and the scientific assessment tasks.

Ina, Bernie, Carla and Jade said that while they were performing their various roles in the science Expo, they networked with other school teachers. Ina, Jade and Jacob described that networking gave them the opportunity to share their science experiences with other teachers, and this had led to having contact with one another since then. Bernie, Fransie and Jacob said that during networking, they discussed experiment tasks related to the school curriculum, as well as trying to find ways of improving how they conducted practical experiments. They also exchanged ideas about handling learners' misconceptions, and challenges that they faced as teachers.

Carla stated that she networked with primary schools nearby to help them with mentoring and judging, as well as helping learners to choose suitable scientific topics. She usually emphasised to her learners that they should consider topics that concerned daily challenges, and they had to think critically to come up with solutions to these challenges.

In terms of benefits they had received, Jacob and Jade gained time management skills through the presentation of learners' projects in the science Expo, particularly in their role as organisers. Ina and Jade obtained organising skills from the school Expo exhibitions while making science Expos interesting for learners. Bernie confirmed that the electronics and mechanics teachers in the Department of Technology at her school helped them with specific scientific experiments, particularly those using electrical circuits and mechanics, such as generators.

Ina described how, through networking with other teachers, she had learnt science practical work, and she had an opportunity to discuss Curriculum and Assessment Policy Statement (CAPS) issues concerning school work. As she enacted her various roles in the Expo, she had an opportunity to exchange her science experiences with other teachers from other schools, specifically regarding CAPS issues. Ina said:

> *Yes, like for instance I always like to communicate with other teachers. Especially with Grade 10-12, especially with the science because I like from in*

> *my region, I like to talk to teachers in other schools to see where they are with the syllabus in the first place, with their rating CAPS, for example, is very full. So I like to see where we are, and are we on track and asking about questions. I believe it's good to communicate* [T9, 337-353].

Figure 4.1 represents responses in terms of overarching sub-themes within the theme of overall benefits to teachers. The diagram summarises the responses that were provided by the ten high school teachers during their interviews, according to the categories in Table 4.4.

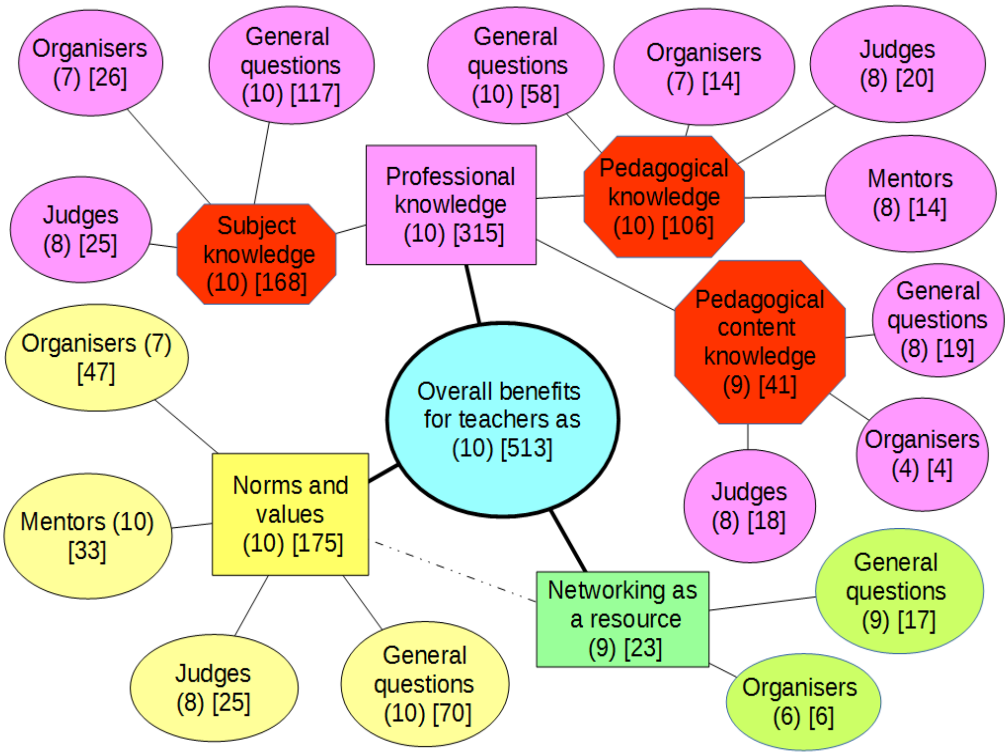

Figure 4.1: Thematic diagram showing the relationships between sub-themes (and knowledge categories) seen by teachers as beneficial for them according to their Expo roles.

The counts given in parentheses show the unique teachers, while the total relative counts are given in brackets. Further explanation is provided in the text. The dotted dash lines from networking as a resource to norms and values means that norms and values have an influence on networking as a resource. It also includes all figures with the same concepts.

SK=Subject knowledge, PK=Pedagogical knowledge and PCK= Pedagogical content knowledge. G=General, which includes both educational significance and sustained participation, O=Organiser, J=Judge, and M=Mentor.

4.5 Benefits of science Expo for participating learners

The benefits for learners who take part as they conduct their scientific investigation projects are shown in Table 4.5. The groupings are categorised according to key words obtained from the teachers' responses during their interviews. These are shown in descending order by the number of teachers as a primary ranking parameter, and aggregate counts as a secondary parameter.

Table 4.5: Benefits of science Expo for learners (according to the teachers)

Sub-themes	**Categories (sub-categories are indented)**	**Responses: Total count, counts according to roles, expressed as UT (T): [G, O, J, M]***
Knowledge widened and enhanced	Knowledge in the curriculum, enhanced science knowledge, investigation and research skills	10 (194): [100; 18; 10; 66]
Developing higher thinking skills	Skills of discovery, critical thinking, presentation skills imitation of scientists	10 (101): [65; 10; 7; 19]
Rewards (Expo and school)	Rewards	10 (54): [44; 10; 0; 0]
	credit and acknowledgement	10 (20): [16: 4: 0: 0]
	gold for learners who reach national and international fairs	9 (9): [9; 0; 0; 0]
	appear in school newspapers	4 (4): [4: 0: 0: 0]
	acknowledgement at the school assembly	3 (3): [3; 0; 0; 0]
	host science Expo	10 (16): [10; 6; 0; 0]
	school website announcement	2 (2): [2: 0: 0: 0]
Science career opportunity	Enhanced interest in a science career, networking with peer learners and scientists winning a bursary	9 (37): [23; 3; 1; 10]
Knowledge about science	Scientific literacy	7 (7): [7: 0: 0: 0]

*UT (T): [G, O, J, M] follows the convection as used in Table 4.4

All of the teachers answered that the participating learners benefitted through widened and enhanced knowledge, improved knowledge in the curriculum (science content); developing higher thinking skills (critical thinking, as well as presentation skills, innovative thinking, and experiment practices); a science career opportunity (bursaries, imitation of scientists' attitudes, science careers, and discovering science); as well as knowledge about science (scientific literacy). Rewards included hosting science Expo, receiving credit and acknowledgement, obtaining gold for hard working learners who reached the national and international level. This further included support, appearing in the school's newspaper, being acknowledged in the school assembly, and being included on the school's website information or announcements.

The thematic diagram in Figure 4.2 summarised the learners' benefits from the Expo, as identified by the interviewed teachers. Six sub-themes emerged from the total number of teachers' responses, namely, 'Knowledge widened and enhanced', 'Developing higher thinking skills', 'Science career opportunity', 'Knowledge about science', as well as 'Rewards gained by learners' from the Expo itself, and the recognition given to Expo participation in 'School support'.

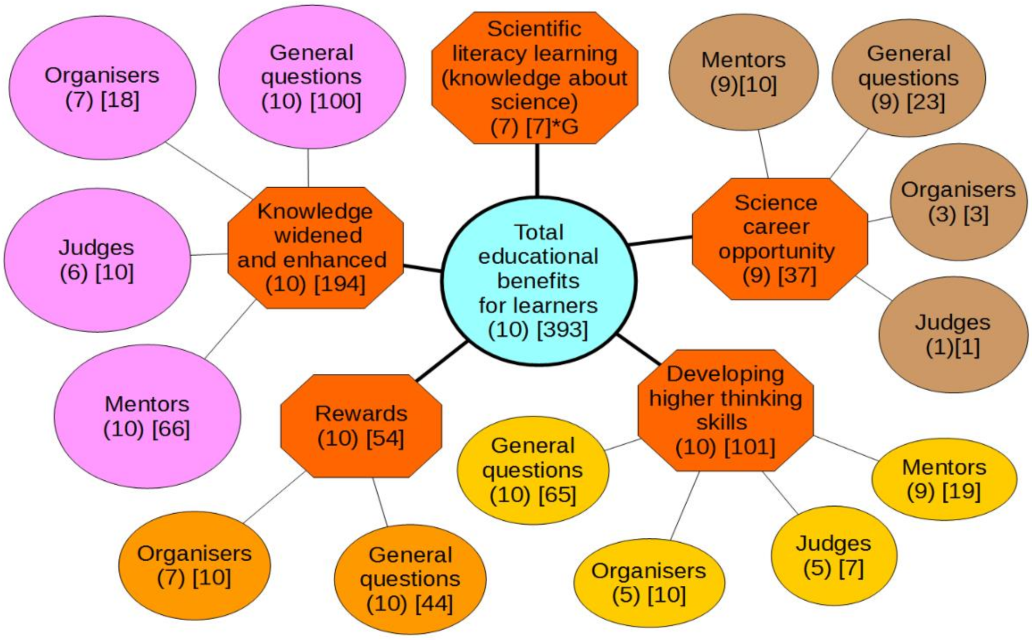

Figure 4.2: Thematic diagram showing the relationships between the sub-themes and categories regarding the benefits for learners according to the teachers' roles.

Counts in parentheses count unique teachers (out of ten), while total relative counts are given in brackets.

4.5.1 Knowledge widened and enhanced

The sub-theme 'Knowledge widened and enhanced' consists of: investigation and research skills, enhanced scientific factual knowledge, knowledge in the curriculum, as well as academic improvement.

Eight teachers mentioned that learners who participated in the science Expo explored and developed an understanding of scientific methods and processing skills. The 'Knowledge widened and enhanced' sub-theme was the most influential concept according to the number of comments and responses from the teachers in their interviews (Table 4.4). The learners were stimulated in their science learning through the application of scientific process skills and inquiry strategies. This agrees with

Smasal *et al.* (2006), who argue that learners' meaningful science education can be achieved through the use of inquiry-based strategies, which will eventually result in the learners becoming science literate.

According to all of the participating teachers, the science Expo improves learners' academic performance. Annlin, Carla, Fransie and Jacob mentioned that learners who were involved in the science Expo were more exposed to scientific topics. In the Expo, learners have the opportunity to experience authentic scientific investigation and learn research skills, more so than at school. Nine teachers maintained that investigative and research skills were two of the main advantages with which the learners participating in the Expo were equipped.

Jacob said:

> *Well, we expose learners to real scientific research. It's much deeper than, and elaborated than school science, and they also are exposed to topics in science that are not covered in the normal school curriculum. Yes, and also they will go deeper into specific study fields than we do in the school. In other words like, let's say, for example, if we are doing esters now, so but we are only touching at it, or polymers, but when they do research they go much, much deeper than what we do in a normal CAPS curriculum* [T5, 439-443].

Annlin, Carla, Jacob and Fransie claimed that scientific processing skills were one of the aspects of the Expo that enabled learners to be more knowledgeable about science topics and science as a subject. Carla said:

> *My kids are doing better, because I'm a better teacher, because I do science Expos* [T3, 696-697].

Carla and Jade explained that learners who participated in the Expo had a better chance of understanding research and investigative processes because they had learnt how to design research questions, present their findings, interpret data, and draw conclusions.

Danielle, Fransie and Ina, also found that science Expo activities were relevant to the science school curriculum policy document in which scientific method processes are also prescribed.

Fransie asserted that scientific method processes were not being taught in sufficient detail in her school. Thus, it seems that science Expo project investigations supplement the school curriculum. Fransie's opinion supported Jacob:

> *I think learners learn the process of research, which is the most important, because scientific method is not emphasised much in the syllabus other than in practical work. So I think the most important thing that they learn is how to carry out research, or how to follow the scientific method* [T6, 28-31].

Jade argued that research is very important for learners:

> *There isn't another place in the curriculum for them to apply their skills in such a large, such a big way than with the science Expo, an extra part of the curriculum* [T10, 456-459].

The interpretation and questioning skills listed by Carla and Jade reflect in the development of higher order thinking skills.

4.5.2 Developing higher order thinking skills

All ten of the interviewed teachers affirmed that in science Expo investigations, learners imitate professional scientists. Learners learn to be independent through presenting their investigation project tasks, and also become critical in their thinking in order to come up with new ideas.

The teachers also reported that learners who conducted investigations found solutions to problems that could help with the scientific challenges that are being encountered by themselves and the citizens of South Africa at large.

In discussing the skills being gained by learners to become scientifically literacy, Fransie is quoted as saying:

> *Yes, because of the exposure those learners get, because they learn from each other, because it's discovery learning. They are constructing their own knowledge by doing something on their own. They do everything on their own. It's just guidance that we offer them. Everything else they do on their own, so at the end that product that they form from the fair is all their work, and I think it is, it's good for them* [T7, 501-506].

In corroboration with Fransie's explanation, Jacob stated:

> *Well we expose learners to real scientific research. It's much deeper than, and elaborated than school science, and they also are exposed to topics in science that are not covered in the normal school curriculum* [T5, 434-437].

It was discussed that communication skills were developed during learners' presentation of their projects through in carrying out research and reporting on their procedures. Learners gained critical thinking skills as well as review their own learning, as clarified by Fransie:

The topic that they choose, they definitely have a better understanding of the topic they choose. I mean if they choose to do something in electricity they're obviously going to work, study, read up more on that, or construct that circuit and they can understand what's happening. So within that topic that they choose, they become more, they understand better [T6, 169-173].

