DYNAMICS INFLUENCING LEARNERS` PERFORMANCE AT SCIENCE FAIRS IN LIMPOPO PROVINCE OF SOUTH AFRICA.

By

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DECLARATION

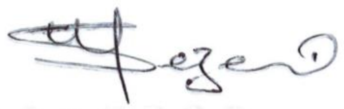
I declare that, “Dynamics influencing learners` performance at science fairs in Limpopo province of South Africa.” is my work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I have not previously submitted this work, or part of it, for examination at UNISA for another qualification or at any other higher education institution.

Mupezeni Sure

ETHICAL CLEARANCE

I, Sure Mupezeni author of “Dynamics influencing learners` performance at science fairs in Limpopo province of South Africa”, have obtained the applicable research ethics approval for the research described in this work. I declare that I have observed the ethical standards required in terms of the University of South Africa’s Code of Ethics for Research.



Sure Mupezeni

DEDICATION

This thesis is dedicated to my Lord and Saviour, Jesus Christ, and to my beloved wife Olipha Kasonde Mupezeni, my parents Annah and Handinachiro Kundishora, and my children, Pontianos, Tichafara, Piedad, Belkis, Verdad, Musawenkosi for your support and allowing me to use part of your family time for my studies, I love you all.

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Abstract

Rural and urban learners from primary and secondary schools participate in science fairs all over the world, but their performance differs. To investigate the dynamics influencing the performance of rural and urban learners at science fairs, specifically in the Limpopo province of South Africa, an interpretive paradigm was used because it allowed the rich qualitative data with subjective experiences of the participants to be interpreted within the social contexts of the learners and teachers. The subjects of the study were rural and urban school learners, teachers, mentors, judges, parents, school principals and Department of Science and Innovation (DSI), the Department of Basic Education, the Eskom Expo for Young Scientists (EEYS) managers. The cultural-historical activity theory (CHAT) theoretical framework was used to analyse data and to show the tensions between the subjects, resources and the science fairs. The research instruments used to collect data were: personal meaning mapping, focus group discussions, observation protocol, physics test, interviews and researcher notebook. Trustworthiness was adhered to by establishing credibility, transferability, dependability, confirmability and authenticity.

All 40 participants were purposefully selected. They comprised of 12 learners (six from rural schools and six from urban schools), nine managers representing the sponsors and partners of the science fair, and three judges. From both the rural and urban areas, two school principals, two teachers, two mentors and two parents were selected. This study supports the findings of other studies on the dynamics influencing learners` performance at science fairs. In addition, this research has established a connection between science clubs and the learners` participation and performance in science fairs, weaknesses of science fair organizers for not reaching out to all rural learners, and not giving material support, training on scientific research skills to those they reach. The study revealed the negative impact of verbal and written communication on learners` performance. As a result, using vernacular language may be useful to the learners' performance Further research is recommended to explore the views and reasons of learners and teachers who stopped participating in the science fairs.

Keywords: Cultural and historical activity theory, depth of knowledge, level of attention, mentor, personal meaning mapping, science fair.

List of Outputs from the Research

1. Mupezeni, S., & Kriek, J. (2018). Out-of-school activity: A comparison of the experiences of rural and urban participants in science fairs in the Limpopo Province, South Africa. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(8), 287-310.

2. Mupezeni, S., & Kriek, J. (2018). Teachers going the extra mile: Science teachers' perceptions of science fairs in Limpopo, South Africa. Paper presented at the *STEMI Olympiads and Competitions Community of Practice Conference.* Pretoria: National Research Foundation.
3. Mupezeni, S., & Kriek, J. (2017). Factors influencing the learners` performance at science fairs. In J. Kriek, A. Ferreira, K. Padayachee, S. van Putten, & B.-I. Seo (Eds.). *Proceedings of the ISTE Conference on Mathematics, Science and Technology Education 23-26 October 2017* (pp. 331-338). Pretoria: University of South Africa.

4. Mupezeni, S., Kriek, J, & Potgieter, M. (2016). The influence of science expos on entrepreneurial intention of learners in South Africa. In J. Kriek, B. Bantwini, K. Padayachee, S. van Putten, H. Atagana, H. Letseka, W. Rauscher, & S. Faleye (Eds.). *Proceedings of the ISTE Conference on Mathematics, Science and Technology Education.* (pp. 318-325). Pretoria: University of South Africa.

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List of Acronyms and Abbreviations

CAPS	Curriculum Assessment Policy Statement
CHAT	Cultural and historical activity theory
DBE	Department of Basic Education
DSI	Department of Science and Innovation
EEYS	Eskom Expo for Young Scientists
PMM	Personal Meaning Mapping
ISF	International Science Fair
STEM	Science, Technology, Engineering and Mathematics
ISEF	International Science and Engineering Fair
BYSCC	Beijing Youth Science Creation Competition
CAST	China Association for Science and Technology
OKSEF	Oğuzhan Özkaya Education – Karademir Science Energy Engineering Fair
PDI	Previously Disadvantaged Individuals
FGD	Focus Group Discussions
RSFD	Regional Science Fair Director
PC	Provincial Coordinator
NPO	Non-Profit Organisation
DBE1 DBE2 DBE3	Department of Basic Education managers
DSI1 DSI2 DSI3	Department of Science and Innovation managers
EE1 EE2 EE3	Eskom Expo for Young Scientists managers
J1 J2 J3	Science fair judges
MR1 MR2	Mentors rural
MU3 MU4	Mentors urban

PR1 PR2	Parents rural
PU3 PU4	Parents urban
RF1 RF2 RF3	Rural female participants
RM4 RM5 RM6	Rural male participants
SPR1 SPR2	School principal rural
SPU3 SPU4	School principal urban
TR1 TR2	Teacher rural
TU3 TU4	Teacher urban
UF7 UF8 UF9	Urban female participants
UM10 UM11 UM12	Urban male participants

Chapter 1: Introduction

1.1 Introduction

Science fairs are activities that are completed outside of the learners' routine instruction. They are events where learners' exhibit, present, and discuss the findings of their science projects. These projects are judged. Finally, prizes and awards are given to winning participants (Chen, Lin, Hsu, & Lee, 2011). Science fair activities improve learners` scientific knowledge and skills (Gilbert, 2010; Schmidt & Kelter, 2017) and offer social characteristics of learning (Batiibwe, 2019) such as the sharing of ideas and research between the teachers and learners. Learners who participate in science fairs improve academically (Kahenge, 2013) by enabling the learners to solve their problems freely, with more independence and flexibility (Sahin, Ayar, & Adiguzel, 2014; Türkmen, 2019; Welsh, Hedenstrom, & Koomen, 2020). In this study, the term "out-of-school" is being used interchangeably with "science fair" (Aubusson, Griffin, & Kearney, 2012; Yildirim, 2020; Young, Ortiz & Young, 2017). The focus of this study is on the Eskom Expo for Young Scientists (EEYS) which is regarded as both an out-of-school activity and as a science fair.

Countries are transforming their industries and societies to conform to the incoming 4th industrial revolution, a new world of artificial intelligence, robotics, and advanced use of internet and technology. There is a need to prepare learners with 21st-century skills and Science, Technology, Engineering and Mathematics (STEM) knowledge (Kivunja, as cited by Kiah-Ju, Ying-Chyi, & Ding-Yah, 2019).

The purpose of the EEYS science fair is to provide a platform for learners to gain valuable research experience (Mupezeni & Kriek, 2018), to connect high-achieving youth to innovators, to enrich the learners' skills, to inspire the learners to explore their passions and become more knowledgeable on the topic they are researching (Gray, 2014). Furthermore, the science fair participation offers learners a form of learning (Naidoo-Swettenham, 2017).

The out-of-school programs have supported scientific literacy (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Robelen, 2011). Well-planned out-of-school programs can "foster interpersonal competence, help define life goals and promote educational success" (Wirt, 2011, p. 48). While the learners are participating in these out-of-school activities, they could acquire scientific skills and possibly improve their communication skills (Mupezeni & Kriek, 2017) as well as improve on the content knowledge of the science relevant to the project (Fisanick, 2010; Tran, 2011). Involving learners in STEM related out-of-school activities assist building their STEM interest, and they are likely to pursue STEM careers (Sahin, 2013). Conversely, some ethnic groups do not pursue careers in the pure sciences because they think that these careers are only for white men (Wong, 2015).

A significant number of teachers believe that science fairs could help learners to develop skills, attitudes, and knowledge leading to a career (Czerniak, 1996). Therefore, schools, parents, and science mentors should provide a platform for learners to explore their STEM interests in a less formal environment. As a result, STEM innovation and creativity can be nurtured (Wagner, 2012) thus preparing them for the 4th industrial revolution (Kiah-Ju et al., 2019).

1.2 Personal Motivation for This Study

I work as the Provincial Coordinator for EEYS, responsible for planning, organizing and execution of all science fairs in the province of Limpopo, South Africa. Part of my duties is to train teachers, mentors and learners on how to plan and complete science projects. During my work, I have observed learners completing their science projects and their participation in science fairs. In addition, I have noticed the differences in the performance at science fairs of rural learners and urban learners. As a result, there is a need to establish the intricacies influencing these learners' performances. Rural learners would have sound scientific ideas, but they will perform poorly at science fairs. I wanted to understand why the learners who perform well at the district level competitions fail at national competitions. Over time, these same learners would stop participating at science fair competitions. It is necessary to understand the various dynamics the learners face throughout the whole process. Also, I noted that the physics category was the least chosen by learners, even at the national level of competitions.

1.3 Establishing the Gap in Literature

Science fairs are under-researched area in the field of science education, given that a large number of science fairs are held each year (Bowen & Stelmach, 2020). Therefore, a literature review was completed to establish the current studies focusing on science fairs. Google Scholar, World Wide Science, and ERIC are three databases used for the review of literature. Studies particularly relevant are discussed in Chapter 2 (see sections 2.5 to 2.13).

The reviewed literature describes many studies on science fairs. Research conducted on science fairs focused on the following 11 main areas:

a) The impact of science fairs on attitudes and motivation towards science learning (STEM) and choice of STEM major (Dabney et al., 2012; Kiah-Ju et al., 2019; Miller, Sonnert, & Saddler, 2018; Sahin, 2013; Schmidt & Kelter, 2017; Wharton, 2019).
b) The process, development, and challenges of science fair projects (Demirel, Baydas, Yilmaz, & Goktas, 2013; Koomen, Rodriguez, Hoffman, Petersen, & Oberhauser, 2018; Naidoo-Swettenham, 2017; Robertson, 2016).
c) How science fairs foster inquiry skills, project based thinking skills, and enhance learning (Jürgen, Lederman, & Groß, 2016; Keçeci, 2017; Ndlovu, 2013; Paul & Groß, 2017; Tortop, 2013; Ulusoy, 2016; Welsh et al., 2020).
d) The gaining of scientific literacy by learners (Mackey, 2014; Mackey & Culbertson, 2014).
e) The stackholders` perceptions of participating in expo science fairs (Ngcoza et al., 2016).
f) How anxiety is originated and managed in the context of science fairs (Dionne et al., 2012; Reis, Dionne, & Trudel, 2015).
g) The perceptions of teachers in participating in science fairs on their professional development (Durmaz, Oğuzhan Dinçer, & Osmanoğlu, 2017; Mbowani, 2016; Mbowane, De Villiers, & Braun, 2017).
h) Recommendations and comments from science fair judges, and weaknesses of science fair judges themselves (Bowen & Stelmach, 2020; Rillero & Zambo, 2011).
i) Reflections on how science fairs engage underprivileged learners, and the role of parents (Alant, 2010; Pittinsky, 2020; Schank, 2015).
j) The accessibility of science fairs to the general public and how people interact with learners at the science fairs (Kennedy, Jensen, & Verbeke, 2018; Pittman, 2016; Tuttle et al., 2017).
k) How adults view science fairs as an informal teaching platform, the social learning experience (Griffiths, 2014; Kahenge, 2013).

After reviewing all the previous studies, there appears to be a dearth of research into the dynamics influencing the performances of rural learners and the urban learners at science fairs who have physics-related science projects. Furthermore, this study filled the gap in the paucity of studies from the African continent. Out of the 39 studies reviewed, six studies came from South Africa, and eight studies were from other parts of Africa.

The reviewed literature did not focus on the following:

a) Expectations of science fairs sponsor and partners and how these were achieved by science fair participants.

b) Exploration of the dynamics influencing the performance of rural learners and urban learners at science fairs.

c) The views of rural and urban school principals, teachers, judges, mentors and parents.

c) Linking the science fairs to academic performance of the learners.

d) The participation of the learners in physics category at a science fair.

e) The use of Webb`s Depth of Knowledge and the level of attention on science fair activities.

f) The use of CHAT framework to analyse science fairs.

There seems to be no study focusing on a specific subject and category of the science fairs. Furthermore, there is no study on learners` projects participation in the physics category at any science fair. According to the reviewed studies, no work explored the performance of rural learners and that of urban learners at the science fairs. Therefore, this work fills this gap by determining the dynamics influencing the participation of rural and urban school learners competing with physics-related projects in the EEYS science fair. In this study dynamics refers to the changes in learners' interactions with each other, and other members of the community, with materials and equipment for the development or non-development of science projects. Furthermore, only one study focused on the stakeholders: learners, teachers and two expo organizers (Ngcoza et al., 2016). This study focused on many stakeholders by including Department of Basic Education (DBE) managers, Department of Science and Innovation (DSI) managers, EEYS managers, judges, school principals, mentors and parents.

When learners manage their focus and attention during the learning process, they will perform better (Lodge & Harrison, 2019). Therefore, this study introduced the Level of Attention (distraction, focus and engagement), Personal Meaning Mapping (PMM) and Depth of Knowledge to understand the performances of learners at science fairs.

The theoretical framework, Cultural and Historical Activity Theory (CHAT) provides the analysis of the tensions between the constructs of CHAT. The analysis of the data revealed the tensions between the learners and the rules and regulations of the science fairs, the learners and the resources and equipment, learners and the community, and learners and the science fair activity itself.

It is against this backdrop that this research is conducted, to learn and understand the dynamics influencing the performance of learners at science fairs in Limpopo province.

1.4 Statement of the Research Problem

There are various causes for the poor performance of learners at science fairs. One example is the lack of resources and teacher assistance (Alant, 2010; Flanagan, 2013; Ndlovu, 2013; Ramnarain & de Beer, 2013). Another reason why learners` projects fail is because they plagiarize other people's projects and present these copied projects as their own work (Tortop, 2014).

The EEYS has organised national science fairs in the past five years (2015-2019) where an average of 2500 projects competed. During these five years, only 70 projects were in the physics category. According to the EEYS, in 2019, of the 504 projects competed at the national science fair, 19 projects competed in the physics category, and only one project came from Limpopo province. It is against this backdrop that this research is conducted, to learn and understand the dynamics influencing the performance of rural and urban learners at science fairs in Limpopo province.