Ina, Glory and Carla described that the learners who participated in the science Expo had further sharpened their innovative thinking and discovery skills, such as using the latest technology. Therefore, as they conducted their project investigations, they were in the process of gradually becoming young scientists who are more innovative.

Science Expo activities that are integrated into the school curriculum in terms of methodology implementation are worthwhile and of educational significance to learners. Danielle and Fransie confirmed this, with Fransie saying:

> *I think learners learn the process of research, which is the most important, because scientific method is not emphasised much in the syllabus other than in practical work. So I think the most important thing that they learn is how to carry out research, or how to follow the scientific method* [T6, 28-31].

4.5.3 Science career opportunities

Danielle described how learners who were involved in the Expo ended up recognising that science is not a boring subject, but rather an interesting discovery process. This occurred because they discovered their own interests in science, which could lead to science careers.

Several teachers mentioned that Expo learners had the chance to learn more about various science careers. Jacob mentioned that he saw an opportunity in the Expo for learners to meet scientists, which could change their perceptions of science, thus influencing learners to choose science as a career:

> *I told you already, it was to expose them to actual scientists to go pursue a career in the natural sciences* [T5, 423-424].

Bernie, Annlin, Carla, Fransie, Glory, Ina, Jacob and Jade reported that they were looking forward to seeing learners furthering themselves in science careers due to a shortage of scientists in the country; which is a major reason for their persistence in their various roles in the science Expo. The institutional school ethos and support in hosting mini-expos is another way of encouraging learners to further their studies in scientific careers.

To conclude, Danielle stated:

> *Yes they do, because while their researching their topic, they find something interesting and if they enjoy reading about that topic, then they become more curious and it encourages them to work harder at their science fair, and if it's a topic they enjoy then they read further on it. Even after the science fair. So they become interested in different careers. They find what they like to do* [T6, 470-474].

4.5.4 Knowledge about science

The teachers elaborated that Expo projects taught learners more about the nature of science, as well as how to observe and understand science as a subject at an integrated level. The interviewees continued by saying that Expo learners had the advantage of understanding science as a subject, not only at a theoretical level, but also in terms of scientific investigative processes that involve the following concepts: innovation, discovering, critical thinking skills, practical experimental work, presentation and communication processes, as well as scientific literacy.

Annlin confirmed the views of Carla, Jacob and Glory as she asserted that her learners learnt more about the body, function, and the basic principles of science, therefore they their scientific literacy skills were enhanced:

> *I think they will have a better understanding of how science as a body functions in the outside world, and if they have a basic knowledge about science, I will say that they are scientifically literate* [T1, 184-186].

4.5.5 Rewards (at the Expo and at school)

Participants may win recognition through awards earned at the Expo, or recognition may be more subtle, for example, through the importance that a school assigns to Expo participation.

All of the teachers indicated that those learners who won medals and certificates at the expos (provincial, national and international) were acknowledged. The schools would follow this up in various ways, including merit points (ten teachers), by mentioning the learners in the school newspaper (four teachers), being mentioned in an announcement in school assembly (three teachers), and placed on the school's website (two teachers). Nine teachers mentioned that their learners had been awarded gold medals at the Expo.

Carla confirmed this in explaining:

> *Yes, they have, you have to do extremely well in our school to be, and you get a certificate of merit. Then if you're chosen to go to Gauteng North expo, they usually let those children stand in the hall and they call them out by name, so the rest can see, ooh look at these clever kids. So they like it. Then if you get gold at regionals you'll get special merits, you get a silver you'll just get merits* [T3, 729-735].

Annlin further described that Expo medallists were awarded honours colours at school:

> *The honour colours are for the children that made it into the regional expo and won a gold medal or a silver medal or a bronze medal* [T1, 519-20].

While Bernie maintained that:

> *Hulle kom in die skoolkoerant as hulle deelgeneem het, en ons gee meriete punte as hulle deelgeneem het.*
>
> Translation*: They appear in the school newspaper if they participated and they get merit points* [T2, 467-9].

Ina described how she gained a sense of achievement in having guided learners to success, while as an additional benefit, the learners could also obtain bursaries:

> *Well, I enjoy helping learners, to discover new ideas, and get new opportunities and to help learners to perhaps; they can win a bursary if they went through to the Northern Gauteng expo. It's part of teaching that I love. It's, yes… I like it and I enjoy it when I can help learners to reach their maximum potential* [T9, 556-560].

Schools also show their support for Expo participation by hosting Expos themselves, for example, the first Expo that began the national movement was held at one of the participating schools in 1980, as described by Gray (2014, p. 27). Carla described this when asked whether and how her school supported Expo participation:

> *Giving us the opportunity to host the science fair for a week, a whole week we have the hall to ourselves. ... sometimes with materials ... Expo boards ... there is a budget for that* [T3, 385-6, 392, 395, 398].

The ethos of these schools celebrated learner participation, with learners even possibly receiving merit points for participating in Expo. Some of the schools gave out merit badges, merit points, certificates, and publicised the achievements of the learners who won awards.

4.6 Disadvantages for learners participating in the science Expo

In terms of this study, the disadvantage in learners participating in the Expo is the fact that they are not included in the Professional Identity model of Beijaard *et al.* (2004), however, this does influence teachers' Professional Identity in a negative way. To further elaborate on the negative consequences of teachers' identity, in spite of the strenuous effort and the hard work that both teachers and learners are putting in, a lot of the time the teachers are the ones who end up facing the difficulties of the Expo alone. The total responses on the theme 'Disadvantages of science Expos for learners' are grouped as shown in Table 4.6.

The negative factors that discouraged learners from taking part in the Expo were resource inequalities, time constraints, poor research design, judges being too strict, learners felt unacknowledged and disappointed, they struggled to get the right topic, and the literature review was confused with projects, and lastly, there was the aspect of group work disagreements.

A particular disadvantage that discouraged learners from pursuing science careers, according to the teachers, was that the judges were too strict while judging these learners. Harmony emphasised this, saying:

> *I think they are very strict when judging at our regional expo, and the children are disappointed in the results* [T8, 44-46].

Fransie argued that another disadvantage was that scientists did not judge the learners fairly according to their actual level as school pupils, expecting too much:

> *Well, it usually its teachers, because we find that sometimes the scientists and engineers, even the university professors, they don't judge the learner according to… I mean this is a Grade. 10 learner. You can't now judge them for their project as if they were a Master[s] student* [T6, 301-304].

Table 4.6: Disadvantages for participating learners of science Expo according to the teachers

Sub-theme	**Categories**	**Responses:** UT (T): [G, O, J, M]*
Negative factors that discouraged learners from taking part in Expos	Resources inequalities	7 (7): [7; 0; 0; 0]
	Time constraints	5 (5): [5; 0; 0; 0]
	Poor research design	5 (5): [5; 0; 0; 0]
	Judges too strict	5 (5): [5; 0; 0; 0]
	Learners feel unacknowledged and disappointed	4 (4): [4; 0; 0; 0]
	Struggle to get right topic	3 (3): [3; 0; 0; 0]
	Literature review confused with the projects	1 (1): [1; 0; 0; 0]
	Group work disagreements	1 (1): [1; 0; 0; 0]

*UT (T): [G, O, J, M] follow the convention as used in Table 4.4

Jacob and Carla explained that this was why they did not invite professors to be judges at their schools. Carla further clarified that they preferred to call in expert science teachers from the neighbouring schools to come and judge the learners and their projects rather than professors. The thematic diagram (Figure 4.3) summarises the findings from Table 4.6.

Other disadvantages mentioned by teachers were that science Expo resources were expensive, which limited learners from poor backgrounds in participating in the Expo.

Learners also need support from their parents and teachers. Jacob emphasised that learners whose parents were not in science-related professions were disadvantaged (while some teachers complained that some parents were too involved in their children's project tasks):

> *Disadvantages, well learners who don't have the support from teachers, parents other scientists. ... If they don't have the support from parents, teachers and scientists/laboratories. ... Yes, well yes, because if, then you really cannot achieve gold, yes* [T5, 49-50, 57-58, 60-61].

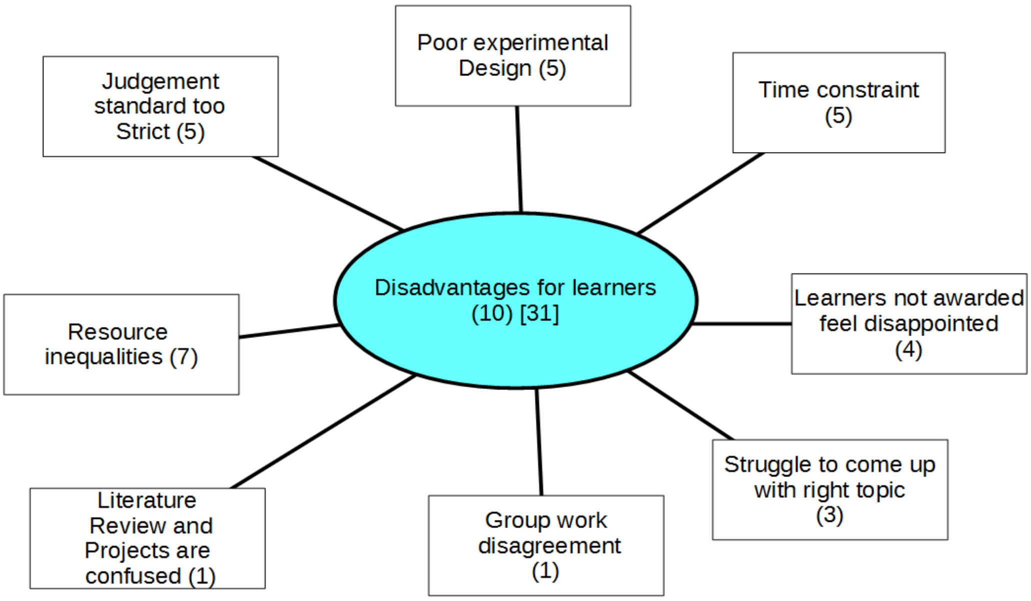

Figure 4.3: Thematic diagram showing the relationships between sub-themes and categories in terms of disadvantages for learners, according to the teachers

Counts in parentheses show unique teachers (out of ten), while total relative counts are given in brackets.

Finally, it was important for the judges to know their subject. Carla was quoted as saying:

> *Make sure that you have knowledgeable judges, there's nothing that really breaks down a child as much, if they've put in a lot into their science Expo, and they are being judged by somebody who doesn't have an idea about their topic* [T3, 364-368].

Although all of the teachers mentioned both advantages and disadvantages for learners, the aggregated count for disadvantages (30) was much less than that for the advantages (513) mentioned.

4.7 Teachers' participation and their Professional Identity

The concepts derived from the teachers' responses were categorised according to the elements of Professional Identity (Beijaard *et al.*, 2004) (see Section 1.6) as subthemes, namely, 'professional knowledge', 'attitudes', 'beliefs', 'emotions', as well as 'norms and values' and 'agency'. The categories were then further associated with each element in Table 4.7. In this way, the theme 'Teacher participation in expos and their Professional Identity' was developed according to the sub-categories raised by participating teachers.

The total number of responses indicated that the sub-theme of 'professional knowledge' dominated the response frequencies (Table 4.7). Therefore, it seems that science teachers and learners who take part in the Expo are most aware of the benefit of gaining scientific knowledge.

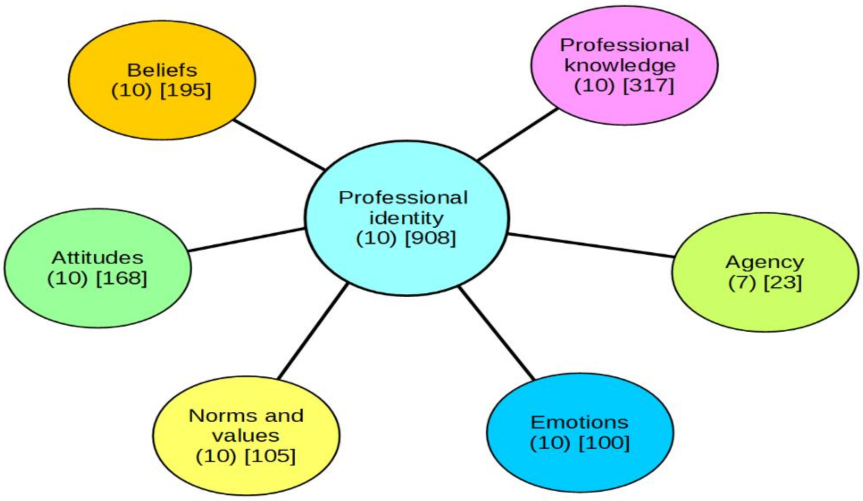

Figure 4.4: Thematic diagram showing the relationships between the sub-themes of Professional Identity (with response totals derived from categories)

Counts in parentheses count unique teachers (out of ten), while total relative counts are given in brackets.

Figure 4.4 shows the relationships between the sub-themes (with response counts obtained from the sub-categories and categories that link to the sub-themes), as related to the teachers' Professional Identity.

Table 4.7: Teachers participation in Expos and their Professional Identity

Sub-themes	Categories	Sub-categories: Grouping of responses according to (Beijaard, 2004) Professional Identity model	Responses: Total, sustained participations and by roles as UT (T): [G, O, J, M]*
Professional knowledge	subject content knowledge,[CK] pedagogical knowledge [PK] pedagogical content knowledge [PCK]	Procedural knowledge Declarative knowledge Knowledge in the curriculum Methodological integration Assessment tasks Enhanced teaching skills Critical thinking skills Skills of discovery Judgement skills Discovering misconceptions of learners	10 (317): [195;44 ;63; 14]
Beliefs	Beliefs	Scientific literacy Knowledge widened and enhanced (investigation and research skills, knowledge in the science and enhanced science factual knowledge) Academic improvement of learners	10 (195): [101; 18; 10; 66]
Attitudes	Attitudes	Mentoring skills Organising skills Learners develop higher thinking skills (skills of discovery, critical thinking, presentation and imitating scientists) Learners gain science career opportunity (enhanced interest in science career, win a prize and networking with the scientists and peer learners)	10 (168): [102; 24; 8; 34]
Norms and values	Norms and values	School ethos Administration /time management School support by hosting Expos Acknowledge and awards learners by school Budget for Expo competitions Teacher collaborating within the school	10 (105): [42; 42; 6; 15]
Emotions	Emotions	Gained enjoyment by interacting with the learners	10 (100): [42; 16; 19; 23]
Agency	Agency	Networking as a resource	7 (23): [17; 6; 0; 0]

*UT (T): [G, O, J, M] follow the convention as used in Table 4.4

4.7.1 Professional knowledge

Here, professional knowledge was formed from three categories: Subject content knowledge (CK), Pedagogical knowledge (PK), and Pedagogical content knowledge

(PCK). Items of professional knowledge were grouped into the following sub-categories: scientific method processes, science content knowledge, data analysis and interpretation in the form of tables and graphs, research questions and hypothesis design, and assessment tasks, which concerns the process of recording the learners' marks from their investigation tasks into their school science curriculum. 'Knowledge in the curriculum' and 'critical thinking skills' were also concepts of 'professional knowledge'.

In light of this, Glory mentioned that she had developed by gaining knowledge from participating in the Expo:

> *Sometimes the kids come up with the best ideas, some stuff that I haven't even thought of, so for me it's developmental as well* [T7, 70].

Carla expanded on this in reporting that she was able to learn how to teach the learners better regarding awareness of mistakes and methods of investigation:

> *So if you judge projects, you have a certain concept of that everybody's supposed to know this, and then you so, but ok they don't know it. So you can better prepare them for possible mistakes and investigations* [T3, 537-540, as well as 543 quoted above].

Fransie mentioned that she had learnt to become aware of how learners think and their misconceptions, both of which are aspects of PCK:

> *Understanding how the learner thinks, that's the most important, I think. You understand how they grasp certain concepts, often when they are explaining to you, their project. You'll pick up on misconceptions that they may have, so you are more aware of how they think, how they understand knowledge, how they construct that knowledge* [T6, 83-87].

The teachers have mentioned gains in their knowledge, ranging from content knowledge to pedagogical content knowledge as the most prominent changes which can be related to a change of the professional knowledge element of their Professional Identity.

4.7.2 Beliefs

The teachers also held the belief that the investigations that were being conducted by the learners were similar to what scientists do, and thus the learners were imitating scientists by conducting procedures in a similar fashion as scientists. Beliefs are constituted by scientific literacy, knowledge that is widened and enhanced, and academic improvement. Knowledge that is widened and enhanced, as presented in Table 4.5, consists of investigation and research skills, knowledge in the science curriculum, and enhanced scientific factual knowledge.

Seven teachers (Bernie, Carla, Jacob, Fransie, Glory, Jade, and Ina) confirmed that they hosted mini-expos for learners in their school, and they showed that they believed that the science Expo was good for learners as they learnt how science functions beyond the normal expectation of school or curriculum bound science.

Annlin corroborated these beliefs in stating:

> *If you are a scientific investigator, you have to further collect information, and it's the same for a project, you have to collect information. ... Yes, and then you have to design an experiment at least to be able to test what the question is asked* [T1, 121-123, 125-126].

Six teachers (Carla, Annlin, Bernie, Jacob, Ina and Jade) mentioned methodological integration of science Expo activities into the school science curriculum and stated that this is educationally worthwhile for both teachers and learners. Carla argued that teachers learnt a lot in expos as she related that there were some topics that teachers may not quite be aware of, but one learns through participating in Expos.

Beliefs were built as the second most prominent element of Professional Identity, as mentioned by teachers.

4.7.3 Attitudes

Participation enhances teachers' knowledge, organising, and mentoring skills, which they value. Developing higher order thinking skills involves skills of discovery, critical thinking, presenting, and imitating scientists. The learners' presentation skills (independent learning and communication skills) were enhanced, as well as their attitude towards opportunities in science careers. Science career opportunities as a category included an enhanced interest in a career in science, winning prizes, and networking with scientists and other learners. Aspects of these attitudes are discussed in Sections 4.4 and 4.5.

Carla, Ina, and Jade explained that they tried to ensure that the learners did well and were successful in their science Expo competitions. Most of the schools from which teachers were interviewed excelled in both academic performance and Expo competitions.

The teachers' attitudes were strengthened when working with their learners, and in becoming successful at Expo competitions. Carla reasoned as follows:

> *Yes, love to, I love thinking out of the box. I would be a great inventor, because I'm constantly looking for but why is this working in such a matter or in such a way and isn't there a possibility of bettering it? So through investigation you become an entrepreneur, and I love being an entrepreneur, because I think you need to encourage children to become an entrepreneur, and if you, if you never practice…* [T3, 342-347].

These discussions concur with Flores and Day (2006), who found that collaborations, commitment, and context are elements that stimulate attitudes.

4.7.4 Norms and values

The concept of norms and values also reinforces teachers' dedication and involvement in science fairs. Most of the teachers (nine) argued that the Expo was part of their school's ethos context, and was compulsory for both them and their learners, which many had internalised and accepted. Norms and values also comprise the schools' ethos, time management and administration, institutional support through hosting mini-expos, acknowledgement and awards given to learners by the school, budget for Expo competitions, and collaboration between teachers within the schools.

According to the interview responses, the schools provided positive institutional support to the science teachers by enabling them to collaborate with one another in mentoring, organising, judging, and guiding the learners with their projects. Thus, this enriched the teachers with the inquisitiveness, passion and acquiring a specific mind set, as well as the strengthening of the teachers' commitment and passion.

In light of this discussion, Jacob emphasised:

> *I told you already it was to expose them to actual scientists […] to go pursue a career in the natural sciences … also that science is more hands on […] than theoretical work* [T5, 423-424, 427-428].

4.7.5 Emotions

The teachers mentioned that they gained enjoyment from teaching through interacting with the learners. Emotions reflect passion, inquisitiveness, eagerness and teachers' desire to help, reward, support and interact with learners.

Carla was an inquisitive and a passionate science teacher who was always willing to help her learners in whatever she encountered:

> *I like science and I like to, I am inspired by innovative thinkers. So if I see a topic somewhere which someone did research on, I think of how I would have done it, what would I have done differently. So that leads to a project for a child for a next year. What about if you investigate this aspect of a subject. So I learn more about creativity, and it inspires me to have different ideas in different fields. The more you come involved in science Expos, it really opens up your eyes to the world* [T3, 505-511].

Emotions involve time constraints, job descriptions, inquisitiveness, as well as teachers' passion for guiding, supporting, and encouraging learners in Expo projects. As discussed the context of attitude sub-theme, the teachers were emotional in that they were passionate and eager to help learners to be successful in the Expo in spite of time limitations. Emotions are interrelated with beliefs (Canrinus *et al.*, 2012), as well as with caring attitudes. These are derived from performance (pedagogical), profession (management and retention), as well as norms and values (O' Connor, 2008). Thus, once learners are successful, teachers' emotions are elevated due to the fruits of their dedication.

4.7.6 Agency

'Networking as a resource' mentioned by seven teachers is associated with *agency* (see Section 1.6.2). The teachers reported that they collaborated with teachers from other schools as they enacted their roles in the Expo through the sharing of experiences related to science curriculum content knowledge. Ina spoke positively about her collaboration with other teachers:

> *Yes, like for instance, I always like to communicate with other teachers. Especially with Grade 10-12, especially with the science because I like from in my region, I like to talk to teachers in other schools to see where they are with the syllabus in the first place, with their rating CAPS, for example, is very full* [T9 337-341].

School ethos that support Expo participation are an extrinsic factor that is reflected in both *Norms and Values* (as a school norm accepted by teachers or reflected in their own expectations as a professional) and in *agency*, as this supports the perception that they will be supported in Expo participation and thus feel more able to act. This dual effect is seen in Jacobs' statement:

> *Well it's for the same reason as one of the other questions, it's nice. I'm a science teacher, it was also part of my job description* [T5. 412-414].

4.7.7 Professional Identity as a theme

In Table 4.7, the elements of Professional Identity have been ordered according to the decreasing number of responses from 'professional knowledge' (317 responses), 'beliefs' (195), 'attitudes' (168), 'norms and values' (105), 'emotions' (100) (mentioned by all of the teachers), and 'agency' (23), which was mentioned by 7 teachers.

The elements of Professional Identity have been associated with the categories that arose from the teachers' responses through the use of the conceptual framework. However, the natural way in which this has been achieved in Table 4.7 provides validation for the use of this theme. In this way, a link is provided for research sub-question (i).

4.8 Benefits for teachers through their various roles at the Expo

This section questions the teachers' scientific knowledge enhancement as they carried out their roles as mentors, organisers and judges at the Expo. They were further asked questions about the relationship between the projects presented at the Expo and the process of discovery used by professional scientists. The integration of science Expo activities into the school science curriculum, and the link between the research carried out at the Expo and the school curriculum were also addressed in this section. The theme 'Teachers and their various Expo roles' is grouped in Table 4.8.

The thematic diagram Figure 4.5 indicates the overall total responses (232) provided by all ten of the interviewed teachers. This was in terms of the roles that they enact in the science Expo. The total responses were grouped into five categories, as indicated in the figure.

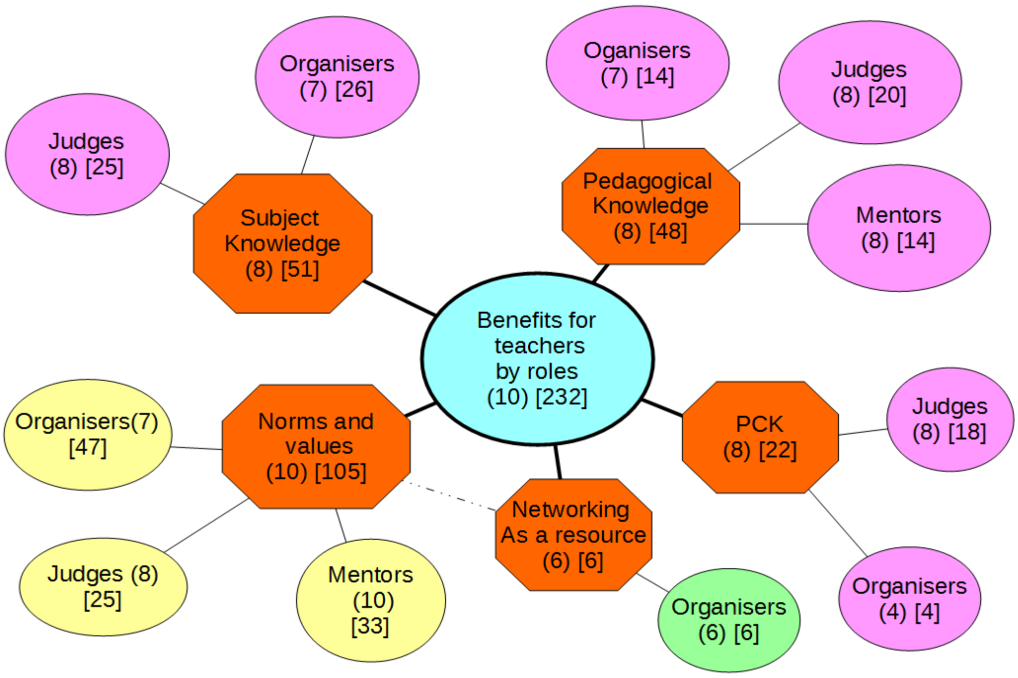

Figure 4.5: Thematic diagram showing the relationships between the sub-themes in terms of the benefits for teachers per role

Counts in parentheses count unique teachers (out of ten), while total relative counts are given in brackets. The dashed lines mean that norms and values stimulate and influence networking as a resource as well.

Table 4.8: Teachers and their various Expo roles

Theme	Categories	Responses: Total, sustained participations and according to roles, as UT (T): [G, O, J, M]*
Benefits of science Expos for teachers	Norms and values	10 (105): [0; 47; 25; 33]
	Subject content knowledge	8 (51): [0; 26; 25; 0]
	Pedagogical knowledge(PK)	8 (48): [0; 14; 20; 14]
	Pedagogical content knowledge (PCK)	8 (22): [0; 4; 18; 0]
	Networking as a resource (agency)	6 (6): [0; 6; 0; 0]

*UT (T): [G, O, J, M] follow the convention as used in Table 4.4

4.8.1 Norms and values

Five teachers (Carla, Fransie, Annlin, Ina and Jade) noted that they and their peer teachers at their school were judges at their school Expo. All of the teachers mentioned that they had to judge science Expo activities as an expectation within their school environment, at least at the school level Expo.

4.8.2 Subject content knowledge

Subject content knowledge was listed second in importance in terms of the teachers' roles at the Expo, with 51 responses from eight interviewed teachers.

4.8.3 Pedagogical knowledge

Five teachers (Bernie, Carla Jacob, Ina and Jade) mentioned that they gained new knowledge from other school teachers. Jacob said:

> *Well I got new ideas from them, how they did it at their schools, asking them who really participate as part of the curriculum. Which grades, which classes, which subject* [T5, 239-241].

4.8.4 Pedagogical content knowledge

Six teachers (Annie, Carla, Ina, Jade, Jacob and Fransie) found that the judging procedure provided them with an opportunity to interact closely with their learners in terms of Expo activities, and in return they discovered learners' scientific misconceptions. The issues that they came across while judging helped the teachers to discover the misconceptions of their learners. Carla emphasised this:

> *Yes, you see their misconception* [T3, 543].