1.5 Aim of the Research

There are 13 categories (Appendix A) where learners compete at the EEYS science fair. Of these 13 categories, very few learners from Limpopo province choose to participate in the Physics category. Therefore, it is important to understand the dynamics that influence the learners` performance with physics-related projects at science fairs. Along with these dynamics, it is necessary to compare and/or contrast how learners from rural and urban schools choose their projects. Also, it is important to understand the expectations of the stakeholders: DBE, DSI, EEYS, teachers, science fair judges, school principals, mentors and participating learners. Lastly, this study aims to determine how the learners’ attention and depth of knowledge of physics are affected.

1.6 Research Questions

The study sought to answer the following research question:

What are the dynamics influencing the performance of learners at science fair competitions in the Limpopo province?

Sub-research questions are:

1. How do the constructs of CHAT uncover the dynamics contributing to the difference of rural and urban schools' learners' performance at science fair competitions?
2. How do the tensions in the constructs of CHAT reveal the disparity between urban and rural science fair learners?
3. What is the effect on the performance of learners competing at science fairs in the Physics category? In terms of
    a. the level of attention
    b. depth of knowledge in physics.

1.7 Definitions of Terms

The following terms need to be defined as related to this study:

Out-of-School Activity: This study takes out-of-school activity as the non-formal learning activities that the learners do after normal school time, like science research projects. These activities may be done at school premises after school closes for the day, at home or other sites and venues (Eshach, 2007). The out-of-school activities may be done by individuals, or in groups, with or without the assistance of family members, friends, teachers or mentors (Dillon, 2012; Sahin et al., 2014).

Mentor: In this study, a mentor refers to an individual who assist, give wise advice and guide the learner who is doing a research project (Clutterbuck, 2014).

Science Fair: It is a gathering of learners exhibiting their results of science research projects for adjudication by judges. In this thesis, the science fairs are the EEYS organised fairs and the term "science fair" also refers to out-of-school activity (Gray, 2014; Koomen, Rodriguez, Hoffman, Petersen & Oberhauser, 2018).

Physics Category: In EEYS science fairs, the learners participate in 13 different categories (see Appendix A) of which Physics, Astronomy, and Space Science is one of the categories.

Sponsor: individual, company, organization or government department which provides financial support to fund for EEYS events.

Partner: These are institutions of higher learning, organizations, government departments who support the EEYS events without a financial contribution by promotion, permissions, advice or services.

Rural School: In South Africa, rural schools are the outlying schools from the cities and towns which are characterised by shortage of qualified teachers, inadequate resources, poor infrastructure, parents mostly living in poverty with communities that are of the lower socio-economic background (Gina, 2015).

Stakeholders: In this study, stakeholders refer to the sponsors and partners of expo science fair namely, DBE, DSI and EEYS.

Urban School: The terms “urban” and “rural” are highly debatable in South Africa. Therefore, it is no longer suitable to define urban and rural as compared to one another (Gardiner, 2017). In this study, urban schools are those schools with adquate resources, qualified teachers and with parents above the poverty datum line.

1.8 Delimitation of the study

The study seeks to explore the dynamics influencing learners` performance at science fairs in Limpopo province of South Africa**.** This study is delimited to grade 10 learners who participated in the physics category at the science fairs. This qualitative study is limited to the examination of the dynamics affecting both the rural and urban learners` performance on the physics test and at the science fairs. The study focused on learners in one of the nine provinces, Limpopo province.

In order to get a deeper understanding, interviews were conducted with purposively selected parents of the participants, mentors and teachers of these learners, their school principals and the science fair judges. The interviewed sponsors and stakeholders were Limpopo DBE managers, DSI managers, and EEYS managers.

There were limitations considered when interpreting the results of this study. For example, the use of purposive sampling may have introduced a source of bias into the study. There is a possibility that the learners, teachers and sponsors who were excluded from this study may have had different views from the study’s participants. Notwithstanding these limitations, the research was conducted upholding the ethical issues and the appropriate methodological requirements.

1.9 Significance of the Study

The findings and recommendations of this study will be made available to teachers, learners, mentors and judges. The EEYS produces mentor’s and judge’s guide books of which this researcher is also an author. These findings and recommendations will be included in these books. The EEYS and the DSI are establishing science clubs in schools, and these findings will help in the formation and execution of the science clubs. The beneficiaries of this study are:

a) The learners: The learners will be aware of the dynamics influencing performances at science fairs. It is hoped that the learners will be in a position to find and utilize best practices that are revealed in this study and implement them.
b) The school: The popularity and external profile of the school is enhanced by the achievements of learners at science fairs (Jürgen, Lederman, & Groß, 2016). Learner achievement at the provincial and national competitions often brings awards to the school. This study has highlighted the assistance the learners require from the school for them to produce award-winning science projects.
c) The teachers: The learners` academic achievements are enhanced by participating in science fairs (see section 2.12).
d) The stakeholders: EEYS, DBE, DSI will be able to determine whether their expectations of the learners are or are not met. Also, stakeholders who are the key sponsors will be able to identify areas of improvement for the science fairs and the type of support the learners and schools require in order to improve the learners’ performance.
e) The science fair judges: The study has outlined the concerns of the learners with regards to the judging process and the judges` characteristics. If judges take into consideration the issues raised by the learners, which will be included in the judges’ guide books, then there may be improvements in the science fairs.
f) The study has offered the social characteristics of learning (see section 2.15 and section 4.7.1).

1.10 Structure of the Study

This study is organized under five chapters as shown in Figure 1.1 below:

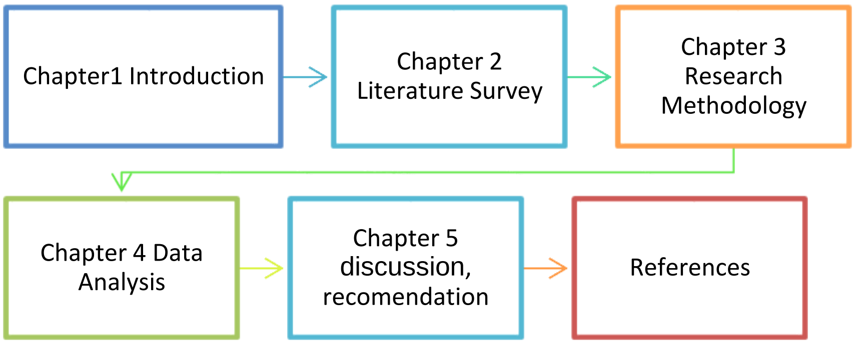

Figure 1.1: Chapters of this Study.

The following is a summary of the chapters:

1. Introduction

The chapter introduces the topic of this study and described how the gap in literature was revealed by providing an overview of the literature, the research questions as well as the significance of study.

2. Literature Survey

Chapter 2 is an in-depth review of the literature, and it includes the history, advantages, and disadvantages of science fairs. Learner performance at science fairs and the development of their scientific skills due to science fairs are discussed. Also included are the benefits and disadvantages of science fairs to the teacher. Finally, is the theoretical framework used in the analysis of the data.

3. Research Methodology

Chapter 3 presents the research methodology and addresses the research questions, research methods, research design, suitable techniques for data collection and data analysis. The rationale for the methodology, the trustworthiness of data, ethical consideration and validation of instruments were explained.

4. Results

Chapter 4 presents the findings after the data was collected and analysed. This chapter will explain the integration of the findings with the research framework.

5. Discussion, Recommendations and Conclusions

Chapter 5 starts with the introduction and an overview of the previous chapters. The research questions were answered, and the conclusion of the study is presented. This chapter also shows how this the study contributed to the body of knowledge. Finally, recommendations for future research were made.

1.11 Summary

This chapter introduced and explained the personal motivation of completing this study. It not only showed how the gap was established from reviewing various studies related to science fairs, but it also explained the significance of the study. Likewise, the aim of this research and the statement of the research problem were presented. Furthermore, the chapter presented the research questions and the definition of terms used. The structure of the study was shown, briefly explaining the aspects covered in each of the five chapters. The next chapter presents the literature review.

Chapter 2: Literature Review

2.1 Introduction

This chapter provides an overview on origin of science fairs in the Americas and United Kingdom (see section 2.2) and in South Africa (section 2.3). The different continents were compared and contrasted with South Africa (see section 2.3.1).

Other studies focused on how science fairs enhance inquiry skills (Koomen et al., 2017; Ulusoy, 2016), scientific skills (Schmidt & Kelter, 2017; Türkmen, 2019) and science literacy (Miller et al., 2018; Mupezeni & Kriek, 2018). These studies offer insights into the science fair activities (see section 2.4; section 2.9; section 2.10; section 2.11). However, they deliver only partial explanations of the dynamics influencing the performance of learners at science fairs; none of these studies refer to the expectations of the stakeholders, sponsors and partners of science fairs.

Finally, there is a discussion of the theoretical framework. The Cultural and Historical Activity Theory (CHAT) was used as a lens to explain the dynamics influencing the learners' performance at science fairs (see section 2.16).

2.1.1 The Organization of the Literature Review

The literature search focused on previous studies that are relevant to the three research questions of the study. Only books, peer-reviewed articles, current periodicals, and dissertations that are no more than 20 years old were used.

The literature review was organized under these headings: Origin of Science Fairs (section 2.2), Science fairs in South Africa (section 2.3), Government's view on Science Fairs (section 2.4), South African Physical Science Curriculum (section 2.5), History of EEYS (section 2.6), Understanding Science Fairs and STEM Majors (section 2.7), Out-of-School Activities (section 2.8), Advantages (section 2.9) and Disadvantages (section 2.10) of Science Fairs, Causes of Poor Science Fair Performances (see section 2.11), Science Fair Influence on Teachers (see section 2.12), Science Fair Judges (section 2.13), Depth of Knowledge (section 2.14), Social Characteristics of Learning (see section 2.15) and the Theoretical Framework (see section 2.16).

2.2 Origin of Science Fairs

Current science fairs originated in the United States of America (USA). E.W. Scripps founded the Science Service in 1921 which had the goal of making the public aware of the scientific world. The Science Service was later upgraded to Science Clubs of America. Later, Science Talent Search was created to encourage young people to pursue science and engineering courses (Schock, 2011). According to the Society for Science and the Public (2012), the Science Talent Search led to the birth of the National Science Fair. This fair was first held in Philadelphia, Pennsylvania, USA, in 1950. It is also known that the first science fair was held in 1928 (Bellipanni & Lilly, 1999). Eventually, the National Science Fair became to be known as Intel International Science and Engineering Fair (Intel ISEF) in 1998. Some examples of science fairs held today in the USA are: Intel International Science and Engineering Fair, Broadcom MASTERS, RoboRAVE International, Young Scientist Challenge, MIT THINK Scholars Program, The Conrad Spirit of Innovation Challenge, Regeneron Science Talent Search and the Google Science Fair (Henneberg, 2013; Subotnik, Olszewski-Kubilius, Worrell, & Lee, 2017; Thorstensen, 2016). Currently, the competitions are open to the international world and the format is the same. The science fairs are similar to EEYS. Each year selected participants from EEYS fairs compete in the USA, Asian and European fairs.

In the United Kingdom (UK), fhe first science festival was the annual conference held by the British Association for the Advancement of Science in 1831. By the 1980s, it became known as the Festival of Science. Currently, it is known as the British Science Festival (Buckley & Hordijenko, 2011). Over the years, the UK increased the number of science fairs. Some of the popular fairs are: Brighton Science Festival, Sheffield Festival of Science & Engineering, Cambridge Science Festival, Edinburgh International Science Festival, Royal Society Summer Science Exhibition, British Science Festival, Malvern Festival of Innovation, London Science Festival, and the Peterborough STEM Festival (Hooker, 2017; Kennedy et al., 2018). The EEYS models UK science fairs in terms of organization and the judging processes.

2.3 Science Fairs in South Africa

The first EEYS was held at Pretoria Boys High School from the 30 September to the 4 October 1980 with 198 science projects (Gray, 2014). Even though it is sponsored by Eskom Holdings, EEYS is an independent non-profit organisation (NPO), registered under section 21 of the Company’s Act, 1973. The EEYS is managed by Provincial Coordinators (PC) in all nine provinces of South Africa. These provincial coordinators work closely with the volunteers called Regional Science Fair Directors (RSFDs), who are based in the districts of each province. Covering 35 districts in the nine provinces of South Africa, the aim of EEYS is to promote scientific exploration, content knowledge, and skills development among learners. Currently, the EEYS is affiliated with the DBE and the DSI.

Learners compete at the school level, the district level, the regional level and/or the provincial level. When the learner reaches the national level, they are competing in the International Science Fair (ISF). Participants are learners in grades 5 to 12. During the provincial competitions best science projects are selected to compete at the national science fair. For a project to win a gold medal, it must score 80% and above, a silver medal 70–79% and a bronze medal 61–69% as judged by adjudicators.

2.3.1 Science Fairs in South Africa and Europe

In South Africa, there are four science fairs. The main one is EEYS which is the ISF. The other three fairs, Imbeu Science Fair, SciFest and Tritech are not found in all regions of the country. The EEYS in South Africa is affiliated to Intel ISEF in the USA. Other affiliated countries are Taiwan International Science Fair, Kenya Science and Engineering Fair, Beijing Youth Science Creation Competition (BYSCC)-China, China Association for Science and Technology (CAST)-China and Oğuzhan Özkaya Education-Karademir Science Energy Engineering Fair (OKSEF)-Turkey. Similar to other science fairs, the EEYS follows international standards. In addition, EEYS annually assist learners, so the learners can participate in this international event.

2.4 Government's View on Science Fairs

Science fairs in South Africa are open to all citizens to encourage them to understand science and what it is all about (Flanagan, 2013). South Africa's Department of Science and Technology (DST) has set one of the pillars of its Science Engagement Framework (SEF), namely to popularise science, engineering, technology, and innovation making it attractive, relevant, and accessible to all (DST, 2014). This Department set out achieving enhancing scientific literacy and awakening interest by learners in relevant STEM careers (DST, 2014).

Furthermore, the acting Director-General Mr. S.G. Padayachee in the DBE sent a letter to all provincial offices in the country stating that "Eskom Expo [for Young Scientists] is South Africa`s primary and only existing science fair for school learners" (see Appendix B). Based on this letter, the Director-General further directed that, "all STEM learners to participate in the Eskom Expo" (see Appendix B). Therefore, schools, parents, and science mentors should provide a platform for learners to explore their interests in a less formal environment to enable innovation and creativity to enhance STEM learning (Wagner, 2012).

2.5 South African Physical Science Curriculum

South Africa's physical science curriculum emphasizes practical investigations and development of learners` scientific process skills (DBE, 2011). According to the Curriculum and Assessment Policy Statement (CAPS), these skills are; "observation, data collection, analysis and concluding" (DBE, 2011, p. 8). The learners acquire scientific process skills when they carry out practical investigations (DBE, 2011; DST, 2014; Jackson, de Beer, & White, 2018). The EEYS offers learners an opportunity to develop these scientific skills by completing research projects which will ultimately improve their performance in physical science (DBE, 2011; Makgato, 2007).