Glory explained that as an Expo judge, she was also able to realise learners' misconceptions, and gained improved judging skills that assisted her in her methodological instructional classroom practices. She again emphasised that due to the Expo, she could address misconceptions, particularly with regard to variables:

> *Yes definitely, just in normal, when we explain practical investigations. When we do the judging for the science fairs, we see that there are definitely learners who struggle with identifying the variables, for example. So that reminds me in turn, when I'm in my normal class to explain that properly, and in more detail than what I usually did* [T7, 223-227].

4.8.5 Networking as a resource (agency)

The teachers collaborated with teachers from other schools to exchange their experiences of the science curriculum, and their experiences with science Expo projects to assist the progress of their learners. Six unique teachers mentioned networking opportunities. Bernie is quoted in Afrikaans:

> *Ons maak maar kontak met ander skole, of my kollegas, en met eintlike enige praktiese eksperimente wat ons moet doen ook.*
>
> Translation: *We make contact with other schools, or my colleagues, and in fact with any practical experimental work that we are supposed to do* [T2, 258-260].

Networking as a resource contributes to *agency*, as described in Section 4.7.6. It appears to be primarily the role of organising that gave rise to this comment. The reason for this could be that the need to take responsibility may require actors to ask more experienced colleagues for advice, which could hence lead to an appreciation of this resource.

4.9 Teachers' sustained participation

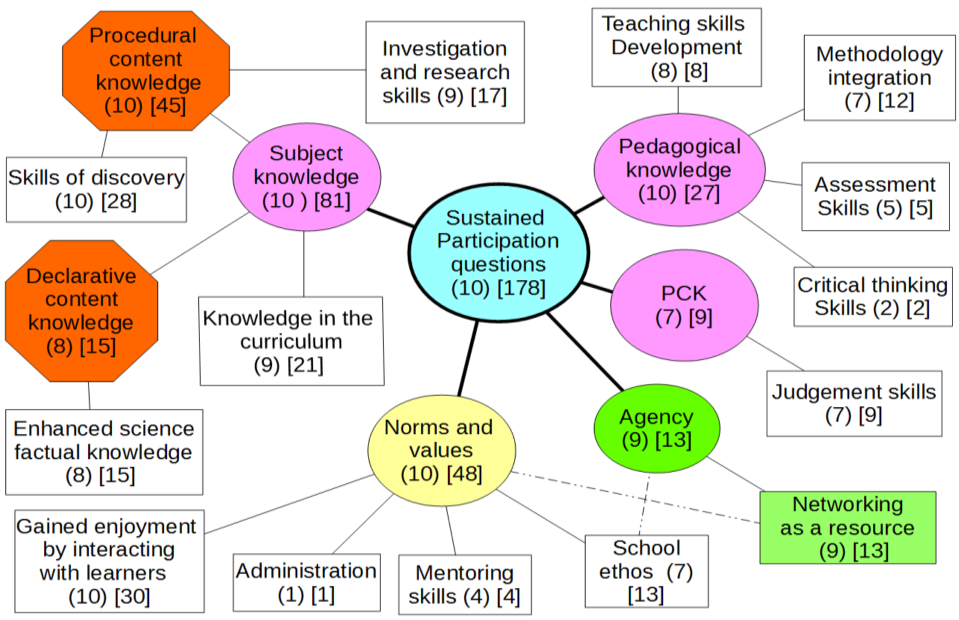

Figure 4.6: Thematic diagram showing the relationships between the sub-themes and categories in terms of teachers' benefits that they say sustain their participation

Counts in parentheses count unique teachers (out of ten), while total relative counts are given in brackets.

This section looks at the replies to the interview questions of Section 3 (a) to (e) of the interview schedule (Appendix 4), which address the teachers' reasons for participation, and particularly sustained participation. The categories contributing to the theme 'Sustained participation of teachers' is grouped in Table 4.9, and links are illustrated in Figure 4.6. Each sub-theme (professional knowledge with categories: Subject knowledge, Pedagogical knowledge and Pedagogical content knowledge, Norms and values, and Networking as a resource) is discussed separately.

Table 4.9: Sustained participation of teachers

Sub-theme	**Category**	**Responses Total, Sustained participations and by roles as UT (T): [G, O, J, M]***
Professional knowledge		10 (117): [117: 0: 0: 0]
Subject content knowledge	Procedural content knowledge, declarative content knowledge, and knowledge in the curriculum	10 (81): [81, 0, 0, 0]
Pedagogical knowledge (PK)	Methodological integration, critical thinking and assessment skills	10 (27): [27, 0, 0, 0]
Pedagogical content knowledge (PCK)	Judging skills	7 (9): [9, 0, 0, 0]
Norms and values	Gained enjoyment by interacting with learners, school ethos, mentoring skills, administration skills	10 (48): [48, 0, 0, 0]
Agency	Networking as a resource	9 (13): [13, 0, 0, 0]

*UT (T): [G, O, J, M] follow the convention as used in Table 4.4 (Category counts that contribute ro sub-theme counts are indented)

4.9.1 Professional knowledge

The three components of professional knowledge that were identified in Table 4.9 will now each be discussed separately.

- ***Subject content knowledge***

The sub-theme 'Subject Content Knowledge' relates to procedural content knowledge, which consists of investigative and research skills, skills of discovery, as well as declarative content knowledge. This includes factual knowledge gained, whether within or outside of the school curriculum.

The teachers who took part in the science Expo and carried out various roles gained scientific knowledge. Carla expanded on this:

Oh, a lot, because there are certain topics of which you aren't a master of, and through expo you learn so much more of a, in depth of a certain topic. ... Ok, for physics and science, as I said, there are some topics, which I learned so much more [T3, 66-67, 84-85].

- ***Pedagogical knowledge***

Ten unique teachers identified the aspects of pedagogy that they had gained. They learnt how to integrate the methodology of science Expo activities into the school curriculum, as well as critical thinking and assessment skills. Glory commented that in her school, research projects were included and assessed in school curricular activities:

Yes, we have a research project for Grade 11s and they do a research project as part of formal assessment. ... For the Grade 11s, we do exothermic and endothermic reactions as a research project [T7, 138-139, 143-144].

Carla commented on the educational significance of the Expo to science teachers:

Latest discoveries, ... I'm more aware of how important it is for a child to do research in the correct way. ... My knowledge increased a lot. My way of thinking changed. ... I'm all about critical thinking and innovation. ... My kids are doing better because I'm a better teacher, because I do science Expo. ... So my involvement in science Expo really bettered me as a teacher [T3, 665; 673-674, 677-678, 681, 696-697; 719-720].

- ***Pedagogical content knowledge***

Most of the teachers stated that they were knowledgeable about judging as they judged learners' projects in the Expo. Carla explicated that as a lifelong learner, she kept on learning about the learners' conceptual errors:

You are more aware of the limitations that children have. So you can help them overcome that barrier. It's important because if you, if you judge science Expos, you get to know where children make mistakes. So in your subject you can better address that [T3, 525-528].

Alternatively, Danielle maintained that they had to take part in order to be well-informed regarding judgement criteria:

> *Yes, I think so. I do think so, because without judging you won't be, you won't know what is out there and how to coach and teach your learners in future. You need to know what is out there before you can coach them properly* [T4, 287-290].

The professional knowledge gained from the Expo was mentioned by all of the teachers, with subject content knowledge and pedagogical knowledge mentioned the most often, while PCK was mentioned by seven of the ten teachers in the context of judging. It was in this context that these teachers discovered misconceptions, and better ways to address the preparation of their learners, both in the classroom and for Expo participation. Annlin expressed that:

> *I think a science fair, or a science project helps you to think in a certain manner. So you have to organise information, it helps with processing skills and organising skills. ... And organising skills, and rational thinking skills* [T1, 93-95, 97].

4.9.2 Norms and values

All of the interviewed teachers claimed that the science Expo was regarded and considered seriously within the school ethos, to the extent that their schools expected Expo participation from the teachers and learners. Jacob, Annlin, Carla, and Fransie reported that scientific method processes were not emphasised enough in the school science curriculum, and that the Expo provided the opportunity for learners to gain process skills. These teachers thus integrated science Expo activities into the school curriculum as methodological incorporation for the assessment tasks. This occurred due to the schools' ethos, and the institutional support provided. Annlin explained:

> *Yes, it's part of the marks, its part of the School Basic Assessment (SBA). It's like 20% of the SBA* [T1, 166-168].

Ina elaborated that Expo competitions were part of her school science curriculum:

> *Compulsory from Grade 8, I think, up to matric, and all this learners with all their creative ideas. It was just so amazing to see what creative ideas high school learners can come up with, and it inspired me to see, because they are the new scientist of tomorrow. So yes, I like it to see what, what's new, what investigate* [T9, 362-366].

Jacob added that his school expected Expo participation:

> *Well it's for the same reason as one of the other questions, it's nice. I'm a science teacher, it was also part of my job description* [T5, 412-414].

These views of the teachers formed part of their expectations in terms of their professional role, and as such reflects their internalisation of these norms and values. This concurs with Flores and Day (2006), who describe the influence of school atmosphere on Professional Identity.

4.9.3 Agency

Six teachers agreed that they had obtained some resources from other teachers who were also involved in the Expo, and therefore they recognised the networking opportunity provided by the Expo as a resource. The teachers also explained that they were constantly communicating with one another in terms of the school science curriculum. Fransie asserted:

> *Yes, because organising a science fair, or going for a science fair, you need different teachers, you… most of you share the same subject. So you learn, you'd often discuss, because that's what you have in common. Different teaching approaches, discuss how your learners understand different topics. Yes, your conversation you know, how you explain certain things, what have you found that your learners struggle with, how do you explain it*? [T6, 340-346].

The Expo is thus viewed as a resource and affects Professional Identity, in particular linking to the element of *agency*. This item has consistently been identified as a sub-theme in the responses of the teachers. The valuing of networking opportunities as a resource could be seen as reflecting norms and values, and correspondingly, this link is shown as a dashed line in Figure 4.6.

4.9.4 Teacher identified factors

The questions that directly addressed teacher participation identified professional knowledge gains most frequently, as mentioned by all of the teachers, (with the role of judging providing opportunities to discover learners' misconceptions as PCK) followed by the internalisation of the schools' ethos, thus developing their norms and values. In addition to these effects on their Professional Identity, nearly all of the teachers valued the opportunity to network with other teachers at the Expo, although this was mentioned less than the other factors.

Many responses that explain continued participation, in addition to the direct questions of Section 3, of the interviews are provided. An analysis of all of the questions (which include those of Section 3) in terms of Ajzen's factors provided further explanatory insights, which are discussed in the next section.

4.10 Reasons for sustained participation, as identified using Ajzen's theory

In order to understand the reasons given by the teachers for taking part in the Expo, and particularly why their participation was sustained, it was useful to include Ajzen's (1991) Theory of Planned Behaviour (TPB). Ajzen's theory provides a structured basis for identifying predictive factors that lead to the intention to participate, and with sufficient perceived efficacy and control, to actually participate in the Expo (the theory and its merits are discussed in Section 2.7). In this section, the categories that can be interpreted in terms of variables in Ajzen's theory are grouped and linked to the elements of Professional Identity and are presented in Table 4.10. These associations enabled the researcher to rank the factors that contributed to these teachers continued participation in the science Expo.

Ajzen's theory postulates three variables that are linked to intention, namely, the *attitude towards the behaviour* (the degree to which an individual favourably considers participation), *subjective norms* (the degree to which an individual is pressured to perform in the community, such as the school ethos, whether remaining external or internalised), and *perceived behavioural control* (including self-efficacy beliefs and refers to the perceived ability to perform the behaviour).

Table 4.10:Teachers' overall responses that correspond to the elements of Ajzen's (1991) theory and concepts of Beijaard's (2000, 2004) model of Professional Identity

Elements of (Ajzen's, 1991) Planned behaviour theory	**Responses: Total, sustained participations and by roles as UT (T): [G, O, J, M]***	**Concepts of Professional identity that relate to Elements in Ajzen's theory**
Perceived behavioural control	10 (535): [314; 68; 73; 80]	
(*Professional knowledge*)	10 (317): [196: 44: 63: 14]	Professional knowledge
Procedural content knowledge Declarative content knowledge Knowledge in the curriculum	10 (170): [119; 26; 25; 0]	Subject content knowledge
Methodological integration, Critical thinking skills, Assessment skills, Self-enhanced teaching skills	10 (106): [58; 14; 20; 14]	Pedagogical knowledge(PK)
Judging skills, Discovering misconceptions	9 (41): [19; 4; 18; 0]	Pedagogical content knowledge (PCK)
(Self-efficacy beliefs) Scientific literacy Knowledge widened and enhanced (investigation and research skills, knowledge in the science and enhanced science factual knowledge) Academic improvement of learners	10 (195): [101; 18; 10; 66]	Beliefs [involves benefits to learners and teachers]
(*Agency*) Resources and opportunity	9 (23): [17; 6; 0; 0]	Agency
Subjective Norms	10 (275): [112; 63; 44; 56]	
Gained enjoyment by interacting with learners, Collaboration of teachers with the schools, School ethos, Administration and time management, Academic improvement and successes of learners provides a sense of their professional achievement, and thus supports. *Perceived behavioural control* (Organising skills, Mentoring skills)	10 (175): [70; 47; 25;33]	Norms and values
Gained enjoyment by interacting with the learners Supportive development of self-efficacy also influences *attitudes towards the behaviour* having positive consequences, as well as supporting *perceived behavioural control*	10 (100): [42; 16; 19; 23]	Emotions
Attitudes towards behaviour	10.(168): [102; 24; 8; 34]	Attitudes
Organising, Mentoring, Developing higher thinking skills, science career opportunities		

*UT (T): [G, O, J, M] follow the convention as used in Table 4.4. (Contributory counts are indented)

Table 4.10 includes the overall responses from the teachers that stimulate initial or strengthen self-efficacy beliefs and beliefs in the value of the science Expo, attitudes towards the Expo, and subjective norms and perceived behavioural control in relation to the prediction of intentions (motivations). These are anticipated to vary across behaviour and conditions. The Professional Identity concepts based on Beijaard *et al.*'s (2004) have been classified in Table 4.7 and analysed in Section 4.7, and will not be repeated in this section. Table 4.10 shows the responses (978) obtained from the ten teachers. The categories that contributed to perceived behavioural control (PBC) dominated with 535 responses, followed by subjective norms with 275 responses, and attitudes towards behaviour as the lowest ranking with 168 responses.