South African learners are performing poorly in physical sciences mainly due to a lack of practical activities during the teaching of the science subjects. The Department of Basic Education (DBE) has linked the low pass rate in the National Senior Certificate (NSC) examinations in the physical sciences subject to the learners' deficiency of practical work (Bhaw & Kriek, 2020b). In an earlier study, it was observed that the low learner performance in the Physical Sciences could be due to the lack of teachers' content knowledge, inadequate resources or teachers not knowing how to use equipment supplied by the DBE (Kriek & Grayson, 2009).

2.6 History of EEYS

Table 2.1 gives the total number of participants in the EEYS in South Africa for 2017, 2018 and 2019. The number of girls participating in EEYS has always been higher compared with the number of boys during these same three years. As one can see, the number of participating girls and boys nationally has been decreasing over the years.

Table 2.1

The Number of Participants at the EEYS

Year	Number of Boys	Number of Girls
2017	6890	9711
2018	5845	8649
2019	5823	8583

However, the number of participants in Limpopo province has been steadily increasing over the years. In 2016, there were 845 learners. There were 1039 learners in 2017. In 2018, there were 1182 learners, and in 2019, there were 1430 learners. (See Table 2.2)

Table 2.2

The Number of Participants in Limpopo

Region		2016	2017	2018	2019
Vhembe	Total participants	343	335	376	412
	Females	172	185	269	222
	Males	171	150	107	190
Waterberg	Total participants	96	181	230	351
	Females	55	108	123	207
	Males	41	73	1o7	144
Mopani	Total participants	234	229	244	320
	Females	138	158	151	192
	Males	96	71	93	128
Capricorn	Total participants	172	294	332	347
	Females	105	175	198	186
	Males	67	119	134	161
	TOTAL	**845**	**1039**	**1182**	**1430**

2.6.1 Participant Demographics by Race and Gender

EEYS stipulates that all learners in the country are to participate regardless of race or gender. EEYS competitions require 50% female participation. From 2016-2019 the participation of female learners has been well above 50%. (See Table 2.3)

Table 2.3

Participant Demographics by Race and Gender in Limpopo

		2016	**2017**	**2018**	**2019**
Gender	Males	275	271	269	265
	Females	305	340	346	328
	Unknown / Other	0	0	3	0
Race	Black African	264	306	328	323
	White	217	186	136	129
	Indian / Asian	69	77	101	91
	Mixed Origin / Other	30	42	50	50

Table 2.3 shows a decrease in learner participation by the whites and Indian learners. Two possible explanations for this drop in the expo participation may be:

a) The formation of Tritech Science Fair in 2009, which started in Limpopo province and now in Mpumalanga province. Most white schools have withdrawn from EEYS and are having their learners participating in Tritech Science Fair.
b) The establishment of the Imbewu Science Fair in 2017. Some schools are participating in the Imbewu events and are mostly white and Indian learners.

In 2016, there were 217 white participant learners, reduced to 186 in 2017, reduced again to 136 in 2018, and further reduced to 129 in 2019. In the same way, the Indian learners were 101 in 2018, and reduced to 91 in 2019. Similarly, the black learners were 328 in 2018, and reduced to 323 in 2019.

2.7 Understanding Science Fairs and STEM Majors

Science projects connect learners to the practices of science, problem-solving, knowledge building, and stimulating interest in STEM educational activities and careers (Welsh et al., 2020). When learners` interest in science is encouraged earlier and they become motivated to learn science, these learners are likely to choose science majors during their high school, and eventually pursue STEM-related careers (Kiah-Ju et al., 2019). Similarly, science fairs allow learners to explore STEM interests outside the classroom environment (Grinnell, Dalley, Shepherd, & Reisch, 2017). In addition, science fairs enhance learners` interest in science and science careers (Lakin, Ewald, & Davis, 2019).

Some learners who are now in tertiary education have indicated that their parents and teachers motivated them to complete science projects. Also, these same adults influenced the learners’ choice of a STEM discipline (Forrester, 2010). In addition, learners who participate in science fairs may be inclined to choose a STEM career (Miller, Sonnert, & Saddler, 2018). When learners do projects, using minds-on inquiry, they create interest in science and are likely to have STEM careers (Selco, Bruno, & Chan, 2012). However, for learners to pursue a STEM major, they must not only enjoy it but also have the support of adults who contribute to learner enthusiasm for science career (Abernathy & Vineyard, 2001; Schmidt & Kelter, 2017).

In order to increase the number of students choosing STEM fields, there is a need to engage their interest and motivate them while they are at the early secondary level (Maltese & Tai, 2010). Students say they fail to pursue science courses because they lack exposure to opportunities in science, and they doubt their capabilities (Cleaves, 2005; Mupezeni & Kriek 2018). The adults` support and encouragement are strong contributions to the learner’s choice of STEM careers (Maltese & Tai, 2010). Finally, STEM careers offer students practical, real-life experiences (Hazari, Sonnert, Sadler, & Shanahan, 2010).

Even though learners have learned about the scientific process and engineering design, they may not have positive attitudes towards STEM fields (Schmidt & Kelter, 2017). On the other hand, it was found that EEYS is not an effective means of encouraging learners from impoverished backgrounds, townships and rural areas into careers in science (Taylor, 2011).

If learners are engaged with science research projects, they are likely to choose a STEM career (Welsh et al., 2020). In addition, adult support impacts positively on the learners` choices of the STEM careers (Forrester, 2010). Similarly, if the learners attain the research skills and are exposed to science at an early age, they might choose the STEM careers (Miller et al., 2018). On the other hand, findings indicate that EEYS is not doing enough for the impoverished, rural learners in order to enable them to choose STEM careers (Schmidt & Kelter, 2017). This study did not pursue the EEYS participants to learn if their participation in science fair activities influenced that in choosing STEM career choices.

2.8 Out-of-School Activities

Out-of-school time or out-of-school activities include science Olympiads, robotics, and science fairs (Sahin, 2013). These programs offer a way for learners to join science fairs (Sahin et al., 2014). A significant number of researchers around the world have shown interest in out-of-school learning that takes place outside the school building like science clubs, science fairs and science Olympiads (Aubusson, Griffin, & Kearney, 2012; Dillon, 2012; Fallik, Rosenfeld, & Eylon, 2013; Kisiel, 2013; Kong, Dadney, & Tai, 2014; Rahm, 2010; Stocklmayer, Rennie, & Gilbert, 2010;). There is evidence that learning mathematics and science in an out-of-school setting is beneficial because out-of-school time closes the gap between home and school environments (Stott, 2015). On the other hand, the research regarding the effectiveness of science fairs in supporting student learning and the learners' attitudes towards STEM is inadequate (Schmidt & Kelter, 2017). Teachers who assist learners with their out-of-school activities, like science projects, increase their pedagogical knowledge (Kisiel, 2013). Finally, these out-of-school programs offer a way by which learners can register for participation in science fairs (Cicek, 2012; Sahin et al., 2014).

2.9 Advantages of Science Fair Participation

Science fairs have lifelong benefits by giving learners a platform for creativity and innovation with the possibility of becoming researchers and entrepreneurs (Gray, 2014). Some learners have upgraded and developed their projects to business ventures, thereby creating employment and generating income (Mupezeni, Kriek & Potgieter, 2016). These learners also gain scientific skills and scientific knowledge (see section 2.9.3).

2.9.1 Communication Skills

In EEYS science fairs, learners write reports of their science projects, and they orally present their findings to judges. The judges interview the learners on their projects, and the learners have to be prepared and knowledgeable of their projects. In addition to the judges, the learners communicate with other learners, parents and stakeholders who come to the science fair event. The whole process helps the learners to improve on their verbal and written communication skills (Fisanick, 2010; Schmidt & Kelter, 2017).

2.9.2 Satisfying Learners Research Interests

Science fairs assist learners to increase their curiosity, thereby learn new areas of scientific knowledge (Jensen & Buckley, 2014). The EEYS provides an opportunity for cultivating science interest and literacy at an early age and thereby creating a foundation for adult learning and future interest in science (Naidoo-Swettenham, 2017). Learners have described science fairs as facilitating their research interests, something that is not always done in the classroom environment (Betts, 2014),

2.9.3 Scientific Knowledge and Skills Development

When learners participate in science fairs, their understanding of scientific inquiry is increased. As a result, this knowledge has positively influenced the attitudes of most learners in their study toward STEM courses and careers (Schmidt & Kelter, 2017). When learners engage in science fair projects, they have enhanced their understanding of scientific inquiry in designing experiments, collection and data analysis, and evaluation of the correctness of the hypothesis of their research projects (McComas, 2011; Schmidt & Kelter, 2017).

Furthermore, the benefits of developing science fair projects are creating explanations, evaluating skills, sharing skills information, developing and utilizing prototypes, computer technology, and computational thinking (Koomen et al., 2017). South African teachers admitted that the EEYS offer learners opportunity to gain scientific literacy, to enhance their academic performance, and to give them research skills to conduct scientific investigations (Mbowane 2016). The same study added 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" (Mbowane, 2016, p. 113).

Studies have highlighted that South African learners who participate in EEYS science fairs improve their content knowledge about the physical sciences and research skills (Kahenge, 2013; Ndlovu, 2014; Mbowane, 2016). When learners are involved in science fair projects, their science skills and subject content knowledge are enriched as they become more knowledgeable (Schmidt & Kelter, 2017). Likewise, learners develop scientific process skills and improve creativity during the preparation of their projects (Ulusoy, 2016). In addition, learners develop their research skills, critical thinking skills, and confirmatory attitudes toward science when they plan and complete research projects (Kahenge, 2013)**.** These young scientists investigate their topics using effective and appropriate methods of scientific inquiry (Türkmen, 2019). The science projects empower learners to showcase their creativity, cooperativeness, perseverance, and their scientific skills (Woolnough, 1994). It is noted that the purpose of a science fair is to assist the learners in understanding the scientific process and to gain knowledge and skills (Koomen et al., 2017).

2.9.4 Entrepreneurial Intentions

The EEYS can create entrepreneurial intentions among learners. In a study of national science fair participants (N=125) taken from all the nine provinces of South Africa, they showed that 79,2% of the learners have intentions of starting businesses and establish own companies (Mupezeni, Kriek & Potgieter, 2016). Also, South African learners desire to be entrepreneurs and have intentions of starting their own businesses (Steenekamp, Van der Merwe, & Athayde, 2011). In a cross-sectional survey of 349 learners chosen from 11 secondary schools in the township of Mamelodi, they evaluated the predictive validity of the theory of planned behaviour on entrepreneurial intention of learners from secondary schools (Mothibi & Malebana, 2019). All the three studies agreed that family members and friends have an effect on the learners' entrepreneurial intentions which shows the social learning experiences of learners.

2.9.5 Mentors

Some science fair participants from the urban advantaged schools have the benefit of having a professional mentor such as a doctor, engineer, or technician (Bernard, 2011). The mentors assist learners with their projects by teaching them the scientific ways of doing the research. Many schools are unable to support learners with mentorship for science fair projects as the school administrators consider these activities as extracurricular (Akınoğlu, 2008, as cited by Betts, 2014). These findings show that mentors or coaches assist learners with their science projects.

2.9.6 The Role of Parents/Guardians

Science fairs enhance parent-student-teacher communication. Learners who take part in science fair competitions become the source of pride for their families (Ulusoy, 2016). Parents play an important role in the learner's participation at science fairs. Studies have revealed that learners who receive parental support and encouragement are successful in science fair competitions (Grinnell et al., 2018). Likewise, learners who enjoy support from parents in school-related activities have high academic achievements with positive attitudes and appropriate behaviour at school (Park & Holloway, 2013, as cited in Riggs, White, Kuenzi, Sifuentes, Garner, Gleason, ...& Vann, 2019).

Correspondingly, for learners to succeed, teachers should find ways to involve the parents, and all stakeholders in the scientific community in order to support the learners (Smith, 2013). Learners from under-resourced schools get little help from their parents. This lack of support puts them at a disadvantage with learners from well-resourced private and urban schools whose parents are competitively involved in their children's science fair activities (Taylor 2011). In addition, learners lack motivation due to a shortage of support from schools and their parents (Kahenge, 2013). Unfortunately, some parents fail to assist their children due to illiteracy and/or interest in their child's work.

However, some studies have identified the over-involvement of parents in science fair projects. Learners from wealthy families buy their projects, and parents do most of the work. As a result, it becomes a competition between parents and not learners (Pittinsky, 2020; Schank, 2015). In addition, some parents spent a great deal of money to impress judges; one parent hired graphic designers to produce the poster for the science fair (Bowen & Stelmach, 2020). These studies have shown the importance of parents playing a role in the learner's success at science fairs.

2.9.7 The Role of the School

Science fairs enhance lessons and contribute to the external profile of the school (Jürgen et al., 2016). Schools may support science fairs, since the main aim of a science fair is to supplement school curricula by encouraging learners to make use of the scientific methods in designing and executing experiments (Albernathy & Vineyard, 2001).

The Department of Basic Education (DBE) in South Africa has encouraged all schools in the country to take part in the EEYS (see Appendix, B). However, there are discrepancies in terms of the resources needed to complete science projects by rural and urban learners. The learners from under-resourced schools had slim chances of effectively participate in EEYS competitions as compared to learners from well-resourced schools (Ndlovu, 2015). Moreover, in rural schools, the mentors are scarce (Alant, 2010). Rural learners are also referred to as "previously disadvantaged individuals" (PDIs). They are also known to have limited resources and fewer qualified teachers (Alant, 2010; Grinnell et al., 2018; Ndlovu, 2014; Taylor, 2015). It is surprising that some schools have the resources like computers and printers but deny learners to use this technology (Ngcoza, Sewry, Chikunda & Kahenge, 2016).

2.9.8 Studies Criticising Science Fairs

The literature review has pointed out studies that do not find the science fairs benefiting much to learners. In contrast to other studies, Possibly, EEYS might not be the best channel for inspiring learners from poorly resourced schools to participate in science (Taylor, 2011). Science fairs offer a limited view of science, because it mostly teaches students about the experimental design and not necessarily other approaches (Jürgen et al., 2016). In addition, teachers and parents do not agree if the participation in science fairs has advantages (Craven & Hogan, 2008). Despite the various countries` efforts, learners have been losing their interest in studying science (Maltese, Melki, & Wiebke, 2014).

Ndlovu (2014) pointed out that The EEYS initiative is not reaching out to PDIs in rural schools. The level of help in the form of outreach programs and material support is very low in under-resourced rural and semi-urban schools.

However, it is not the nonexistence of support which is the obstacle but how the learners utilise the support and resources given to them (Betts, 2014). Some schools have equipment but do not have qualified teachers to use them. In some instances, the school does not allow the learners to make use of them (Ngcoza et al., 2016).

2.10 Disadvantages of Science Fair Participation

A science project can be a source of stress and disappointment to the learner (Bochinski, 1996). Furthermore, the competitive environment induces students to feel nervous and stressed (Fisanick, 2010, as cited by Keçeci, Zengin, & Alan, 2018).

Some learners who fail to get an award stop participating in the subsequent years. Science fair organizers do not offer avenues for learners to continue discussing their results or expanding on their science projects after the science fair competitions (Ho-Shing, 2017).

The very fact that a science fair is a competition could make the learners focus on winning and not on the aims and goals of the science fair itself (Chiappetta & Foots, 1984). Furthermore, some students are disadvantaged because they do not have access to laboratory equipment, facilities, and mentors (Flanagan, 2013). On the other hand, some learners who perform well are assisted by their parents who are scientists, and these parents may be well known in the community (Grinnell et al., 2018).

In Canada, a study concluded that most of the learners who participate at the Canada-Wide Science Fair were from wealthy families, were socially well connected and had access to laboratory equipment at their schools or universities (Bencze & Bowen, 2009). Therefore, learners who do not have access to professional science facilities, equipment, and mentorship are likely to be unsuccessful at science fairs (Gifford & Wiygul, 1992).

Poor performance at science fairs might emotionally harm the learner and affect their self-esteem. Ultimately, this emotional loss will affect their attitudes towards science in general. A poorly completed project can be a basis of stress to the learners which can result in a refusal to participate in science activities, especially if they fail to win an award (Bochinski, 1996). Science fair organisers do not offer opportunities for the participants to continue upgrading their projects after the science fairs (Ho-Sing, 2017). As a teacher who has worked with EEYS for eight years, learners are assisted to upgrade their projects from one level of competition to the next level, for example from district level to the provincial level and then from the provincial to the national competitions. However, if the learners are in grade 12 and cease to be a secondary-school learner, they will have to seek for other opportunities outside EEYS to upgrade the project.

2.11 Poor Science Fair Performances

The teachers have identified lack of financial resources, limited scientific knowledge and time as obstacles for learners to produce award-winning projects (Demirel et al., 2013; Olive, 2017). Learners lack readiness, research skills, and the competence to prepare and present their research projects and findings (Wharton, 2019). Moreover, some of the learners have problems in understanding the language of communication, English. This lack of English fluency might have impacted their presentation of their research projects to judges (Alant, 2010; Karikari & Yawson, 2017).

2.12 Science Fair Influence on Teachers

Teachers who were active in EEYS activities gained a variety of scientific investigation skills which they could use for classroom-based scientific investigations (Kahenge, 2013). The findings suggest that most teachers consider science fairs as beneficial and contributing to the scientific skills, communication skills, and content knowledge of the learners (Mupezeni & Kriek 2018). When teachers participate in EEYS activities, they develop their own skills, such as research skills, report presentation skills, data analysis skills, critical thinking skills, mentoring, judging skills and improved their teaching skills (Mbowane, 2016; Naidoo-Swettenham, 2017; Tortop, 2014).

Teachers participating in science fairs better understand the characteristics of their learners` pedagogical and content knowledge (Kisiel, 2013). Some studies have outlined the benefits concerning the teachers by increasing their knowledge and scientific research skills (Aubusson et al., 2012; Fallik et al., 2013). These activities enhance the teacher-student relationship and the academic achievement for all the students (Camacho & Fuligni, 2015). During the science fairs, the teacher builds relationships: teacher to teacher, student to teacher, and parent to teacher relationships (Griffiths, 2014).

In addition, teachers who participated in science expo activities gained in knowledge and increased self-belief and self-efficacy (Mbowane, 2016). During science fairs, teachers learn from other experienced teachers, and they, in turn, share the increased knowledge and skills (Taylor, 2015).

The disadvantage of the science fairs is that it exposes teachers who lack scientific research skills and who are unwilling to learn (Baki & Bütüner, 2009; Park & Ertmer, 2008). Some teachers lack the essential information and skills to guide the process of developing a research project (Pektas, 2009, as cited in Demirel et al., 2013). Furthermore, there is too much pressure for teachers to engage with these out-of-school activities, which is not part of their school workload (Bailey & Colley, 2014).

These studies have revealed what the teachers stand to benefit if they participate in science fairs and specifically in EEYS activities. The majority of the reviewed studies have stated that when teachers participate in science fair activities they gain scientific skills (Aubusson et al., 2012; Fallik et al., 2013; Kahenge, 2013; Mbowane, 2016; Mupezeni & Kriek 2018; Naidoo-Swettenham, 2017; Tortop, 2014). However, science teachers with less content and pedagogical knowledge may feel unprepared and inadequate.

2.13 Science Fair Judges

During the EEYS science fairs, judges are recruited mostly from the teachers and a few from universities and private sectors. Abernathy and Vineyard (2001) pointed out that the reason for judging science fairs was to nurture and inspire the coming generations of scientists. Science fairs often struggle to enrol judges, and their training was minimal (Atkins, 2014). It could possibly mean that the judges at some science fairs are not well trained on how to use the judges' rubric even if they might have the content knowledge (Atkins, 2014; Rillero, 2011). These inadequacies might hinder the judging process and negatively affect the learners.

At most science fairs, the learners do not get formal feedback from the judges. This lack of information hinders the learners' development of science processing skills. Judges should be aware of potential biases during the judging process and evaluate projects based on the science and methodology presented rather than the outward beauty and cost of the science project (Ricketts, 2011, as cited in Saunders, 2013). The science fair judging process needs to emphasize why the project was completed and not focus on how it was executed (Atkins, 2014). Some judges have been methodically demeaning and embarrassing learners who failed to answer very technical or complicated questions on their topics (Saunders, 2013). In addition, teachers consider science fairs as beneficial to learners though there are problems with judging (bias and fairness), the emphasis on the competition, and a lack of focus on the science behind the project (Abernathy & Vineyard, 2001). Furthermore, teachers desire that all learners be treated equally regardless of their nature of project and their school`s geographical background (Sharaabi-Naor, Kesner, & Shwartz, 2014). Science fairs have difficulties in recruiting judges, and those who are recruited can get minimal training on the judging process (Atkins, 2014). If the judges only have minimal training, then their judging competence is questionable.

2.14 Depth of Knowledge

Researchers have identified problem solving and critical thinking as fundamental constituents for student learning (Koomen et al., 2017; Schmidt & Kelter, 2017), Hence, many ideas have been suggested to assist in promoting these two practices.

The Bloom's Taxonomy and the Webb's Depth-of-Knowledge are two frameworks that are commonly used (Seaman, 2015). Bloom's Taxonomy is a multi-layered model of categorizing thinking according to cognitive levels of complexity (Forehand, 2010), and each category differentiates between cognitive skill levels leading learning and knowledge skills and transfer to varying tasks and contexts (Adams, 2015).

The Depth of Knowledge model is based on a four-level categorization: recall, concept, strategic thinking, and extended thinking (Webb, Alt, Ely, & Vesperman, 2005). Norman Webb developed the Depth of Knowledge (DOK) framework which has been widely used in understanding types of knowledge needed to solve academic problems. Figure 2.1 shows how Webb has outlined the different levels of content difficultness as follows:

Level 1: Recall

This first level involves basic recalling of information or remembering of formulae, definition of terms or description of a procedure.

Level 2: Skills and Concepts

The second level necessitates a learner to complete multiple steps in order to solve a problem. This might include collection and displaying of data in a table or chart.

Level 3: Strategic Thinking

This level demands reasoning, planning, using information, and a greater level of thinking. Learners are asked to explain and justify their thinking. Level 3 is more complex and abstract than levels 1 and 2.

Level 4: Extended Thinking

Level 4 is the most complex and requires complex reasoning, planning, developing, and needs a longer thinking time. An example would be that of a learner planning, designing and conducting an experiment. How the Depth of Knowledge framework was used in this study is further discussed in section 3.11.

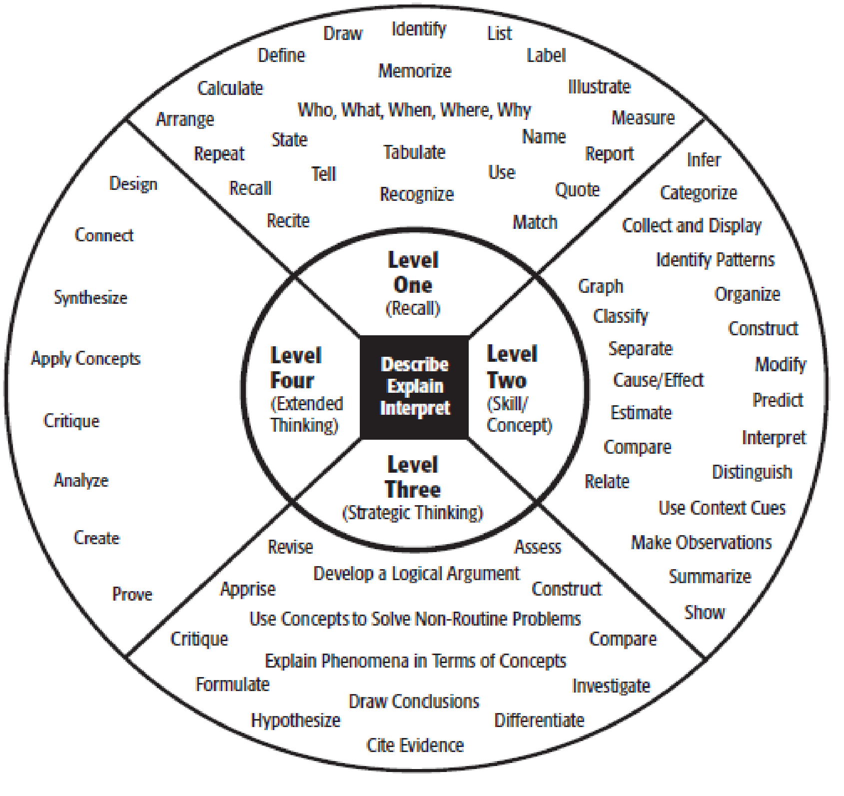

Figure 2.1: Depth of Knowledge Levels

The Depth of Knowledge model is more appropriate than Blooms' Taxonomy because the focus is more to the depth of content understanding and the skills required for completing research projects (Hess, Jones, Carlock, & Walkup, 2009).

2.15 Social Characteristics of Learning

Social constructivists argue that learners acquire knowledge through collaborative learning settings, sharing experiences, constructing knowledge, discussions and solving problems together (Crouch & Mazur, 2001, as cited in Miller, Lukoff, King, & Mazur, 2018; Vygotsky, 1978). Social learning is widespread; however, learners are advised to copy selectively from others considering as to when, what, and from whom they replicate information (Kendal, Boogert, Rendell, Laland, Webster & Jones, 2018). Also, science fairs are described as a community engagement where social learning is done and critical thinking and innovative ideas and skills are shared among participants (Gibbs & Poisat, 2020). Learners` attitudes, capabilities and abilities are influenced by the science they encounter in different social contexts outside the classroom (Lin & Schunn, 2016).

The social learning is based on Vygotsky (1978), a Russian psychologist, explained that socio-culturalism has learners accumulating new strategies and knowledge when they interact in different activities with different individuals. When learners develop projects and present their projects at science fairs, they interact with others at the fail, which result in their sharing experiences and knowledge (Ambrosino, Binalet, Ferrer & Yang, 2015; Sanchez, Garcia & Escudero, 2013).

Learning is social and it allows learners to learn from others, as opposed to individual learner, where they are on their own, like an island (Cheng & Jin, 2015; Mesoudi, Chang, Murray & Lu, 2015; Pittman, 2016; Rennie, 2014). During science fairs, learners learn from each other as they view other learner`s projects, and answering questions from the learners, judges, and teachers in attendance.

2.16 Theoretical Framework

This study has adopted the Cultural Historical Activity Theory (CHAT) as a theoretical framework. Even though Activity Theory and CHAT have been used interchangeably (Batiibwe, 2019), the focus in the literature has been on CHAT. With this theory, researchers need to identify and define their subject, object of study, tools, outcome, rules, community, and the division of labour within the activity system. CHAT is hinged on three main concepts:

a) The collective action of people, learning practically and at the same time communicating.

b) People make different types of tools and artefacts which they use.

c) The process of construction and interpreting the meaning is done by the community (Foot, 2014).

CHAT has gradually been used widely in educational research because of the importance of the social characteristics of learning (Batiibwe, 2019). In CHAT, the construct of activity is centred on the creation of an object. Therefore, it is the object-orientated nature of the human activity that defines the term activity. Activity refers to the actions of the people, modified by tools, community, rules, and culture, while taking into consideration the historically accumulated experiences (Engeström, 1987, as cited in Andrews, Walton, & Osman, 2019).

This theory was later extended by adding division of labour, rules, and community (Engeström, 2014). In CHAT, human learning is positioned and intrinsically intertwined within socio-cultural settings, taking into consideration cultural and historical influences on people`s actions (Karanasios, 2014; Stetsenko, 2005). The main components of CHAT are subject, object, outcome, community, artefacts/tools, division of labour and rules. The **subject** is the key person or groups of people involved in the activity (Cole & Engeström, 1993; Engeström, 2014; Karanasios, 2014). The **object** is the aim or reason behind performing a task (Cole & Engeström, 1993). **Outcome** is the desired objective or the final benefit of doing an activity (Beatty & Feldman, 2012; Engeström, 2014). A **community** refers to a group of people or different groups of people in a system, having the same interest in the object of a given activity and are involved with the subject (Cole & Engeström, 1993; Engeström, 2014). As the learners work on their projects in the community, they will be assisted by other people. Learning is a social process, and this process involves more than one person (Vygotsky, 1978). Of all of the content areas, scientific knowledge is the product of a socially practiced community (Driver, Newton, and Osborne, 2000). **Artefacts/tools** are instruments, signs and intellectual tools that are used as resources to perform different tasks (Cole & Engeström, 1993; Engeström, 2014). According to Vygotsky (1978), learning is socially achieved when a learner is assisted with someone with more knowledge and tools. **Division of labour** describes how tasks, roles and responsibilities are shared among members as they perform an activity (Cole & Engeström, 1993; Engeström, 2014). **Rules** are the regulations, explicit and implicit regulations, norms, conventions, expectations, proper procedures and social relations that guide the community members (Beatty & Feldman, 2012; Engeström, 2014; Karanasios, 2014; Lin & Huang, 2013).

2.16.1 Cultural Historical Activity Theory (CHAT)

CHAT is applied to science fairs using its components for analysing the empirical evidence obtained. The development of science projects can be explained in terms of the transformation of learners (subjects), the transformation of tools (use of computers and laboratory equipment), including the transformation of learners` perceptions of community, division of labour and rules (Kaptelinin & Nardi, 2012). CHAT provides a holistic and contextual method of discovery that may be used to help in qualitative and interpretative research. This case study explored the science fair design activity by answering the question: What are the dynamics influencing the performance of learners at the science fairs? The CHAT framework was used to describe different learner participants and dynamics that influence the performance of learners in science fairs. Furthermore, CHAT analysis highlights and systematize the various factors that exist in the research study (Roos, 2012).

In CHAT, the mental capabilities and ability to learn by an individual must not be treated in isolation. This learning should include the physical, cultural, and technical world (Engeström, 1987). When CHAT is used as a research lens, the following has to be identified: tools, rules, subject, object, community, and division of labour (de Beer, 2019).

The CHAT framework describes a triangular structure with six interdependent and related components (see Figure 2.2).