Perceived behavioural control involves *professional knowledge* (317 responses, with subject knowledge having 170, pedagogical knowledge with 106, and pedagogical content knowledge with 41), with *beliefs* showing 195 responses, and *agency* 23 responses.

In addition to PBC, the factors leading to the intention to participate were both extrinsic and intrinsic appreciation and expectations as '*subjective norms*' (275 responses) (from *Norms and values* – 175, and *emotions* with 100 responses). As shown in Table 4.10, aspects of *Emotions* are themselves supportive for *Perceived behavioural control* and *Attitudes towards the behaviour*, which tends to support Ajzen's use of the relationship (greyed) arrows implying a belief of overlap between the three causal variables in Figure 4.7. However these potential shifts in possible interpretation do not influence the overall conclusion of a dominant role for PBC.

Participation is viewed as beneficial and contributes to the variable '*attitudes towards the behaviour'*.

It can be concluded that these teachers continued their participation in the Expo because their perceived behavioural control was continuously maintained and strengthened, while their norms and attitudes remained positive, yielding the positive intention to participate.

4.10.1 Perceived behavioural control

PBC contains *professional knowledge*, *beliefs* and *agency* elements of Professional Identity. Professional knowledge (Tables 4.4-4.8 and discussed in Sections 4.4-4.8) dominates. All teachers stated that they were enhanced with knowledge such as procedural content knowledge skills (IBL), declarative content knowledge (facts) and knowledge in the curriculum.

Teachers (Annlin, Bernie, Carla, Danielle, Jacob, Fransie, Jade and Ina) stated in Section 4.5 that their learners are doing better when it comes to scientific investigation knowledge and academic performances. Most teachers like Annlin, Carla, Bernie, Jacob, Fransie, Glory, Ina and Jade have already been quoted and discussed in the Sections 4.4 to 4.8 as well as Table 4.4 to 4.8 based on beliefs and perception of benefits.

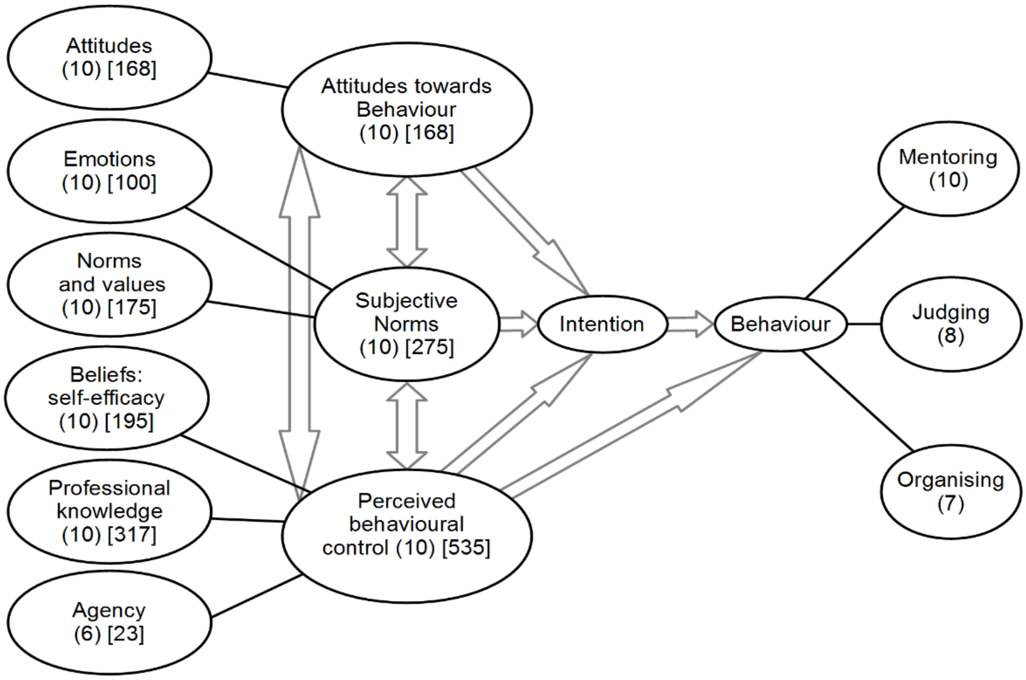

Figure 4.7: A conceptual diagram showing a relationship between the sub-themes (elements) of Professional Identity and Ajzen's variables with counts that show the relative importance (or ranking) of factors expressed as benefits by teachers that lead sustained participation.

Counts in parentheses represent unique teachers (out of ten), while aggregated relative counts are given in brackets.

Greyed hollow arrows show the relationships established by Ajzen (1991), while the links to Professional Identity and roles are superimposed as solid lines. PBC is dominant.

Agency (which includes networking as a resource, but is also supported by internalised school and professional values) positively influences PBC which stimulates both intentions and behaviour which depends on resources and opportunities.

Disadvantages to (some) learners would reduce the strength of the intention to participate, but this negative factor can be managed through selection of the level particular learners must achieve to be given the opportunity to compete outside the school (section 4.6).

4.10.2 Subjective norms

Subjective norms consists of norms and values, and emotions. Norms and values have already been discussed in Section 4.4. Emotion was also discussed in Sections 4.5 and 4.7; and this element influences Ajzen's *subjective norms*, and has supportive roles in both *Attitudes towards the behaviour* and PBC. Overall, these have reflected as positive, and some 275 responses were noted. The perceived value of participation leads strongly to the intention to participate.

4.10.3 Attitudes towards behaviour

Attitude (directly influencing Ajzen's *attitudes towards behaviour*) has been discussed in Sections 4.4, 4.5 and 4.7. The teachers (Annlin, Bernie, Carla, Danielle, Jacob, Fransie, Jade, and Ina) understood that learners participating in the science Expo had opportunities to appreciate and aspire to science careers, and meet scientists. The teachers reiterated that the learners' ability to discover, their critical thinking and scientific thinking skills respectively were enhanced. Thus, this satisfies the desire of most teachers who are eager to see their learners furthering themselves in careers in scientific fields.

4.10.4 Relationship with Professional Identity

Perceived behavioural control was the dominant factor supporting the teachers' participation with 535 responses. Subjective norms followed with 275 responses, and attitudes towards behaviour had 168 responses.

Teachers' beliefs, emotions, and caring attitudes towards their learners in the science Expo in terms of mentoring, organising and judging had influenced their self-efficacy. Motivation, commitment, job-effectiveness and satisfaction, as emphasised by Canrinus *et al.* (2012) and Day *et al.* (2006), were enhanced and expressed through PBC. This reflects strengthened Professional Identity.

4.11 Updated conceptual framework that includes Ajzen's TPB

The model shown in Figure 4.8 describes the dependence of the teachers' roles on Professional Identity in terms of a simple Input-Process-Output systems model. The Theory of Planned Behaviour (Ajzen, 1991) provides the process that links the Professional Identity of teachers (Beijaard *et al.*, 2004) (as input) to their roles in the science Expo (as output). It was expected that the teachers sustained their participation in the science Expo because participation brought enhancement in some way to their Professional Identity. This postulated effect is shown as a feedback loop in Figure 4.8.

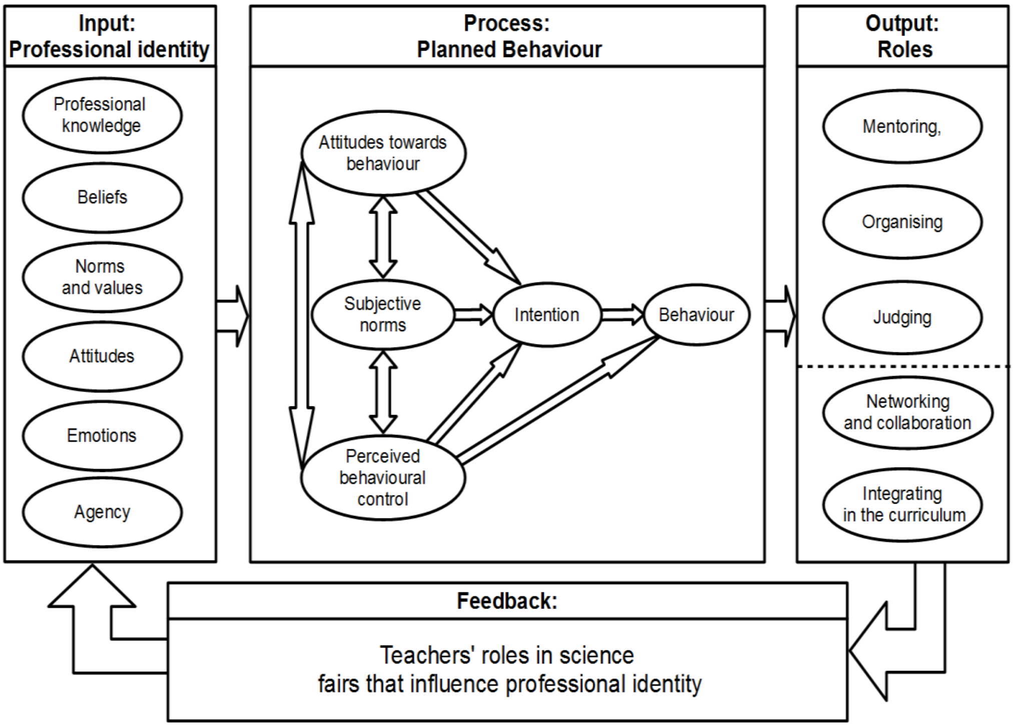

Figure 4.8: A general IPO systems model with feedback that links the Professional Identity of teachers to the teacher's roles in science fairs through the processes described by the Theory of Planned Behaviour

As shown in Figure 4.7, the elements of Professional Identity (Beijaard *et al.*, 2004; Flores & Day, 2006) can be associated with variables of the Theory of Planned Behaviour (TPB) (Ajzen, 1991). Similarly, the roles taken up by teachers in the science Expo are a consequence of decisions regarding their behaviour, and thus Ajzen's (1991) "behaviour" variable is associated with the roles (behaviours) in the "output" element of the simple model. The experiences during the explicit actions, and the subsequent activities (below the dashed line in the Outputs section) provide feedback that influences the elements of Professional Identity, and if positive, serve to reinforce the behaviour, and hence sustain participation.

Table 4.3 in Section 4.2 discussed and summarised the teachers' roles in the Expo. Most of the teachers were involved as organisers at school-based mini-expos. Ina was the only teacher who had organised for the national Expo competitions in her school, although all of the teachers participated in mentoring learners.

The role of judging was carried out by most of the teachers (8) at school level, except Jacob and Harmony. Five of the teachers had participated at regional level, while none of the teachers had yet judged at national level.

4.12 Concluding remarks

The teachers who participated in this study were selected from schools that had had learners and teachers involved in the Expo for at least five years. These teachers were thus expected to contribute reasons for their participation and that of their schools, which allowed for the identification of what schools can do in order to increase participation and success in science teaching.

Beijaard *et al.*'s (2004) model of Professional Identity was useful in collecting the categories that arose from the interviews. Expo participation strengthened the level of teachers' knowledge and skills, as well as other aspects of Professional Identity as feedback. This translated mainly as perceived behavioural control, an important variable of Ajzen's (1991) explanatory and predictive Theory of Planned Behaviour. The enhancement of Professional Identity (and professional knowledge and skills, including self-efficacy beliefs) allowed participation in science fairs to be characterised as a form of continued professional development. This is in agreement with Zivkovic (2013, p. 150), who found that teachers "are more inclined to taking self-initiative in professional development than to have it regulated by extrinsic motivators". This characterisation conforms to the explanatory role of perceived behavioural control: teachers do it because they believe that they should and can, and participation provides professional development, and they and their learners benefit.

Seven teachers argued that Expo activities gave them opportunities to interact with their learners in a way that enabled them to discover learners' misconceptions of the science curriculum. In several cases, science Expo activities were included in the school curriculum, and contributed to school year marks. Therefore, they encouraged the learners to participate in an effort to improve their overall marks.

The teachers who were involved in the science Expo obtained scientific content knowledge, scientific process teaching, discovering learners' misconceptions, and methodological teaching integration strategies of science Expo activities into the science curriculum in general.

In the next chapter the findings are organised and presented according to the research questions. These are then critically analysed and, within the context of limitations, tenable conclusions and their implications for further research and practice are discussed.

CHAPTER 5

Findings, discussions, limitations, recommendations and conclusions

5.0 Introduction

Chapter 5 consolidates the findings of Chapter 4 according to the research questions. The limitations, recommendations and conclusions that were deduced from the findings are presented and discussed in this chapter.

5.1 Discussion in terms of the research questions

The collated sub-themes and categories and their analysis have been presented in Chapter 4 (Sections 4.4 - 4.7), and were analysed using the conceptual framework (Section 1.8). This assisted in addressing the main research question through the three sub-questions, which are presented in the following sections. The findings were then synthesised according to the main research question to provide an overall set of findings and conclusions.

5.1.1 Educational significance of participation in science fairs

The first sub-research question was:

> *What is the perceived educational significance of teacher participation in science fairs to their Professional Identity as well as their professional development?*

- **Professional Identity**

Beijaard *et al.*'s concept of Professional Identity (Beijaard *et al.*, 2000; Beijaard *et al.*, 2004) was used as a theme in the analysis presented in Section 4.7, and formed the most important segment of the conceptual framework. Professional Identity consists of '*professional knowledge'*, '*beliefs'*, '*attitudes'*, '*norms and values'*, '*emotions'*, and '*agency*' with each of these treated as a sub-theme.

Of these sub-themes, a gain in '*professional knowledge*' dominated the teachers' responses, with all of the teachers mentioning examples of the knowledge gains that they had experienced due to their participation. These included gains (given in order of importance as reflected in the number of unique teachers and response counts in

Table 4.4) such as subject content knowledge, pedagogical knowledge (all of the teachers) and pedagogical content knowledge (Shulman, 1986) (nine teachers).

Subject content knowledge improvements primarily included procedural knowledge with some declarative knowledge and curricular knowledge enhancement. pedagogical knowledge included the methodological integration of practices gained from Expo participation, critical thinking skills, assessment, and enhanced teaching skills. PCK was enhanced through the ability to judge student activities in relation to scientific knowledge, the guidance of discovery, and gaining awareness of the learners' misconceptions. Many professional development interventions were offered to the teachers with a view to enhancing PCK (Karisan *et al.*, 2013; Tortop, 2014 b). The reason for this was that it was thought to facilitate science teaching and learning, particularly of learners in terms of science literacy and the nature of science (NOS) through the use of inquiry based learning (IBL) (Anderson, 2015).

Next in importance was the sub-theme of teachers' '*beliefs'*. The teachers mentioned that from their viewpoint, through participation in the science Expo, their learners gained scientific literacy, improved academic performance, scientific investigative and research skills, as well as enhanced science factual knowledge (Table 4.5). This belief agrees with researchers who argue that learners who participate in science fairs are exposed to a broad diversity of education (Abernathy & Vineyard, 2001; Bencze *et al.*, 2008; Molefe, 2011, pp. 29, 33, 185). In turn, it may be expected that such beliefs influence pedagogical strategies (Anderson, 2015; Savasci-Acikalin, 2009).

With the sub-theme '*attitudes*' all teachers reported that they were stimulated through mentoring and organising activities as they performed their roles in the Expo, and that their skills in enacting these roles were developed (Tables 4.4, 4.6 and 4.8). The teachers mentioned that learners participating in the Expo gained skills of discovery, critical thinking skills, presentation skills, the desire to emulate professional scientists, and were exposed to science career opportunities (enhanced interest in science careers, winning prizes, and networking with both scientists and peers) (Table 4.5). This supports the findings of Egenrieder (2010), Molefe (2011, pp. 97-100), Nath (2007) and Sahin (2013), who reported that teachers who participate in science fairs develop facilitation attitudes (corresponding to positive experiences and corresponding willingness towards mentoring). This finding can also be extended to the role of organising.

However, the disadvantages for learners, as presented in Table 4.6, influenced the teachers' '*attitudes*' negatively as all of the teachers mentioned that where learners were not awarded or positively complimented, the learners felt disappointed. The participating teachers described other disadvantages in terms of their various roles, such as time constraints and inequalities in terms of resources (learners whose parents were not professors, doctors or in any other professions tended to struggle).

The '*norms and values*' (Tables 4.4 and 4.8) category involved sub-categories of administration and management, guiding, collaboration with peers, school ethos, budget for expos, hosting mini-expo evening exhibitions for learners, as well as acknowledgement of and awarding learners who participated in the Expo. The concepts of school ethos and teachers' collaborative attitudes concur with Grant *et al.* (2013) and You and Craig (2013), who contend that collaboration promotes partnership within the institution, which further enhances teachers' attitudes (Flores & Day, 2006).

In the sub-theme '*emotions*' (Table 4.5), this was enhanced by the teachers' opportunity to work with their learners (teachers gained enjoyment from interacting with the learners). The teachers mentioned that they were impressed to see learners improving in their scientific concept skills, and enjoyed seeing their learners be acknowledged and awarded by the school. This agrees with Botha (2012, pp. 35-36), van Putten (2011, p. 272) and O'Connor (2008), who have found that 'emotions' involve caring attitudes, collaboration, pedagogical expertise, commitment and effectiveness; and appraisal of the situation (Den Brok *et al.*, 2011).

'*Agency*' is about being active in the process of professional activities with the intention of pursuing educational goals through the use of available resources (and even creating resources) (Beijaard *et al.*, 2004; Beauchamp & Thomas, 2009; Day *et al.*, 2006). The participants explained that the science Expo offered them the opportunity to network with teachers from other schools in which they discussed the science syllabus. They further said that as they took part in the Expo, they gained some resources and, in return, they integrated these into their methodology and practices at their various schools. In addition, the schools' ethos was a further extrinsic factor that contributed to agency.

- **Contribution to professional development (PD)**

The findings revealed that teachers who are involved in the science Expo gain growth in all dimensions of their Professional Identity, especially professional knowledge (Table 4.4, Table 4.5, Table 4.7 and Table 4.10), which is often associated with the specific goals of professional development workshops. This participation strengthens their positive 'attitudes', 'beliefs' (which includes pedagogical as well as self-efficacy beliefs), opportunities to improve their support structures through networking, and promotes positive emotions (through sharing in their learners' achievements in both improved learning as well as awards gained through learners' Expo participation). 'Agency' is also strengthened. Hardre *et al.* (2013) report that professional development addresses Professional Identity and self-perception, the teachers' experiences of learners' conceptions, collaborating and social networking with other teachers through new knowledge, resource benefits, reciprocal sharing and learning, complementary and innovative skills, as well as the practical integration of IBL in classroom practices. Similarly, Zivkovic (2013) contends that professional development involves the enhancement and provision of new knowledge, as well as sharing experiences with different teachers. This is strongly in agreement with the benefits described by the teachers regarding their participation in the Expo (Table 4.4).

Participation in the science Expo provides both development as professionals (enhancement of their professional identities) and the correct setting for professional development. Readiness for professional development correlates with Professional Identity, and this readiness is influenced by both intrinsic and extrinsic factors (Coldron & Smith, 1999; Zivkovic, 2013). This is particularly the case if the teachers are themselves aware of the need for development (Zhang *et al.*, 2015).

5.1.2 The educational significance of Expo analysed by roles

The second sub-research question was:

> *What is the educational significance of science fairs in the opinion of the teachers who participate as organisers, mentors and judges?*

Teachers' perceptions that are associated with the various Expo roles, specifically, organising, mentoring and judging learners' projects were analysed mainly through Table 4.8. Table 4.4 contains contributions from Tables 4.5, 4.7, 4.9 and 4.10, with various roles (organising, mentoring, and judging) highlighted in these tables. '*Benefits for teachers in Expos*' involves the teachers' experiences with the categories: 'Subject content knowledge' (CK), 'Pedagogical knowledge' (PK), 'Pedagogical content knowledge' (PCK), 'norms and values', and 'networking as a resource' (agency). These were addressed by the teachers as being areas in which they or their learners gained knowledge, skills or opportunities.

The sub-themes found included skills for conducting research, designing, performing, analysing and presenting investigations, mentoring skills, judging skills, and assessment skills. The participants described discovering the latest technology, innovation, and the development of inquisitiveness and critical thinking in themselves and their learners. They gained new knowledge and were supported through the school ethos, as reflected in their job descriptions, by their schools hosting their own science Expos. They found that their participation in the Expo provided opportunities for networking, which was a resource for collaboration and sharing of experiences with fellow teachers, and similarly amongst the learners.

- **Mentoring**

Ten teachers mentored learners during their Expo participation. The teachers mentioned the enriching experiences they had this role. From these findings, two sub-themes, reinforcement of norms and values, and pedagogical knowledge were found. The teachers noted that their participation helped learners to be successful in "both competitions and at school". They got the opportunity to interact with the learners and their peer colleagues, and to discover learners' misconceptions, as well as the difficulties that learners experienced in learning to perform investigations.

Learners' knowledge was widened, higher order thinking skills were developed and science career opportunities became available (Table 4.5, Figure 4.2). Learners' enrichment in terms of scientific knowledge strengthened and influenced the teachers' attitudes and beliefs about the science Expo. In turn, many of the teachers were able to observe the scientific concepts discovered by their learners.

Norms and values includes aspects of inquisitiveness, enjoying seeing learners being successful, and being passionate about science. They also gained enjoyment from interacting with learners, which was followed by positivity - which involves giving support to learners with their Expo projects, thereby demonstrating the teachers' caring attitudes towards their learners, as also found by O'Connor (2008).

The participants mentioned that as mentors, they had learnt more about the scientific reporting process with improved process skills and data interpreting skills. As dedicated teachers, they also found that they began to teach their learners to be creative and eloquent in their communication during their presentations. The teachers further asserted that they had encouraged their learners to consider science topics that were related to daily challenges, and to come up with suggestions to solve these problems.

- **Judging**

Eight of the teachers had acted as judges and reported that aspects of their norms and values were the most affected, where they enjoyed and were happy to see their learners gaining knowledge and showing success in Expo competitions. They gained subject knowledge and pedagogical knowledge from this role.

Specific judging skills include developing critical thinking, recognising innovation, and assessing practical work. The teachers stated that they used some of the best projects to teach and demonstrate concepts to their learners in their classes. Furthermore, discovering new ideas and misconceptions were mentioned by the teachers as part of the gains in pedagogical content knowledge in this role.

- **Organising**

Seven teachers reported having organised school-level mini-expos. Networking as a resource (contributing to agency) was mentioned by six of these teachers as a particular benefit of this role. They gained the opportunity to interact with learners and network with teachers from other schools concerning issues in science education.

The teachers mentioned that they had learnt more about scientific investigation processes while enacting an organisational role.

Aspects of norms and values were more affected by organising than by the mentoring and judging roles.

5.1.3 Factors that support sustained participation in the science Expo

The third sub-research question was:

> *If teachers' participation in science fairs is sustained for several years, what are the possible factors that support this sustained participation?*

This question addresses why teachers continue as participants over time. Two approaches were used to obtain information for this question. Firstly, a direct set of questions was posed to the teachers asking why they continued to take part in the Expo (see Section 4.9). The second approach used Ajzen's Theory of Planned Behaviour to investigate which aspects of their Professional Identity played a role in initiating, continuing, or expanding their participation in science fairs (Section 4.10) by drawing categories from the entire interview.

- **Replies to the direct interview questions (Section 4.9)**

The theme *sustained participation* had three sub-themes: *Professional knowledge* (consisting of 'Subject Content Knowledge', 'Pedagogical Knowledge' and 'PCK'), '*Norms and Values*' and 'networking as a resource' (*Agency*). The sub-themes form a teacher-identified subset of Professional Identity, and shows that the needs that were consciously identified by the teachers were valued and met through Expo participation. These aspects are reflected in Figure 4.6 and Table 4.9.

Of the categories contributing to professional knowledge, '*Subject Content Knowledge*' ranked the highest. This can be interpreted as forms of topic specific, declarative and procedural knowledge. '*Pedagogical Knowledge*' includes the methodological integration of inquiry based approaches into the teachers' teaching of science. '*Pedagogical content knowledge*' ranked lowest, yet remains one of the most frequent goals of modern professional development programmes (Evens *et al.*, 2015; Zhang *et al.*, 2015), which is of value when it is contextualised and topic specific (Rollnick & Mavhunga, 2013a).

It is not surprising that this topic was mentioned the least as it is an integrated and internalised form of pedagogical and subject knowledge, together with knowledge about the learner (and others such as resources and their use, for example technology). It often concerns a single perspective of misconceptions, which is a popular topic in many teacher preparation programmes.

The teachers' responses regarding '*norms and values'* include a supportive school ethos as an externally imposed norm, which was mentioned by all of the teachers (which also contributes to *agency*). This was experienced through mentoring (Table 4.9, experienced by all of the teachers) and administration or organising (seven teachers). The teachers gained enjoyment from interacting with the learners (which supports a professional and pastoral sense of value) (van Putten, 2011).

'*Networking as a resource'* is the main contributor to *agency*, with a further contribution from school norms and environmental factors.

If one compares these findings with those of Zhang *et al.* (2015) and others (Evens *et al.*, 2015; Zivkovic *et al.*, 2013), the consciously expressed benefits of participation in expos match the needs of teachers, who benefit from professional development interventions, more so when the interventions are sustained.

- **Sustainability, as found through Ajzen's theory**

It is supposed that participation in science fairs strengthens or influences the teacher's Professional Identity. This link is shown as the feedback component of the framework of both Figure 1.1 and the adaptation of Figure 4.8. Linked to this is the question of how or why the participation is sustained, and thus the aspects of identity that lead to the sustained participation of teachers are implicitly included in the conceptual framework.

The factors that affect Professional Identity, and the changes induced through the teachers' participation in the Expo provide the explanatory information for both participation and sustained participation. These were investigated and are reported on in Section 4.10, in which Figure 4.7 shows that professional knowledge, self-efficacy beliefs, agency, attitudes, emotions, and norms and values directly influence the motivational variables of the Theory of Planned Behaviour. *Perceived behavioural control* (PBC) is dominant and is derived from professional knowledge, beliefs (self-efficacy beliefs) and agency. In comparison, the other motivating factors, *Subjective Norms* (linked to the elements of Norms and values, and Emotions of Professional Identity) and *Attitude towards Behaviour* (linked to Attitudes of Professional Identity) together had similar strength.

The latter variables were, themselves, sufficient to form a continued *intention* to participate in the Expo, but PBC (which also supports intention) is in and of itself sufficient to turn intention into participation in the various roles (i.e. the *behaviour*). As the PBC was itself a dominant factor, this explains the promotion of the intention to actual participation.

The teachers' consistent reports have revealed that their roles in the Expo have continually strengthened their Professional Identity. This confirms the sustained positive feedback provided by participation, which continues to drive the willingness and action of the teachers' participation. These teachers participated because they noted that they and their learners gained from it; they felt enabled to do so; they believed that they had the means, the skill and the necessary support to participate; and as they participated, these elements of their Professional Identity continued to be strengthened as a sustainable phenomenon.