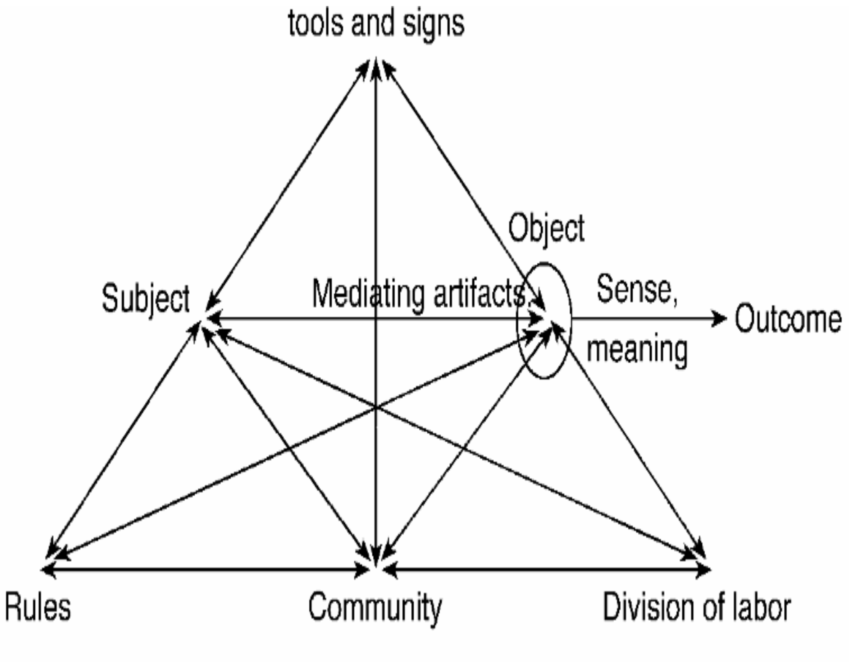

Figure 2.2: Activity Triangle model (Engeström, 1987)

For this study, the components of the activity triangle have been adapted from Engeström (1987) (See Figure 2.3).

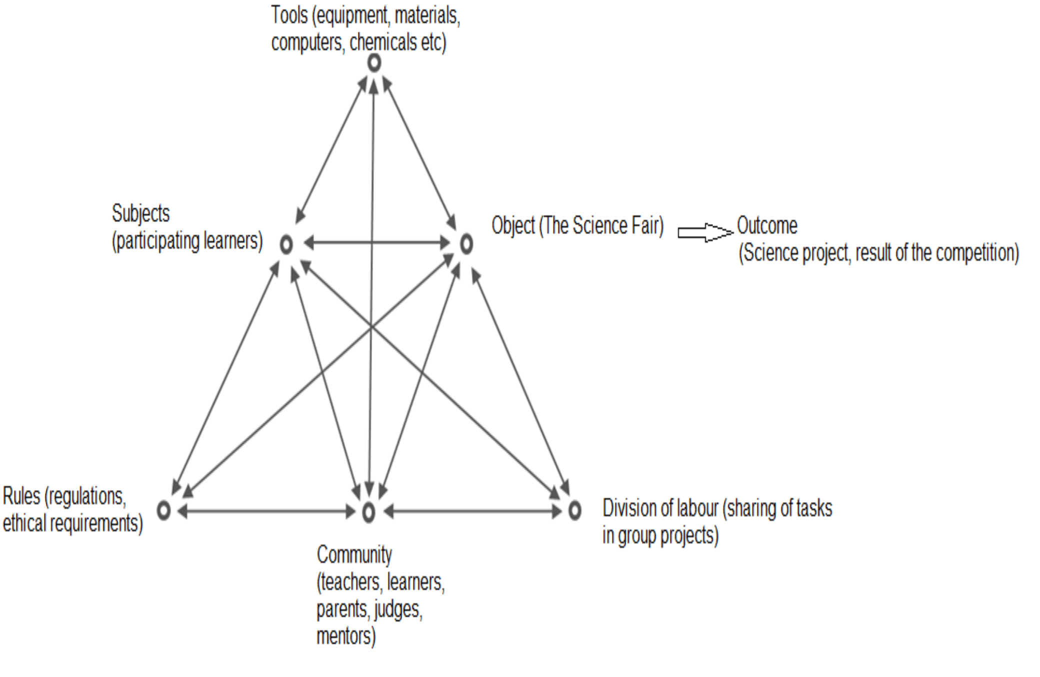

Figure 2.3: Author`s example of Activity Triangle, based on Engeström (1987)

- **Object** is the purpose of the activity is the science fair.
- **Subject** is the individual actors in this study, the participating learners.

- **Community** is the combination of all actors. In this study, the community refers to all stakeholders (DBE, DSI, EEYS), learners, teachers, school principals, mentors, and parents.
- **Tools** are the artifacts used by learners in producing their science projects, which include, but are not limited to, laboratory equipment, materials, computers, and documents.
- **Division of labour** focuses on how the research projects are completed. If it is a group project, it must be clear who does what activity while using what (Ramugondo & Kronenberg, 2015).
- **Rules** refer to all science fair regulations and ethical requirements. The judges enforce these rules. These are social and professional rules and ethics driving the subjects' (learners`) actions (Ramugondo & Kronenberg, 2015).
- **Outcome** is the outcome of learner activity, the science fair project, and the result of the project's presentation.

The activity theoretical perspective outlines the role of other activity systems. Possible individuals who may participate simultaneously are teachers, parents, mentors, peers, and universities (Torkil, Kaptelinin, & Nardi, 2016). There is a relationship between the individual learner (subject) and other stakeholders. This relationship is observed through the component of the community and is facilitated by rules. The relationship between object and community is intermediated by the division of labour (Hettinga, 1998).

In their study, Mentz and de Beer (2017) demonstrated the third generation application of CHAT and how it can be used on an institutional plane. They compared two activity systems: one with best practice to one with intrinsic weaknesses. This comparison was conducted in Finland and South Africa. For this study, the third generation of CHAT has been adapted onto its two activity systems by comparing the performances of rural learners and urban learners at science fairs in South Africa. Figure 2.4 shows a comparison of two activity systems: rural learners` performance with urban learners` performance at the science fairs.

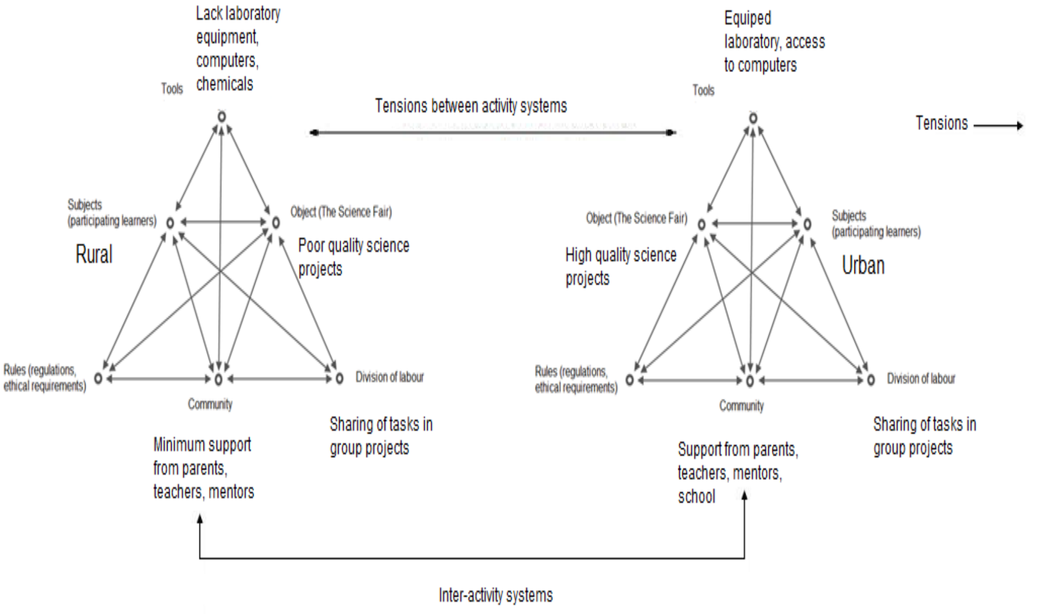

Figure 2.4: An example of third-generation CHAT developed by Engeström (2009), as cited in Mentz & De Beer, 2017)

CHAT elicits the "barometer of tensions" (Mentz & De Beer, 2017, p. 98) and offers an understanding of the two activity systems, by revealing the tensions that are present (de Beer, 2019).

The rural school learners in the province of Limpopo have been performing poorly at science fairs as compared to urban school learners. The rural schools are under-resourced (de Beer & Ramnarain, 2012), in terms of laboratory equipment and computers. In contrast, urban schools have the resources to support learners with their science projects. Current rural learners have inherited schools that were historically disadvantaged from the colonial era. CHAT is used because it allows the exploration of the cultural and historical factors while bringing out the intricacies within the activity system (Mentz & De Beer, 2017).

Therefore, tension arises within the tools that are used. Rural learners do not have resources at their schools such as computers, laboratory equipment, printers, and other materials that they would need to complete their science projects. On the other hand, urban learners have access to equipped laboratories, printers, and computers (Grinnell et al., 2018). Furthermore, tensions exist within the community. Some parents of the rural learners are unable to assist their children since they lack the necessary education and qualifications to do so. In contrast, the majority of parents of urban learners can assist their learners with their projects.

2.16.2 Justification for use of CHAT

CHAT framework has been studied as related to context. Its extensiveness and engagement in its history along with various issues has allowed it to be used in flexible and creative ways (Andrews et al., 2019; Batiibwe, 2019; de Beer, 2019; Jackson et al., 2018; Mentz & de Beer, 2017; Peterson & White, 2018; Ramnarain & de Beer, 2013; Ramugondo & Kronenberg, 2015; Sebotsa, de Beer, & Kriek, 2018; Seleke, Vaughn, & de Beer, 2018; Trust, 2017).

CHAT is appropriate for this study context because the science fair participants come from a background or history of being PDIs. Science is socially and culturally developed (Peterson and White (2018). Therefore, tensions will arise between rules and the community, community and tools and between tools and subject. CHAT addresses the cultural and historical backgrounds when used as a research lens (Carr & Ludvigsen, 2017).

Due to its adaptability and ability to reflect complexities in activity systems, CHAT is convenient as a lens in qualitative research methodologies (Seleke et al., 2018). For this case study, CHAT provided the method of understanding and analysing the science fairs and its participants, stakeholders and sponsors, in order to find patterns and make inferences across interactions. Furthermore, it represents and explains the changes that were identified during this case study. Lastly, the strengths of using CHAT are that it closes the gap between the individual subject and the community by studying both factors through the mediating activity systems.

However, the limitation of using the framework is apparent when the user lacks a shared understanding of the characters and histories of the learners and their communities. The analytical power of CHAT will not be leveraged if the activity system is not understood as a single unit. The CHAT framework compels the researcher to focus beyond learner-project dyad and seek to ascertain how other components are influencing the situation.

2.17 Summary

In this chapter, the existing literature that relates to the origin of science fairs, advantages, and disadvantages of science fairs were explored. The study reviewed the literature and revealed the causes of strong and weaker learner performance at science fairs. Comments from the different literature studies on science fair judges were presented. Also, the chapter presented the theoretical framework for this study. Chapter 3 presents the methodology preferred to conduct for this study.

Chapter 3: Research Methodology

3.1 Overview

The research explored the dynamics influencing the learners` performance at science fairs in the Limpopo Province of South Africa. It sought to answer the following research questions:

1. How do the constructs of CHAT uncover the dynamics contributing to the difference of rural and urban schools’ learners’ performance at science fair competitions?
2. How do the tensions in the constructs of CHAT reveal the disparity between urban and rural science fair learners?
3. What is the effect on the performance of learners competing at science fairs in the Physics category, in terms of the level of attention and depth of knowledge in physics?

This chapter describes the research process, providing information on the method used in doing this research, and its justification. The various stages of the study have been described, which include the research paradigm (section 3.3), choice of research design (section 3.4), the setting (section 3.5), the study’s participants (section 3.6), the research instruments (section 3.7), data collection procedures (sections 3.8), and process of data analysis (section 3.9). There is also a discussion on the trustworthiness of the data that was collected (3.10). The chapter culminates with a discussion on ethical considerations for this study (section 3.11).

The chapter includes the process used for the thematic analysis of transcripts from 28 individual interviews and two focus group discussions (of 12 learners) in order to expose the codes and themes that are represented in the data. The study introduced the Depth of Knowledge paradigm as a way of evaluating the 12 participants, in terms of their depth of knowledge in physics.

3.2 Introduction

The constructivist-interpretivist paradigm was chosen in order to gain an insider view of the dynamics influencing the performance of learners (Creswell, 2014). This study follows an exploratory case-study research design. Thematic analysis, which is the identification of patterns and themes in the data, was also applied (Bertram & Christiansen, 2015; Creswell, 2014; Leedy & Ormrod, 2010; Nieuwenhuis, 2010). Data collection was framed by the research questions and by the consideration of evidence that was needed in order to answer those questions (Erickson, 2012). This information provided insight into the learners' and stakeholders' view on the dynamics that influence learner performance in science fairs.

3.3 Research Paradigm

A research paradigm is a set of beliefs guiding actions and is rooted in educational researches (Creswell, 2008). Using a paradigm helps the researcher making sense of the world, and its impact on the framing and investigating of the research topic (Mukherji & Albon, 2018). Therefore, the researcher's understandings of knowledge and truth influence every process of the research study (Chilisa & Kawulich, 2012; Kivunja & Kuyini, 2017).

The focus of this case study was to attain an in-depth understanding of a phenomenon (science fairs) within their natural setting (Keçeci, 2017; Morgan & Sklar, 2012). A case study design creates boundaries in the study, to better focus on achieving an understanding of the research questions (Creswell & Poth, 2018).

3.3.1 Constructivist-Interpretivist Paradigm

This study focuses on the dynamics influencing the performance of learners at science fairs. To achieve the aim of this study, participants included stakeholders, learners, teachers, school principals, judges, mentors and parents. The goal was to seek their experiences and knowledge on science fairs. How these participants see and view science fairs helped in constructing and interpreting the dynamics influencing learners' performance. This construction and interpretation of experiences encapsulate the constructivist-interpretivist paradigm (Guba & Lincoln, 1989; Merriam & Tisdell, 2016). The interpretivist paradigm was used to understand the internal reality and subjective experiences of learners, teachers, mentors and sponsors through interacting with them (data collection), and interpreting the gathered data (Terre'Blanche, Durrheim, & Painter, 2007). All research paradigms are linked to the philosophical basics which are ontology, epistemology, methodology and axiology (Cohen, Manion & Morrison, 2000).

Ontology is the assumptions people make in order to accept that something is real or practical (Kivunja & Kuyini, 2017). In other words, ontology answers the question, "…what is the truth/reality?" (Maree, 2018, p. 56). In addition, ontology is the way the researcher explains the truth and nature of reality (Antwi & Hamza, 2015; Lincoln & Guba, 2013). In this study, the researcher sought to identify the reality of the dynamics that influence the performance of learners from Limpopo in science fairs.

Epistemology describes how people come to know the reality The goal is to learn what the people consider as knowledge and how it can be acquired and communicated to others (Cooksey & McDonald, 2011, as cited by Kivunja & Kuyini, 2017). Another definition is "how things can be known – how truths or facts or physical laws, if they do exist, can be discovered and disclosed" (Maree, 2018, p.67). Furthermore, epistemology can be referred to as,"the science of how knowledge about reality is acquired" (Sefoitho, 2018, p. 23).

Methodology refers to the research design, research methods, data gathering, sampling, research instruments, approaches, data analysis processes in order to gain knowledge to solve the research problem (Antwi & Hamza, 2015; Kivunja & Kuyini, 2017). Another explanation is as how one studies the world and acquires knowledge (Lincoln & Guba, 2013). According to the constructivist paradigm, there are multiple realities which are created by people's interactions, taking into consideration their social, cultural and historical perspectives (Crotty, 1998).

Axiology considers the relevant ethical issues when completing a research study. Issues include, but are not limited to, human values, respect of participants` rights, moral issues, and cultural issues (Kivunja & Kuyini, 2017). Axiology requires the researcher to, "develop a sense of responsibility for the wellbeing of participants in their research" (Sefotho, 2018, p. 24). This aspect was addressed by taking the participants' ethical issues into consideration (see section 3.11).

3.4 Research Design

A research design is a plan that guides the researcher in the processes of collecting, analysing, and interpreting data (Yin, 1994). It permits the researcher to draw interpretations concerning causal relations among the study's variables.

The researcher sought to learn about the dynamics that influence the performance of learners at science fairs. Therefore, an interpretive case study research design was chosen as it is the most suitable in responding to the research questions. An advantage of the case study method is that it permits in depth examination, description and explanation of the phenomenon by using different types of evidence that has been collected from the varied instruments. Also, this kind of study allows for the research to be conducted in real-life context (Creswell, 2014).

3.5 Setting

This study was conducted in the Limpopo Province of South Africa. Limpopo Province is one of the largest provinces with an area of 125 754 km^2, and it shares borders with Botswana, Zimbabwe and Mozambique. It is also one of the poorest provinces in South Africa. This province is primarily rural with an estimated population of 5.5 million people. There is high unemployment due to weak economic development. Most schools in the province lack resources, and the people have poor access to basic services (Malelelo-Ndou, Ramathuba, & Netshisaulu, 2019).

3.6 Participants

Limpopo Province has four regions that participate in the EEYS fair: Vhembe, Waterberg, Mopani and Capricorn (Polokwane). The Table 3.1 shows the number of learners who participated in the science fairs in the years 2016, 2017, 2018 and 2019.

Table 3.1

Number of Participants from Limpopo Province

Region		2016	2017	2018	2019
Vhembe	Total participants	343	335	376	412
Waterberg	Total participants	96	181	230	351
Mopani	Total participants	234	229	244	320
Capricorn (Polokwane)	Total participants	172	294	332	347
	TOTAL	**845**	**1039**	**1182**	**1430**

The focus of this study is on learners with physics-related projects. The physics category was chosen because very few learners participate in this category. Therefore, it was interesting to learn why this category was unpopular. In 2019, the total number of learners who completed projects under the Physics category were 49 learners out of 1430 participants. Of these participants, seven were from Waterberg region; 11 were from Vhembe region; 13 were from the Mopani region, and 18 were from the Capricorn (Polokwane) region. This population included the learners participating in the science fair (Creswell, 2008; Wegner, 2003). Mopani region was chosen because most of the schools are located in rural areas. By contrast, the Polokwane region was selected because it is a large city with several urban schools.

3.6.1 Sample

The sampling was purposeful, with relevant participants to the problem being investigated (Patton, 2015). Selected participants took part in science fair activities; therefore, they were likely to give relevant information relevant for this study. In addition to learners, there were stakeholders, learners, teachers, school principals, mentors, and judges because they could provide relevant information to answer the research questions. These participants compete in science fairs; therefore, they are knowledgeable and informative about EEYS science fairs which are the focus of this investigation (Etikan, Musa, & Alkassim, 2016).

In reality, while the population may usually be large, the size of the sample is not the decisive factor (Best & Kahn, 1993). The sample for this study was not large. Furthermore, a primary consideration in determining sample size is the methodology that is to be used (Wimmer, 1983). In this study, a qualitative approach was used with no fixed number of subjects that regulated the size of an acceptable sample (Best & Kahn, 1993).

The study had a total of 12 learners. Six learners were selected from rural schools, three boys and three girls. In addition, six learners were selected from urban schools, three boys and three girls. All learner participants were in grade 10 and enrolled in physical science class. EEYS registration information was used to select participants with projects in the Physics category. All participants were pre-assigned identity codes as follows:

Rural female participants:	RF1, RF2, RF3
Rural male participants:	RM4, RM5, RM6
Urban female participants:	UF7, UF8, UF9
Urban male participants:	UM10, UM11, UM12

An additional nine participants were chosen for interviews. Three participants came from EEYS management. Three participants came from the Department of Science and Innovation Management. Three participants came from the DBE provincial management. These organisations are the sponsors and partners of EEYS and have expectations from the participating learners. These participants were selected because of their high level of management of information related to science fairs. In order to give a more holistic picture, four teachers, four school principals, four parents, four mentors and three science fair judges were interviewed. This purposive selection was based on the teachers, school principals and parents with learners participating in science fairs under the Physics category. The selected mentors assisted learners on physics projects, and the selected judges assessed the physics projects at the science fairs. As with the learners, all participants were assign pre-determined identity codes:

Department of Education	DBE1, DBE2, DBE3
EEYS Management	EE1, EE2, EE3
Department of Science and Innovation	DSI1, DSI2, DSI3

Teachers:	
Rural:	TR1, TR2
Urban	TU3, TU4
School Principals:	
Rural	SPR1, SPR2
Urban	SPU3, SPU4
Mentors:	
Rural	MR1, MR2
Urban	MR3, MR4
Parents:	
Rural	PR1, PR2
Urban	PU3, PU4
Judges	J1, J2, J3

All interviews were conducted by the researcher. In order to maintain objectivity and minimize bias with the qualitative analysis the following issues were addressed:

a) The researcher requested all participants to review the interpretations to check whether they represent their views and beliefs.
b) The researcher verified with more than one source to support the interpretations (Creswell & Creswell, 2017).
c) The researcher checked for alternative explanations or justifications for the information gathered. Ruling out alternative explanations resulted in stronger interpretations (Polit & Beck 2014).
d) Three peers were asked to review the findings in order to not only identify gaps in researchers' arguments but also to affirm that conclusions were reasonable based on the collected data (Creswell & Creswell, 2017).

3.7 Research Instruments

The research instruments used in this study were: personal meaning mapping (PMM), focus group discussions (FGD), observations protocol (level of attention), physics test (depth of knowledge), and stakeholders` interviews. This study used a depth of knowledge tool, a physics test, as a data collection tool (see section 3.7.4). All collected data are consistent with this study's aims. Data collection occurred in a number of stages. Figure 3.1 illustrates the process of the design and development of the research.

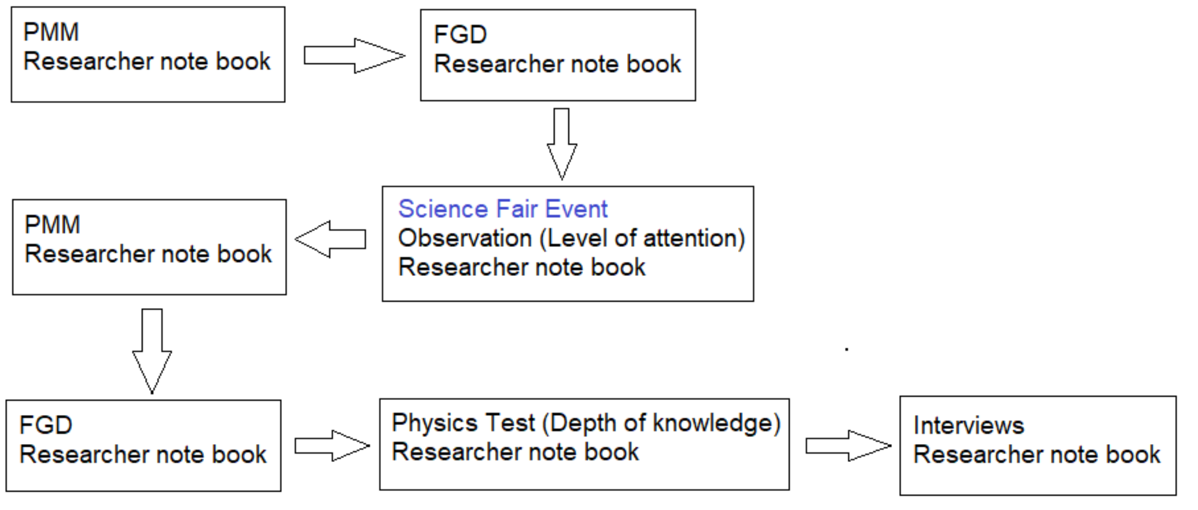

Figure 3.1. Research steps

Firstly, the PMM, FGD and observation instruments were used on a day that the science fair was held. The first PMM and first FGD were completed before the science fair, and the second PMM and second FGD were completed after the science fair. Secondly, the physics test was given to all 12 participants 2 days after the science fairs. Finally, the EEYS, DBE, DSI, teachers, school principals, mentors, parents and science fair judges were interviewed. All interviews and FGD were audio and/or video recorded. Observational data was recorded in the researcher's notebook.

Table 3.2 shows the research instruments and the corresponding research questions.

Table 3.2

Instruments and Research Questions

Instrument	Sub-Research Question
Personal Meaning Mapping (PMM)	1 and 2
Focus Group Questions (FGD)	1 and 2
Observations (Level of Attention)	3
Physics Test (Depth of Knowledge)	3
Interviews	1 and 2

Table 3.2 shows that the PMM instrument was used to collect data for sub-research questions 1 and 2. The FGD method was used to collect data for sub-research questions 1 and 2 as well. The observation protocol was used to collect data for the sub-research question 3. The physics test, which was used to understand the learners' depth of knowledge, was used to collect data for sub-research question 3. Lastly, interview data that was gathered from with the stakeholders, teachers, school principals, mentors, parents and science fair judges, were used to address sub-research questions 1 and 2.

3.7.1 Personal Meaning Mapping (PMM)

The Personal Meaning Mapping (PMM) was originally developed for the museums, festivals and similar events to understand the experiences and knowledge of visitors or participants (Adams, Falk, & Dierking, 2003). PMM is a powerful tool that helps people to explore their knowledge and awareness of different topics. Research has shown that this instrument is a reliable tool to be used as a learning assessment (Falk, Moussouri, & Coulson, 1998). The use of PMM was to understand the participant's knowledge and views about science fairs before the participant enters the science fair and again after participating in the event. It was used to better understand the learners' conceptions of science fairs in general without focusing on the physics aspect. As a qualitative tool, PMM allowed the participants to express their knowledge and diverse meanings of science fairs.

3.7.1.1 Rationale for Using PMM

The PMM afforded the learners a platform for communicating their science fair experiences (Leftwich, 2012). It provided a methodological tool for learners to evaluate their experiences at science fairs.

This research instrument does not require participants to give answers in a linear sequence. Instead, learners could express themselves without the restriction of their responses to only using sentences and/or choosing their responses from pre-set options. In addition, participants are at liberty to use words, phrases, and/or diagrams. Responses are provided in any order with links between concepts and secondary associations with words they have written. Furthermore, PMM does not use potentially leading questions. Lastly, the PMM captures highly personal responses from the learners.

3.7.2 Focused Group Discussions (FGD)

Focus group discussions (FGD) are a social method of gathering research data through informal group discussions on a specific area of interest (O'hEocha, Wang, & Conboy, 2012). FGD data can be categorized into two main groups: content data and interaction data. Content data consists of the verbal (comments or expressions made by a participant in the form of words) and the non-verbal (physical gestures, changes in voice tones or periods of silence made by participant). Interaction data refers (participant`s comments to one or more people in the form of words) and the non-verbal (physical gestures, making of sounds like clapping of hands, change in voice tones and periods of silence) (Nili, Tate, Johnstone, & Gable, 2014; Onwuegbuzie, 2007; Smithson, 2000).

In this study, verbal comments made by participants were recorded and the physical gestures were also noted in the researcher notebook. When people with similar backgrounds and experiences are gathered together to discuss a topic, they form a FGD (Krueger, 1988). FGD was used to gain an in-depth understanding of the participants views on science fairs. Also, FGDs were used to obtain data through informal group discussions on science fairs (O'hEocha et al., 2012).

This method aimed to collect data from a purposely selected group of learner participants (Ochieng, Wilson, Derrick, & Mukherjee, 2018). The rural and urban learners were in two separate groups. Each group of science fair participants were moderated and facilitated by the researcher. It was to ensure that the discussions were lively.

3.7.2.1 Rationale for Using FGD Method

FGD was chosen because it gave science fair organizers an opportunity to give specific details on what influenced the learners` performances at science fairs. It also allowed the participants to explain how they make informed decisions about current and future science fairs. Furthermore, the set-up of FGD is less threatening for the learners when compared to one-on-one interviews (Barbour, 2008).

FGDs are a suitable evaluation technique for design research projects for the following reasons:

1. Flexibility. FGDs allow for an open format and are flexible enough to handle a wide range of design topics and domains.
2. Direct interaction with respondents. The researcher is put into direct contact with domain experts and potential users of the design artifact, which allows the researcher to clarify any questions about the design artifact. Also, the researcher could probe the respondents on certain key design issues.
3. Large amounts of rich data. FGDs interactions produce a large amount of information in the form of feedback. This rich data set allows deeper understandings, not only on the respondents' reactions and use of the artefact but also on other issues that would impact the design.
4. Building on other respondent’s comments. The group setting with its opportunities for interactions allows for the emergence of ideas or opinions that are not usually uncovered in individual interviews. (Stewart, Shamdasani, & Rook, 2007)

FGDs produce large amounts of group interaction data (Belanger, 2012). They are interactive and synchronous, which permits participants to discuss, agree, or dissent with each other's ideas and/or to elaborate on the opinions that they have already mentioned (Nili, Tate & Johnstone, 2017).

There were sufficient guidelines on planning and conducting focus groups (Liamputtong, 2011; Stewart & Shamdasani, 2014). During the FGD, the learners spoke freely and expressed their own opinions without restrictions and this gave credibility to the data. The researcher ensured that each question was deliberated until it reached saturation, (Arksey & Knight, 1999).

Lastly, FGDs are easy to conduct because all of the participants, including the researcher, are available at the same location and at the same time.

3.7.3 Observation Protocol

An observation protocol was arranged by the participants' level of attention throughout the science fair activities. The researcher created the observation protocol, and was aware of presumptions that would influence the findings and the influence the act of observing the learners may cause on their behavior. The observation offered a base on how focused and engaged the learners were during the science fair.

Observations were conducted during the science fairs on six rural learner participants and six urban learner participants. Also noted were learner behaviours and activities during the science fair itself. Learners were observed, for example interacting with other exhibitors, and the reading of display boards of other entrants at the science fair. (see Appendix D).