5.1.4 Synthesis of findings according to the main research question

The main research question that expresses the focus of this study is:

> *From their point of view, what is the educational significance of science fairs (if any, in terms of Professional Identity and professional development) to teachers of high school Physical Sciences, and why did they sustain their participation over many years?*

The participating teachers placed the most emphasis on gains in their professional knowledge, especially in procedural content knowledge, knowledge in the curriculum, declarative knowledge, pedagogical knowledge, and lastly, pedagogical content knowledge in order of importance. This finding is in agreement with that of Zhang *et al.* (2015), who maintain that professional development programmes are most successful when they focus on teachers' expressed needs, with content knowledge being the most important. Together with enhanced self-efficacy beliefs (Bandura, 2012) and agency, the perceived behavioural control variable is a dominant factor in allowing intentions to become action (participation).

The findings revealed that teachers participating in expos are consciously aware that they have been strengthened in their Professional Identity, particularly where they believe this to be of greatest importance.

The findings revealed that these teachers' Professional Identity changed remarkably, yet positively through participation. Thus, the Expo provides a context for sustained professional development that satisfies teachers' professional needs.

5.2 Realisation of the research objectives

The aim of the study was to explore the educational significance of science fairs from the point of view of high school Physical Sciences teachers. The educational significance was measured in terms of the Expo's contribution to the Professional Identity of the teachers, as defined by Beijaard *et al.* (2000, 2004), through their roles of participation (as mentors, judges and organisers) in science fairs. The aim was also to explain why these teachers participated and continued to participate in science fairs in terms of the potential development of their Professional Identity. Finally, the question was raised whether their participation in science fairs provided an opportunity for professional development.

The supporting information was obtained from the semi-structured interviews with the ten participating teachers. This was analysed through a thematic analysis of the responses (Braun & Clark, 2006). The sub-categories and categories developed from the responses were ranked firstly according to the number of unique teachers who raised these sub-categories, and according to the number of responses given, taking care that the counts were not duplicated (Sections 3.5 and 4.4).

These categories were then associated with the specific themes drawn from the model of Professional Identity, and contributions to the elements of the model could be ranked according to the counts obtained from the categories (Section 4.7).

The educational significance found was classified in terms of advantages for teachers, and advantages and disadvantages for learners. These categories were ranked according to the number of individual (or unique) teachers who raised a particular item (and an aggregated overall count by specific roles), which contributed to a sub-category or category and its ranking. This allowed the relative prominence of contributions to elements of Professional Identity to be established (Sections 4.4 to 4.9). These led to the findings as related to the research sub-questions in Sections 5.1.1 and 5.1.2.

Explanatory information was obtained by directly asking the teachers why they participated, and sustained their participation. Information was also gained by linking the developing aspects of their Professional Identity to the factors leading to intentions and behaviours of participation through Ajzen's Theory of Planned Behaviour (1991) (Sections 4.10 - 4.11, and Section 5.1.3).

Additionally, it has been shown that the science Expo provides a sustainable context for the professional development of teachers (Sections 4.9 and 5.1). This shows that the objectives of the study, as expressed in the research questions, have been met through both the confirmation of some of the findings in the literature, as well as the insights gained through this study.

The explanatory nature of the findings, as well as the emphasis on the various benefits gained by teachers (rather than the focus on learners in the literature), are a novelty in this field. The benefits found in this study included professional knowledge gains in its various aspects, the strengthening of self-efficacy beliefs, and the enhancement of positive attitudes towards new approaches to teaching, such as inquiry-based activities that enhance both teachers' and learners' knowledge of NOS and procedural knowledge. Further benefits were the support of teachers' professional attitudes, values and emotions in being able to share in the learners' achievements. Networking opportunities provided enhancement of all the aspects of their Professional Identity, and thus contributed to the sustainability of their teaching functions and continued participation in science fairs.

5.3 Limitations and delimitations of the study

An important limitation of the study was the restriction of the sample to urban high school teachers of Physical Sciences (ten) who had been involved in the Expo for a minimum of five years in Pretoria. The researcher worked and lived in Pretoria, which allowed the sample to be characterised as a convenience sample. Sustained participation was an aspect of the study that required the teachers to have participated in science fairs for a number of years, which added a deliberate and hence purposive sampling approach. However, rural schools that were involved in the science Expo were not taken into consideration by the researcher. Schools that do not participate and their reasons for teachers not participating or sustaining participation could also not be established. The results of the study cannot be generalised, but may help other researchers looking at science fairs to formulate broader investigations, and contribute to an ultimately generalised understanding.

No direct measurement of the professional knowledge of the teachers was established, rather, their views on their professional development were analysed. The teachers' identity and professional development were found to correlate and sustain one another (Zivkovic, 2013). Professional development interventions are successful if they are sustained and meet teachers' conscious needs (Zhang *et al.*, 2015). The researcher suggested that a reported change of Professional Identity is a consequence or aspect of professional development, and correspondingly concluded that the science Expo provides a sustainable opportunity for professional development. This aspect may need to be investigated further through pre- and post- or similar longitudinal research to yield a direct test of the conjectures expressed in the studies of Zivkovic and Zhang *et al.*, although this was supported by the analysis of this research.

Bias was considered and the avoidance of bias was attempted through four major approaches. These are:

(i) Using a thematic analysis with open coding that did not rely on the imposed conceptual framework (although interview questions were developed according to research questions that were given meaning through the framework) (Section 1.6);

(ii) The further process (closed coding) of relating the categories to the four themes of advantages to teachers, advantages to learners, disadvantages to learners (derived from the definition of educational significance (Section 2.3)) and Professional Identity (from the conceptual framework Section 1.6.2) were carefully structured so as to prevent the repetition of counts across these themes;

(iii) Where responses appeared to be encouraged by the way that the interviewer repeated questions, these responses were not counted or used as evidence leading to categories or claims that could not be sustained. This was achieved by careful confirmation of the counts by the co-researchers, who critically analysed each claimed contribution for the suitability of a particular key phrase from the responding teacher (Section 3.5); and,

(iv) Although the teachers often repeated key phrases, this did not bias the results as the responses were analysed according to the questions raised with a single count contributing per question, and the number of teachers who contributed a key phrase or concept at least once was noted. The responses were aggregated over the number of unique teachers per question over all of the contributions to the theme (Section 3.5).

Thematic analysis relies on the interpretation of the researcher at each level of the formation of categories and themes from the key words upwards. Thus, the claims, findings, and conclusions are dependent on the researcher's interpretations. However, by carefully avoiding the duplication of counts, the ultimate crystallisation of relative rankings of various themes is defensible. This was further strengthened in relating the themes to predetermined concepts in the conceptual framework, as well as to clearly developed research questions at the final level, as done here.

An important limitation is that the science Expo includes more subjects than only those drawn from the physical sciences, including biological or life sciences, economic, computational, environmental and social sciences and engineering projects, amongst others shown in Appendix 5. The conclusions drawn here may in fact be applicable to teachers of these other subjects, but the study itself cannot justify such a generalisation, and further research is therefore needed.

A final limitation was that the primary reference to the science Expo was to the school, regional, and national contexts of the various levels of the Expo for Young Scientists in South Africa. Although this is not expected to introduce a broad bias, it remains relevant for researchers looking at other national and international investigational learner competitions and exhibitions to investigate the findings that have arisen from this study in the wider range of contexts. This *caveat* is justified in that the South African Expo is organised in a particularly structured fashion and the styles of science fairs of other countries, schools, or regions may affect the findings regarding the benefits or disadvantages differently.

5.4 Reflections on the study

Generally teachers' professional development involves workshops. This study has shown that networking of teachers in expos gives the opportunity for teachers to exchange and share experiences with each other. I have learned that the inquiry based learning approach is fruitful because both teachers and learners work close together in a way that assists teachers to discover learners' misconceptions, with teachers learning from learners. This assists learners to progress well in both competitions and their academic activities. Thus Expo Projects are able to complement the school curriculum.

Professionally, I have gained as a science teacher, and have decided to implement mini-Expos at my school as organizer, mentor and judge, while asking for help from teachers at neighbouring schools and judging for them as well.

I have also realised that in research critical reading of the literature helps the researcher to gain insight into the topic that is being studied and to be aware of the gaps and opportunities for further investigation.

5.5 Significance of the study

This study provided evidence and a framework to recognise the educational significance of the science Expo, for both teachers and learners, particularly in terms of science as a subject. This study has shown that the Expo provides professional development to participating teachers and improves learners' academic performance, therefore this may possibly influence non-participating high school teachers of Physical Sciences to consider participating in the Expo.

Furthermore, this study has shown that learners get the opportunity to extend their learning beyond the theoretical work in the science class, thus it broadens their perspective of science as a subject and consequently avoids potential boredom. Additionally, the study may benefit researchers, as well curriculum developers of Physical Sciences with insight and understanding regarding the main purpose of the Expo.

The similarity between the findings and the referenced literature is that teachers who are involved in science fairs are enriched with mentoring attitudes (Molefe, 2011, pp. 97-98, Nath, 2007; Science Fair Foundation, 2015; Urban Advantage, 2015; You & Craig, 2013). The other similarity is that teachers participating in expos are also advantaged with a broad diversity of skills of scientific investigation based on inquiry-based approaches (Anderson, 2015; Kahenge, 2013, pp. 29, 118), as well as the opportunity to discover new innovations and inventions (Metljak *et al.*, 2014; Nath, 2007).

Networking and collaboration attitudes (and opportunities) are also provided to science teachers who take part in the Expo (Egenrieder, 2010; Hardre *et al.*, 2013; Meltjak *et al.*, 2014; Prytul & Wieman, 2012; You & Craig, 2013). Importantly, teachers who are involved in the science Expo are provided with their own training workshop (Eskom Development Foundation, 2015; Kahenge, 2013, pp. 86-87; Magrefi-Amitie, 2014; Rauch & Dulle, 2014).

It has been found that science fairs meet the identified needs of teachers as a setting for sustained professional development, which broadens the findings of others who have studied the professional development and the failures of professional development interventions (Anderson, 2015; Expo Eskom Development Foundation, 2015; Urban Advantage, 2015, Zhang *et al.*, 2015; Zivkovic, 2013). The needs met by science fair participation are those that have been identified by policy makers and planners of interventions in many countries, and these needs are met in a sustainable fashion through participation in the Expo.

The reasons for the teachers' participation and sustained roles in science fairs have been addressed through the novel approach of applying Ajzen's Theory of Planned Behaviour as an analytical tool to analyse the responses given by the interviewed teachers. Perceived behavioural control (which includes many contributing factors mentioned by the teachers) has shown to be the dominant factor leading to participation. Science fair participation has also been shown to provide the teachers with professional knowledge, to encourage positive beliefs and attitudes, and to make resources available to them that were previously unavailable.

5.6 Recommendations

The findings in this study were based on the responses from the ten interviewed teachers from five high performing, urban, progressive schools in both academic and Expo competitions, which leaves open a potential opportunity for under-performing and non-participating schools and their teachers to be researched on this topic.

The first recommendation is for a longitudinal study to be conducted on three kinds of teachers, which monitors professional development and actual influence on classroom practice and change of Professional Identity over time. The three kinds of teachers are: (i) beginner teachers in participating schools, (ii) newly participating teachers from regularly participating schools, or newly participating schools as a comparison, and (iii) teachers who have participated in the past, but have joined non-participating schools – do they continue to develop and participate, change the environment of the new schools towards participation or do they stagnate and regress? What are the reasons?

Workshops on scientific methods, the science curriculum, and Expo judging skills should be provided for both teachers and judges (professional scientists) of science fairs. This should particularly be provided at the regional level because the teachers in this study revealed that the Expo judges were often very strict as they expected precise scientific methods to be used by learners. This would provide a formal opportunity for the professional development of these teachers.

Finally, of great importance, the study has shown that participation in the Expo should be recognised as an effective and sustainable form of professional development, and as such, should be assigned continuous professional development points within the CPD system, as managed by SACE, the South African Council for Educators. This is the case for teachers of Physical Sciences, but may be generalizable, which needs to be investigated further. This implies the formal recognition of these activities through support and scheduling carried out by the provincial Departments of Education.

5.7 Conclusion

It has been found that the science Expo offers educational significance to both the teachers and learners who are involved. Teachers, as participants in the Expo, have opportunities to interact with the learners during which they may discover learners' scientific misconceptions and gain new professional knowledge. Learners who take part in the Expo have an important opportunity to be inspired with ideas for future careers, and to improve their academic performances. The academic improvement of learners correlates with the findings of Kahenge (2013, pp. 83, 118, 192) and Molefe (2011, pp. 121, 229), who found that Expo learners do well in both Expo competitions and academic performance.

The findings revealed that South African Expos provide opportunities for professional development, particularly with regard to teachers' professional knowledge. In particular teachers are aware that their subject content knowledge (the bounds of their knowledge were extended with new knowledge of the subject both within and beyond the curriculum), their pedagogical knowledge (such as gaining insight into inquiry based learning approaches), and topic specific PCK are enhanced. Teachers have learned to appreciate and find science resources such as YouTube and technological science channels (TPCK and TK), which they later use in their classrooms. Simultaneously, their Professional Identity is reinforced through networking and collaboration with other teachers, affecting their 'beliefs' their 'norms and values' and their 'agency'.

Scientific method processes (scientific methods, research questions, hypothesis, data interpretation and graphs, as well as tables and analysis) are enhanced for both teachers and learners. The incorporation of science activities into the school curriculum also gives learners an opportunity to use their prior knowledge and skills to solve their scientific problems through inquiry-based approaches. It creates a conducive learning environment within which to develop deeper insight into the nature of science (NOS), as well as encouraging critical and creative thinking skills.