3.7.3.1 Rationale for Using the Observation Protocol

The observation method provides a chance to learn what participants may be unwilling to share in an interview. There is no physical contact between the researcher and the participant, which may enable the participant to act naturally. Also, participants' fear and/or shyness became non-existent (Creswell & Creswell, 2017). In this study, learners were not aware that they were being observed. As a result, they behaved and acted in a more genuine way (Yin, 2017).

3.7.4 Physics Test (Depth of Knowledge)

Learners' depth of knowledge was tested based on a four-level categorization: recall, concept, strategic thinking, and extended thinking (Webb et al., 2005). Their physics knowledge was tested because the participants were competing in the physics category and taking physics classes at school as part of the school subject physical sciences. All 12 participants were in grade 10. Therefore, the physics questions are suitable for grade 10 learners. The questions were selected and arranged into the appropriate four levels of depth of knowledge:

Level 1 question: recall and reproduction. Recall of information such as a fact, definition, term, or a simple procedure, as well as performing a simple science process or procedure; demonstrate a rote response, use a well-known formula, follow a set procedure, or follow a defined series of steps.

Level 2 question: skills and concepts. Requires learners to make some judgements as to how to approach the question or problem; include more than one step.

Level 3 question: strategic thinking. It has more than one possible answer and requires learners to justify the answers; the activities may include drawing conclusions from observations; citing evidence and developing logical arguments with explanations for concepts.

Level 4 question: extended thinking. Learners are required to make several connections—link ideas within the content area or among content areas—and have to choose or devise one approach among various alternatives on how the situation can be resolved.

The four physics questions according to the level. Therefore, question 1 was for a Level 1 question, recalling and reproduction. Question 2 of the assessment is aligned with a Level 2 question, skills and concepts which required more than one step in order to answer it. Question 3 on the assessment was a Level 3 question which required strategic thinking. Finally, question 4 on the assessment was a Level 4 question, one that required extended thinking.

3.7.4.1 Rationale for Using the Depth of Knowledge Model

All participants chose physics subjects at their schools, and all of them competed at the science fair under the physics category. It was, therefore, necessary to assess their knowledge of physics by using a test (see Appendix C) Results from this test was used to compliment the data obtained from PMM, FGDs, interviews and observations.

Face and content validity was established for the physics test by asking the subject advisor if the questions were relevant and applicable to the content of the subject at grade 10. The subject advisors and head of departments agreed that the questions were appropriate for the science curriculum and the school syllabus.

3.7.5 Interviews

Interviews are methods of collecting information orally, whereby the interviewer uses some pre-planned main questions (Creswell, 2014). This researcher used an interview protocol that required flexibility. Telephone interviews were preferred rather than face-to-face due to the COVID-19 pandemic. Participants chose the time and place for the interviews. All interviews were audio recorded.

The researcher used structured interview questions, using predetermined short and clearly worded questions. Structured interviews are easy to conduct, and the questions can be standardised for other participants.

3.7.5.1 Rationale for Using Interviews

This data collection is advantageous when seeking clarity of the participants' comments and/or probing the participants for additional details. Advantages of this method are:

1. Direct communication with the participant often leads to more specific, constructive ideas.
2. The information obtained is more detailed.
3. Small number of participants is required to gather rich, detailed, and informative data.

The interview data helped in the reporting and analyses of all of the participants' feedback: learners, stakeholders of EEYS, teachers, school principals, mentors, parents and science fair judges.

3.7.6 Researcher Notebook

A researcher notebook or a reflexive diary aims at improving the credibility, auditing process, and removing bias in a study. The researcher notebook added ethical rigour and helped the researcher to examine personal assumptions and aims, clarifying personal belief systems (Anney, 2014), Using this notebook helped the researcher to avoid being reactive during interviews and to increase the reliability of the responses, so that same questions would be answered in the same way at another time and place (Liao & Hitchcock, 2018). Also, the notebook assisted in making visible learners` feelings, opinions and experiences in order to avoid bias (Denzin, 1994). The researcher kept a personal record of key decisions, processes and sentiments. These records helped the researcher learn from the process, making it possible to remember how events and processes were completed (Thorpe, 2010).

3.7.6.1 Rationale for Using Notebook

Keeping a researcher notebook is easy, and it can be quickly updated. In this study, during FGD sessions, the researcher was able to design probing questions as the participants spoke (Creswell, 2014; Dodgson, 2019). Notes, description of events and participants` activities were recorded during the observation (Teh & Lek, 2018). The researcher clearly described the contextual interconnection between the participants and researcher, which increases the credibility of results and improves the reader's understanding (Dodgson, 2019).

3.7.7 Instrument Validation

The instruments used in this study fell into two categories: researcher-completed instruments and subject-completed instruments. These are differentiated by the instruments that the researcher administered against those that were completed by the participants. The researcher-completed instruments were the observation forms whereby the performance checklist was used and the interview schedules/guides. The subject-completed instruments were the physics test based on the depth of knowledge levels (see section 3.7.4). The researcher showed that the instruments are valid by ensuring that the interview questions had face validity and content validity. In order to establish face validity, the researcher used two different parties to review the questions. The first group was those familiar with the topic and were used to evaluate if the questions were capturing the topic. The second review was conducted by an expert on question construction who checked for grammatical errors, leading and double-barreled questions.

Content validity involved evaluation of the questions by experts and literature reviews to ensure that they include all the items that are important to the construct domain and removal of undesirable questions. Also, the capturing of the content made relevance of questions and experience of the participants (McCoach, Gable & Madura, 2013). The questions that were formulated and used can be used by others and similar results may occur, meaning that they are reliable.

3.7.8 Interview Questions

The author solicited advice from the people (key informants) who are familiar in the field of research with the aim of knowing how the participants would feel about answering the questions. The questions were revised after talking to the informants. The purpose of doing this was to establish the usability or the ease with which the interview questions can be used and interpreted by the learners, sponsors, teachers, principals, mentors, parents and judges (Lincoln & Guba, 1985).

Validity refers to the degree to which the FGD interview questions bring out the relevant information required for the study and not having any fictitious data (Leung, 2016).

The interview questions addressed accurately what the researcher wanted to know in order to find dynamics influencing the performance of learners at science fairs. The researcher presented the interview schedule to the supervisor for comment, editing and proofreading.

The interview questions were piloted. Member checking was performed. with participants reviewing and validating the transcripts, checking to see if what the researcher wrote was correct. Answers to the questions were found to be consistent in providing the information that they were intended to reveal from the learners and sponsors and this is reliability.

3.7.9 The Observation Protocol

Designing the observation protocol was a constant process of drafting, testing and retesting, consulting experts and re-writing.

An observation protocol is reliable if it is consistent across time and other observers (Mitchell, 1979). Validity is when an observation protocol measures what the researcher intended to measure (Maxwell, 2013).

To ensure the reliability of the instrument and the validity of the observational data, the following steps were used:

1. A review of the literatures was completed, and a provisional list of behaviours was prepared which was used to produce the observation protocol (Creswell & Creswell, 2017; Maxwell, 2013). The observation protocol was given to people who are experts in the field for correction (content validity).

2. A pilot observation was conducted to test the observation protocol with the aim of making any necessary modifications. Pilot testing is used to ensure that the performance checklist captured all the intended information and behaviour of the learners. The pilot test was conducted at a different science fair in the same region, with learners in the same grade and competing in the physics category.
3. Reliability of the observation protocol was tested. The performance checklist had all of the information that the researcher needed to check the learners' level of attention. They are descriptors of focus, distraction and engagement.

3.8 Data Collection Procedures

Before any data was collected, this study was approved by the University of South Africa Ethical Clearance (see Appendix E). In addition, the Limpopo Province Department of Education (see Appendix F) and EEYS (see Appendix G) gave permission for this study to occur. Data collection happened during the two Regional

EESY Fairs. In Mopani, data was collected from participating rural school learners, and in Polokwane, data was collected from urban school learners. The specific data collection procedures, with the criteria for selecting cases and materials were completed (Lazar, Feng, & Hochheiser, 2017). After identifying the data sources; learners, teachers, judges, mentors, school principals, parents, EEYS, DBE and DSI managers, protocols were developed on how to use these sources in order to collect data.

Specific questions for the interviews and FGD were included in the protocol. The structures of the tasks that were performed during observations were specified. Also, the physics test questions were printed and the rubric developed by the researcher and verified by PhD in Physics experts. The researcher took measures to hide the identity and traits of individual participants from other people. The subjects were informed that their participation was voluntary and were allowed to stop participating at any time.

3.8.1 Collection of PMM Data

These guidelines were followed when collecting data from the PMM with FGD:

- Before the science fair, the selected participants were each given a sheet of paper with the identity codes, on which the words "Science fair" were written in the centre. The participants were then asked to write in black ink anything that comes to their minds concerning the words "Science fair"; they included but were not limited to ideas, opinions, information, invention and innovations, and beliefs. (See section 4.2).
- After the science fair, the participants were given their original paper and were requested to re-read their work, making changes or additions to their previous responses. Participants used red pens to make the new corrections and additions on the same paper. (Van Winkle & Falk, 2015)

The first PMM aimed at collecting the information and knowledge that the learners had before the science fairs. The second PMM which was completed after the science fair in order to collect the new information and experiences that the learners might have gained after the science fairs. For example, participants may have new perspectives of the science fair judges.

3.8.2 Collection of FGD Data

The FGD questions were piloted with a group of grade 10 learners who participated in the science fair, in order to check if the questions were well understood by the learners. FGDs were used to obtain additional details and perspectives of the PMM findings. The first FGD was conducted prior to the science fair and soon after the first PMM. The purpose of the first FGD was probe for clarity on the information obtained from the first PMM. The researcher ensured the active participation of all members while maintaining a neutral attitude and taking note of all the participants' opinions (Stewart, 2014). Learners were questioned on their understanding of science fairs and the knowledge they acquired when planning and completing science fair projects (see Appendices H and I). During the FGD, additional probing questions were asked in order to understand the participants' responses.

3.8.2.1 The First FGD

To elicit what learners think to be the factors influencing the performance in the science fairs, these eight questions were used as a guideline:

1. What are the reasons according to you for poor performance in science fairs?
2. What are your views on your teachers` involvement with your research project?
3. What form of assistance do you expect from your school to achieve well?
4. What would you expect your parents/guardian to do for you to assist you with your science project?
5. What are your views on the science-fair judges?
6. Do you understand the scientific method of doing a research project?
7. How do you describe your knowledge of physics?
8. What should be improved on science fairs?

These discussions were audio and video recorded.

3.8.2.2 The Second FGD

The researcher conducted another FGD using same questions, based on the participants' experiences during science fairs and on the alterations made on the second PMM. The discussions were audio and video recorded. Also, the researcher kept notes in a notebook. This notetaking process enabled the researcher to track changes in knowledge of participants from before the science fair and after the fair.

3.8.3 Collection of Observation Protocol Data

Observation protocol data was collected in order to determine the level of attention shown by the participants throughout the science fair activities. Only the researcher observed the six participants at the science fair. It was not difficult to conduct all of the observations because there were only six learners. During this observation the researcher was using an observation protocol (see Appendix D) which was used to determine the scoring of the level of attention of the 6 participants. The validity and reliability of observation protocol was discussed on section 3.7.9.

3.8.4 Collection of Depth of Knowledge Data

All six learners answered questions on the physics test which was designed around the four levels of depth of knowledge (see Appendix C). A day was set for the participating urban learners to answer the questions in Capricorn (Polokwane). Similarly, participating rural learners answered the questions in Mopani. All tests had pre-assigned identity code of the participants, and their names with blocked with a bold marker. All 12 scripts were marked by the researcher.

3.8.4.1 Anticipated Problem

Learners are used to writing tests in a classroom setting with their peers. The setting would have been unfamiliar if the 12 urban and rural learners completed the tests in isolation. They would not likely perform to the best of their abilities. Therefore, steps were taken by the researcher to prevent the problem.

Working with the learners' teacher, the test was completed by all learners in the participants' class. As part of their routine instruction, this assessment would resemble the normal way in which they write their tests. Then, only the participants' papers were collected.

3.8.5 Collection of Interview Data

Appointments for interviews were arranged with EEYS directors, Department of Science and Innovation managers, Department of Basic Education provincial coordinators, teachers, school principals, mentors and judges. Due to the restrictions imposed by the government due to the Covid-19 virus, all interviews were conducted via the telephone. In addition, all interviews were audio recorded.

3.8.6 Collection of Researcher Notebook Data

The focus on the first set of PMM papers was to identify issues that needed to be pursued in the FGDs. These issues were written in the notebook; an example is of a diagram that a learner drew on the PMM (see section 4.2). During the FGD, the researcher noted and wrote questions for further probing during the discussion. Also noted were the learners` who were very active and those who were inactive. The notebook also contained important information that emerged from the discussion but did not directly relate to the study's research questions. Some examples are judges` rudeness and the scolding of learners. This notebook was used to document observed characteristics, behaviours and researcher`s reflections that were not on the observation tool. During the telephone interviews, the researcher wrote important emerging factors and area for clarification.

3.9 Analysis of Data

The qualitative data analysis has been “shaped to some extent by the researcher’s standpoint, disciplinary knowledge and epistemology” (Braun & Clarke, 2013, p. 175). The qualitative data analysis has created new understandings by interpreting the integrated major themes from the study`s PMM, FGD, observations, tests, interviews and researcher notebook. Validity of the coding process was ensured by the researcher through member checking (Lincoln & Guba, 1985). The researcher went back to the interviewees to allow them to view their responses in the themes, were there were disagreements the researcher went back to the recorded interviews, codes and transcripts for reinterpretation. Member checking commenced again after a modification was made. The process was repeated and an agreement was reached.

On the other hand, some researchers have criticized the qualitative data analysis methods as being unsystematic and ambiguous (Grover & Lyytinen, 2015). Data analysis is the process of organizing data to order giving structure and meaning to what was collected (Marshall & Rossman, 1995).

3.9.1 Analysis of PMM Data

The PMM data analysis was completed amongst and across participants (Bertram & Christiansen, 2015). PMM data was coded for thematic analysis using the following coding process:

1. All the mind maps were collected after both sessions.
2. From all the words written in black ink (first session), words, phrases, and diagrams with similar meanings were grouped.
3. Codes were assigned to each group of words.
4. From all the words written in red ink (second session), words, phrases, and diagrams with similar meanings were also grouped, the words that belong to existing groups were added, and those with a new meaning or theme, formed new groups with new codes assigned to them.

PMM data allowed the researcher to compare pre- and post-participation personal meaning maps of the science fairs. These codes became one step in learning why the learners in Limpopo province perform poorly in science fairs. Finally, the PMM data was correlated with FGD qualitative data (Romm & Ngulube, 2015).

3.9.2 Analysis of FGD and Interview Data

FGD data was used for a preliminary analysis of the PMM data (Morgan & Hoffman, 2018). The researcher transcribed all of the comments from the two FGDs. The thematic analysis was done using the qualitative interpretive analysis approach (Saunders, Lewis, & Thornhill, 2012). The process entailed reading the unstructured text-based data of the interview transcripts and searching for similarities and differences. The researcher then identified patterns and drew meaning from the data to identify themes and develop categories. Qualitative data analysis is a quest for general statements about relationships and underlying themes, while exploring and describing the study's data (Strauss & Corbin, 1997).