The conceptual framework provided the structure in which data was gathered, coded and ordered, as well as analysed and interpreted. Initially, the conceptual framework only contained Professional Identity (in the sense of Beijaard et al., 2004) and the roles that teachers enact in science fairs, with a postulated feedback link. However, to explain sustained participation, a model of Ajzen's Theory of Planned Behaviour (Ajzen, 1991) was added. This formed a coherent system model, which has the potential to be applied in other analyses of activities that involve teachers.

The sustained enhancement of Professional Identity through knowledge, skills, attitudes, emotions, and agency indicates that Expo participation is a process, opportunity, and mechanism for the professional development for teachers of Physical Sciences. This is expected to be applicable to teachers of other sciences and subjects. Furthermore, and more importantly, this specific benefit of participation in the Expo over a full range of subjects needs to recognised and supported by professional educational structures, such as educator councils and the various regional and national Departments of Education.

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Appendices

Appendix 1: Permission of the Gauteng DBE

Appendix 2: Letters to school principals

Appendix 3: Letters to Physical Sciences teachers

Appendix 4: Teachers' interview schedule

Appendix 5: Categories for Regional and National Finals

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Appendix 1: Permission of the GautengDBE

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no: D2015 / 347

GDE RESEARCH APPROVAL LETTER

Date:	28 November 2014
Validity of Research Approval:	9 February 2015 to 2 October 2015
Name of Researcher:	Mbowane C.K.
Address of Researcher:	Hoerskool Gerrit Maritz
	P. O. Box 16151
	Dorandia
	Pretoria North
	0116
Telephone Number:	012 546 6685; 072 766 9730
Fax Number:	086 618 1057
Email address:	u98321732@tuks.co.za
Research Topic:	Exploring the educational significance of Science Fairs for High School Teachers
Number and type of schools:	SEVEN Secondary Schools
District/s/HO	Tshwane North and Tshwane South

Re: Approval in Respect of Request to Conduct Research

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

2014/12/01

The following conditions apply to GDE research. The researcher has agreed to and

1

Making education a societal priority

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

may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

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

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

Kind regards

....

Dr David Makhado
Director: Education Research and Knowledge Management

DATE: 2014/12/01

Making education a societal priority

Office of the Director: Knowledge Management and Research
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Appendix 2: Letters to school principals

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

2014-10-24

Dear Headmaster,

I am a student studying through the University of Pretoria. I am currently enrolled for my Masters of Education (MEd) in the Faculty of Education. I have to complete a research module and one of the requirements is that I have to conduct research and write a research report about my work. I would like to ask you whether you are willing to allow me to conduct a part of this research in your school.

The topic of my research is: Exploring the educational significance of science fairs for high school physical sciences teachers. Science fairs play a vital role for learners who participate in Science Fairs like EXPO for Young Scientists since they come to understand inquiry-based activities and experience science investigations. The teacher's roles include those of organiser, mentor and judge. It is important that l understand the educational value for the participation by physical science teachers in science fairs. Some research has been done on this topic but mainly for learners, rather than from the point of view of the benefits and professional development of teachers.

If you agree to allow me to conduct research in your school, I shall interview two teachers at your school who are taking part or have taken part in science fairs with a minimum of three years experiences. Teacher participation is voluntary and can be withdrawn at any time. The identity of the school and all participants will be protected. Only my supervisors and I will know which schools were used in the research and this information will be treated as confidential. Pseudonyms will be used for your school and teachers during data collection and analysis, and no other identifying information will be given.

The information that will be collected will only be used for academic purposes. Collected data will be in my possession or my supervisor’s and will be locked up for safety and confidential purposes. After completion of the study, the material will be stored at the university’s Science Mathematics and Technology Education Department according to the policy requirements.

I attach a copy of the interview and questionnaires schedule for your information. Questionnaire will first be pilot before handing out to teachers for a good standard.

Interviews will be conducted at a venue and time that will suit the teacher, but may not interfere with teaching time. Interviews will be audio-taped and transcribed by me for analysis purposes.

If you agree to allow me to conduct this research in your school, please fill in the consent form provided below. If you have any questions, do not hesitate to contact my supervisor or me at the numbers given below, or via E-mail.

----------------------------------- ------------------------------

Signature of student Signature of supervisor

Name: Clement Kapase Mbowane Prof Rian de Villiers

Contact number: 0727669730 rian.devilliers@up.ac.za

E-mail: u98321732@tuks.co.za

Consent form

I, ____ (your name), Headmaster of ____ agree/ do not agree (delete what is not applicable) to allow Clement Kapase Mbowane to conduct research in this school, the topic of the research being: Exploring the educational significance of science fairs for high school Physical Sciences teachers. I understand that two Physical Sciences teachers will be interviewed and questionnaires will be handed out first about this topic for approximately one hour at a venue and time that will suit the teacher, but will not interfere with school activities and teaching time. The interview will be audio taped. I understand that the role of the researcher will remain objective and non-invasive. I understand that the researcher subscribes to the principles of: Voluntary participation in research, implying that the participants might withdraw from the research at any time. Informed consent, meaning that research participants must at all times be fully informed about the research process and purposes, and must give consent to their participation in the research. Safety in participation; put differently, that the human respondents should not be placed at risk or harm of any kind. Privacy, meaning that the confidentiality and anonymity of human respondents should be protected at all times. Trust, which implies that human respondents will not be respondent to any acts of deception or betrayal in the research process or its published outcomes.

Signature: ___________________________ Date: ___________________

Appendix 3: Letters to Physical Sciences teachers

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

2014-10-24

Dear Physical Sciences teachers

I am a student studying through the University of Pretoria. I am presently enrolled for my MEd in the Faculty of Education (SMTE). I have to complete a research module and one of the requirements is to conduct a research interview and write a report about my work. I would like to ask you whether you will be willing to participate in this research.

The title of my research is: Exploring the educational significance of science fairs for the high school Physical Sciences teachers. Science fairs have advantages for participating learners in terms of inquiry based learning and science investigations. Teachers play major roles as mentors, organisers and judges. However in spite of this being potentially time-consuming, they often sustain their involvement. I would like to find out the educational significance (in your view) and the factors that support your sustained participation.

If you agree you will be given out questionnaires first, then interview will follow about the topic. The interview will take place at a venue and time that suit you, but it will not interfere with school activities or official school teaching time and will take less than an hour. The interview will be audio-taped and transcribed for purposes of analysis. The information will only be accessed by me and my supervisors as all information is regarded as confidential and will be kept anonymous in all reporting and analysis processes. Your identity will be protected. Only I and my supervisors will know your real name, as pseudonyms will be used during data collection and analysis. Your school name will also be given a pseudonym. Your participation will be voluntary and you must know that you have the right to withdraw at any time of the study, for any reason without any prejudice.

The focus group interview will follow later after going through the data from the first interview, with other teachers interviewed at your convenience time and place on the condition of mutual agreement. It will clarify issues emerging from the data and it will enable teachers to narrate the information and it will be audio taped upon your agreement once more.

The information you give will only be used for academic purposes. In the research report and in any academic communication, your pseudonym will be used and no other identifying information will be given. Collected data will be in my possession or my supervisors and it will be locked up for safety and confidential purposes. After completion of the study, the material will be stored at the university's Department of

Science, Mathematics and Technology Education according to the policy requirement of University of Pretoria.

If you agree to take part in this research, please fill in the consent form provided below. If you have any questions, do not hesitate to contact me at the numbers given below, or via email.

Signature of student
Name: Clement Kapase Mbowane
Contact number: 0727669730
E-mail: U98321732@tuks.co.za

Signature supervisor
Prof Rian de Villiers
rian.devilliers@up.ac.za

Consent form

I, ____ (your name), agree / do not agree (delete what is not applicable) to take part in the research project titled: Exploring the educational significance of science fairs for high school Physical Sciences teachers. I understand that I will be interviewed and questionnaires will be handed out and analyse first , then interviews follow about this topic for approximately one hour at a venue and time that will suit me, but that will not interfere with school activities or teaching time. The interview will be audio taped. I understand that the role of the researcher will remain objective and non-invasive. Understand that the researcher subscribes to the principles of:

Voluntary participation in research, implying that the participants might withdraw from the research at any time. Informed consent, meaning that research participants must at all times be fully informed about the research processes and purposes, and must give consent to their participation in the research. Safety in participation; put differently, that the human respondents should not be placed at risk or harm of any kind e.g., research with young children. Privacy, meaning that the confidentiality and anonymity of human respondents should be protected at all times. Trust, which implies that human respondents will not be respondent to any acts of deception or betrayal in the research process or its published outcomes.

Signature: __________________________ Date: __________________

Appendix 4: Teachers' interview schedule

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

2014-10-24
Email: U98321732@tuks.co.za
Cell No: 0727669730

1. Biographical questions

a) How old are you? --------------------

b) Gender Male or female?

d) Home language?
What languages are you able to speak? --

Which language(s) did you grow up with? --

What languages do you teach in? --

e) What are your qualifications(s?)--
-

f) Which grades are you teaching now? --

h) For how long have you been teaching physical science in high school? ---

g) How many times have you been involved in in each kind of science fair, and in what roles: (please complete the table?)

	Type of Fair:		
Role/activity	**School (mini) science fair (Mini-EXPO)**	**Regional EXPO**	**National EXPO**
Organiser			
Mentor			
Judge			
Any other role(s)?			

h) What best describes the region of your school? (Please circle.)
Rural / urban / near a city / far from a city in a suburb / city centre

Interview questions

1. Educational significance of the science fairs/EXPO:

(a) In your view, what are the most important benefits of science fairs to learners who take part in them?

(b) In your opinion, what are the most important (possible) disadvantages to learners, if any?

(c) How did participation in science fairs enhance your knowledge of science investigations?

(d) Do you believe that there is any relationship between projects presented at science fairs and the way that the processes of discovery used by professional scientists actually occur? Please provide some examples of similarities and differences.

(e) Do you incorporate science fair activities into the Physical Sciences subject in your school? Yes or no. If yes, please provide an example.

(f) In your knowledge of science fairs, is there any link between science investigations carried out for the fairs and investigations that are normally undertaken in the school curriculum?

(g) Do learners who take part in science fairs show better scientific literacy than those who are not involved? Please elaborate.

----

2 Significance of roles taken in science fairs

(a) If you have been an organiser of a science fair (at any type of fair, mini, regional or national) please answer the questions in this section

(i) Why did you organise a science fair or science fairs?

(ii) If you have been involved in science fairs as organiser more than once, what have been your experiences in organising science fairs?

(iii) Has your school supported your involvement in the science fair(s)? Please give some examples, or if they did not support your involvement, provide some possible reasons for this.

(iv) Does networking (or collaborating) with other teachers benefit you as a science fair organiser? How?

(b) If you have been a judge at a science fair (at any type of fair, mini, regional or national) please answer the questions in this section

(i) What inspired or persuaded you to be a judge in science fairs?

(ii) Do you think it is useful for science teachers to judge projects in science fairs? Please provide some examples regarding why science teachers benefit from being judges?

(iii) Have any of your teaching skills been enhanced by participating as a judge in the science fair? Please provide examples.

(c) If you have been a mentor of students preparing to participate in a science fair (at any type of fair, mini, regional or national) please answer the questions in this section

(i) What inspired or persuaded you to be a mentor of the learners who participate in science fairs?

(ii) Do learners gain from taking part in science fairs, such as strengthening their interest in a scientific career or are there any other benefits? Please tell me more about how you recognise this and can you give some examples.

(iii) As a mentor, in your experience, do you think science fair activities are relevant to the school curriculum? Please provide some examples.

(iv) Do you integrate inquiry investigation strategies into your school curriculum, and if so, how?

----

3. GENERAL QUESTIONS:

(a) What do you feel you gained from taking part in science fairs as an organiser, judge and/or mentor that is/are most important to you as a science teacher?

(b) Is there any professional development that you gained by taking part in science fairs? If your answer is yes, elaborate.

(c) Does your school reward learners who participate in science fairs? If your answer is yes, give examples.

(d) If you have participated as organiser, mentor or judge in science fairs for a long time, why do you still do it?

(e) Do you think it is important or not for the science teachers to participate in science fairs?

Appendix 5: Categories for Regional and National Finals

Retrieved: June 16, 2016. http://www.exposcience.co.za/index.php/categories.html

Category
Agricultural Sciences
Animal & Veterinary Science, including Marine Animals and Animal Ecology
Chemistry and Biochemistry
Computer Science and Information Technology
Earth Science– including Geography, Geology, Oceanography and Housing and Settlement Studies
Energy: Non-renewable - fossil fuels and use of electricity
Energy: Renewable - Solar, wind, wave, hydro
Energy: Renewable - Biofuels, geothermal, bio digesters
Energy efficiency and conservation: efficient use of energy and ways of using less energy
Engineering: Electronics and Electrical
Engineering: Chemical, Metallurgical, Civil and Mining
Engineering: Mechanical, Aeronautical and Industrial
Environmental Management: study of human interaction with the environment (e.g. waste management, deforestation, land management and bioremediation)
Environmental Science: changes to the environment (e.g. pollution, climate change, carbon emissions)
Food Science, Food Technology and Healthy Eating (Diet)
Health Care and Sports Science
Innovation and Technology
Mathematics and Statistics
Medical Sciences: Human Biology (anatomy, genetics, physiology)
Microbiology and Diseases, Disease-causing organisms, Medicine
Physics, Astronomy and Space Science
Plant Sciences including Marine Plants and Plant Ecology
Social and Psychological Sciences
Sustainable Development , Recycling and Recycled materials

Appendix 6: Language editing certificate

Exclamation Translations

To whom it may concern

The Master's dissertation, "Exploring the educational significance of science fairs for high school science teachers" has been edited and proofread as of 27 July 2016.

Please take note that Exclamation Translations takes no responsibility for any content added to the document(s) after the issuing of this certificate.

Kind regards

Melissa Labuschagne

Melissa Labuschagne trading as Exclamation Translations.

072 995 8740

info@exclamationtranslations.co.za

www.exclamationtranslations.co.za