3.9.2.1 Coding Process

All FGDs and interviews were audio recorded. Transcriptions were created from the audio recordings and the information from the researcher's notebook. For each FGD and interview protocol question, the main ideas that occurred in the responses were noted. Passages of the text were identified by applying labels to them indicating that they are examples of a particular theme or idea, Level 1 coding (Babbie & Mouton, 2001). The main ideas were then reviewed to identify recurring ideas. The recurring ideas were used to identify themes, Level 2 coding. The researchers' final goal was to identify the dynamics that have led to the poor performance of learners in Limpopo province with regards to science fair competitions.

3.9.3 Analysis of Observation Protocol Data

The analysis of the qualitative observational data had the same coding process as the interview and FGD data. However, the observation was conducted in three categories of distraction, focus, and engagement. These three categories were used because when learners are concentrating on their activities they may be less vulnerable to distraction and their attention may be more focused and likely more engaged (Linnell & Caparos, 2013). The coding process consisted of 5 steps. Firstly, the data logging, the raw data collected by the researcher through observation was recorded in a sheet (see appendix D). Simultaneously, the researcher`s explanations, views and assumptions and other emerging ideas were also recorded in the researcher`s notebook. Secondly, the logged data was written clearly and legibly and was restructured, making it more understandable when forming anecdotes (new version of logged data). Thirdly, vignettes from the researcher notebook and observation tool were used for the reader to gain a better understanding of the process and possible be convinced that the procedure was credible. The themes were captured for distraction, focus, and engagement categories. Fourthly, data coding was done and it aimed at minimising observation text (anecdotes) into manageable meaningful segments of text for tagging to a particular theme. Lastly, by inferring to the words completed in the observation form and observations made and recorded by the researcher, the coding was done. This was done by checking repeated phrases or words, activities for similar patterns or similar understanding of the behaviors.

3.9.4 Analysis of Physics Test

The determination of the rubric used was based on four aspects:

1. Specific criteria: The researcher and the learners were aware of the expectations. The mark allocation for each of the four questions was indicated on the question papers.
2. Performance levels: The total marks for the test was 30. The scoring included 4 performance levels; excellent (25-30), good (15-24), fair (6-14) and poor (0-5).
3. Reliability: The rubric was tested by different raters, and they arrived at the same scores when marking same learners` answer sheets.
4. Validity: The rubric was checked by physics experts and it was agreed that the rubric was rating what it was supposed to rate and was scoring what was key to the task.

The researcher marked the learners` test and scored the marks and gave 2 other experts in physics to remark the scripts using the same rubric and any mark deviations were scrutinized and corrected. Data analysis was conducted per level question and per totals of the questions (see section 4.5).

3.9.5 Analysis of Researcher Notebook Data

The information from the researcher note book was used immediately as it was obtained to improve the research process. Salient issues noted from the PMM were used on the FGD for clarity. The researcher designed questions from the issues raised by the learners during the FGD. These questions were then given to teachers, principals and judges` for their interviews. However, issues which did not directly related to the focus of the study were also noted for possible inclusion in future studies.

3.10 Trustworthiness of Data

The trustworthiness, a contributing factor to the quality of research was ensured by giving sufficient detail of the procedures and the assumptions made during data collection and its analysis (Marshall & Rossman, 2011). Also, trustworthiness refers to how the data has been gathered, sorted and classified. This evaluation focuses on the credibility, confirmability, dependability, transferability, and authenticity of the research (Di Fabio & Maree, 2012; Lincoln & Guba, 1985).

Credibility is informed by credible evidence, such as interview transcripts and participant test results. Participants need to ascertain whether they agree or disagree on the presentation of the report. It is a means of validating the results. This process is referred to as member checking, when the participants check to determine that what the researcher wrote is correct (Nieuwenhuis, 2010).

In this study, data was collected from more than one research instrument: PMM, FGD, observation, physics test and interviews. To support this data, the researcher kept a notebook. To attain credibility, the researcher’s self-awareness was essential, bias and values and their impact on the study were written in the researcher notebook (Di Fabio & Maree, 2012; Polit & Beck, 2012). Pilot interviews were conducted to determine whether the interview questions would be able to produce data that provides answers to the research questions. The transcribed notes and video recordings were carefully examined by peers, to critically evaluate the researcher’s own actions. The researcher reviewed the questions when instances of manipulation or leading of the participants was noted including too broad answers. Credibility of the research outcome was dependent on a well-structured mechanism for managing research data (Birks, 2014).

The triangulation of data, is the use of several methods or sources of data to develop a complete understanding of the study’s purpose and results (Patton, 2015, as cited in Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2014). Triangulation is completed by corroborating findings across data sets and reducing the impact of potential biases. Results from the PMM, FGD, interviews, observation and physics tests were analysed, and the results were compared to each data set. The results from one method were cross-examined with the results of another method.

Transferability is giving an elaborative and vivid description of the study settings to give readers sufficient information so that they make a judgment whether the finding can be applied in different settings (Streubert & Carpenter, 1999). Transferability is the extent to which the findings of the research can enable other researchers to follow the process of the inquiry and be able to transfer findings to other settings (Nili et al., 2017). The PMM, FGD, observation and interviews data may be transferrable to different learning contexts. The study`s outcomes may be applicable to other situations, populations, and times when other researchers apply the information and strategies they have learned to a new context. The researcher kept detailed and accurate records of the research process, including the voice recordings of the FGDs and interviews (Cooper & Endacott, 2007; Nili et al., 2014).

Dependability of this study would be high if another researcher is able to replicate this study with similar participants under similar contexts (Lincoln & Guba, 1985; Polit & Beck, 2012; Thomas & Magilvy, 2011). The research instruments, data collection processes, and data analysis processes can be used in different learning environments. The procedural information is clearly stated.

It is important to note that dependability might not be entirely possible as the condition of schools change. Some poor rural schools may acquire resources, enrol different learners, and/or hire more qualified and helpful teachers. Repeating the same study at these schools may produce different results due to the dynamic context, researcher, and culture.

Confirmability of the data in this study gives an accurate representation of the information from the rural learners, urban learners, sponsors and partners of EEYS. No data nor the interpretations of the findings was fabricated (Di Fabio & Maree, 2012; Polit & Beck, 2012). The results reflected the participants` voices, while the biases and views of the researcher were avoided (Lincoln & Guba, 1985; Polit & Beck, 2012). Data, in the form of actual quotations from the interview transcriptions, show how the information is credible and confirmed (Graneheim & Lundman, 2004). Also, to maintain accuracy, the researcher maintained a notebook during the data collection process where incidences were reported, including experiences and reactions by learners (Lauckner, 2012).

Authenticity is established when the conduct and the evaluation of the research is honest and credible with regards to participants' lived experiences and the social implications of the study (Lincoln & Guba, 1985; Polit & Beck, 2012). Authenticity, therefore, establishes trustworthiness, so it may give some benefit to the community, impacting the people within the community. The focus of this research was to assist members of the community, the learners, and the sponsors of science fairs, by revealing the dynamics that influence the performance of learners at science fairs. Hence, in the data analysis, codes emerged that showed the tensions between the sponsors and the learners, learners and the school, learners and resources, rural and urban learners as a system and the EEYS, judges and EEYS, rules and learners.

3.11 Ethical Considerations

Permission to do the research was granted by the Ethical Committee of the University of South Africa. In order to get this permission all protocols were adhered to, in addition permission was also obtained from the Department of Education (see Appendices E, F). The value of research depends on its ethical veracity and the novelty of its discoveries (Walliman, 2011), In addition, transcriptions, interpretations, and reports were available to the participants upon request, and the participants` rights wishes and interests are to be honoured.

3.11.1 Confidentiality

The researcher assured participants that their identities and the identities of their teachers, parents, mentors, and schools would not be revealed to anyone or made public in any media. Participants` consent was sought before recordings were done. Audio and video recordings and their transcripts were stored safely to ensure confidentiality. All data has been assigned a pre-determined code (see section 3.6.1).

3.11.2 Beneficence and Non-Maleficence

All participation was voluntary, and participants were informed that they were free to withdraw from the study at any time. In terms of beneficence, it is anticipated that the findings and recommendations in this research will encourage more studies aimed at revealing challenges faced by all stakeholders before, during and after science fairs.

3.12 Chapter Summary

The chapter began with an overview of the chapter. The introduction was followed by the research paradigms. The study's research design was explained. In addition, the population and sample size were described. The research instruments used in the study were described: PMM, FGD, observation protocol and interviews. The rationale behind using all the methods was explained, including how data was collected and analysed for each instrument. The trustworthiness of data, ethical considerations and instrument validation were explained in this chapter.

Chapter 4: Results

4.1 Introduction

This chapter presents the results of the interpretive case study conducted to answer the main research question: What are the dynamics influencing the performance of learners at science fair competitions in the Limpopo province?

The chapter triangulated the different data sources to strengthen the analysis. The results were separated and presented under the following 5 main headings:

1. Personal meaning mapping
2. Focus group discussion
3. Observations (level of attention)
4. Depth of knowledge (Physics test)
5. Interviews
6. Researcher notebook.

Included in the chapter are tables and graphs that were used to present detailed codes and theme information, as well as vignettes from the 28 interviews conducted to underscore key themes. This chapter exclusively focuses on presenting the results in a way which facilitates the discussion, which will be offered in Chapter 5.

4.2 Results of Personal Meaning Mapping (PMM)

Figure 4.1 is an example of a rural learner`s PMM. Two colours were used. Black ink documents the PMM prior to the science fair, and the red ink documents the learner`s additional inputs after the science fair.

Figure 4.1. PMM for Learner RF1.

Table 4.1 identified the themes and categories that emerged from Learner RF1.

Table 4.1

Themes and Categories That Emerged from Learner RF1

Themes	**Categories**
Desire to win	-----
Lack of computers	No laptops, photocopies
Teacher involvement	No science experiments, teachers, school
Science clubs	Science
Science fair judges	Projects judged by teachers, interview, crying
Science careers	---------
Appreciating other projects, people, schools	Girls with beautiful hair, new uniforms, buses
Scientific methods of doing research	Variable, procedures, method, hypothesis, graphs
Parents assistance	------
Science equipment, stationery	Batteries, electricity, magnets, textbooks
Models, products	-------------
Other	Eating food

Figure 4.2 is an example of an urban learner`s mind map.

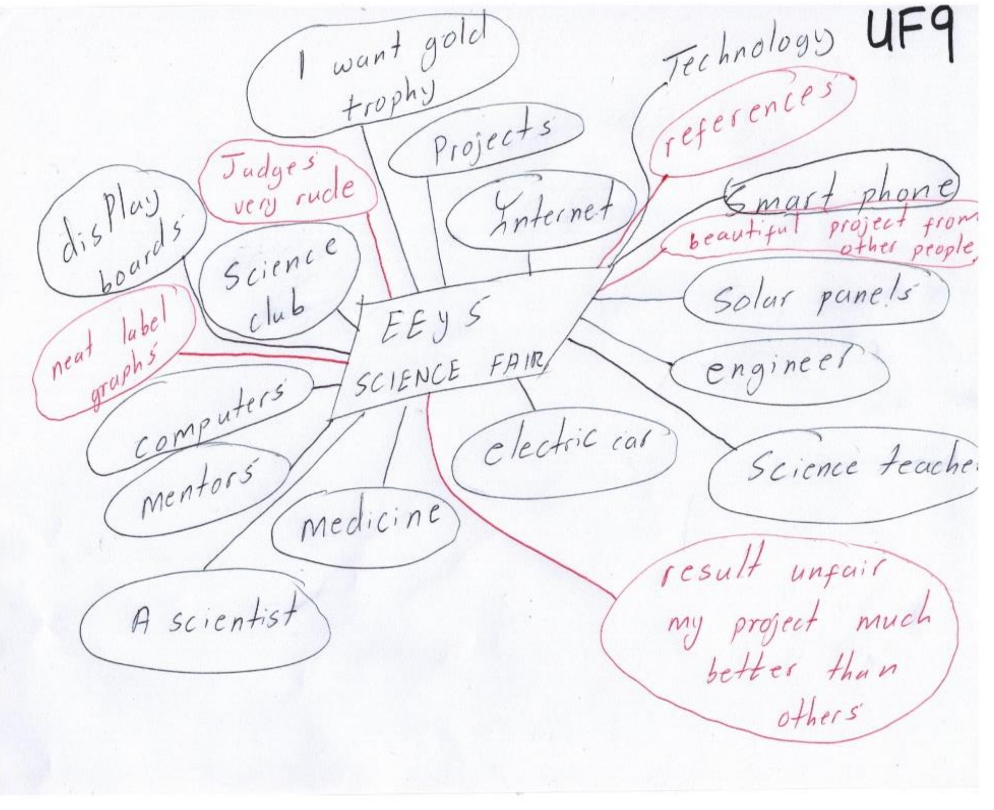

Figure 4.2. PMM for Learner UF9.

Table 4.2 identified the themes and categories that emerged from Learner UF9.

Table 4.2

Themes and Categories That Emerged from Learner UF9

Themes	**Categories**
Desire to win	I want gold, trophy
Lack of computers	Smart phones, computers, internet
Teacher involvement	Science teacher, mentor
Science clubs	Science club
Science fair judges	Judges very rude
Science careers	Engineer, technology, a scientist
Appreciating other projects, people, schools	Beautiful projects from others
Scientific methods of doing research	References, display boards
Parents assistance	---
Science equipment, stationery	Solar panels
Models, products	---
Other	Electric car, medicine, projects

Table 4.3 documents the results of the two PMM sessions:

Table 4.3

Results of the Two PMM Sessions

Themes	**Rural Learners (n=6)**		**Urban learners (n=6)**	
Total participants (N=12)	Before science fair	After the science fair	Before science fair	After the science fair
Desire to win	4	1	6	3
Lack of Computers (laptops)	4	0	1	0
Teacher involvement	2	0	5	0
Science clubs	0	0	2	0
Judges` unfairness	1	5	2	4
Science careers	3	1	4	1
Appreciating other projects, people, schools	0	4	2	3
Scientific methods of doing research	3	4	2	3
Parents assistance	2	0	4	1
Science equipment, stationery	4	1	1	1
Models, products	1	1	2	2
Other	1	0	0	0

4.2.1 Similarities in the Themes

Before the learners started the science fair competition, 67% of the rural learners and 100% of the urban learners desired to win the competition. Concerning the theme, "problems in project writing" all rural learners (100%) indicated that they had problems with writing a science project report. They indicated that they have problems in stating aims, goals, hypotheses, variables, writing up procedure, analysis, results. This theme is common to the 2 groups as 83% of the urban learners have the same challenges. Science clubs are non-existent in the rural schools of the participants in the sample of study while only 2 urban learners indicated that they have science clubs at their schools. All learners have indicated that that the science fair judges were not fair.

4.2.2 Differences in the Themes

While 66% of the rural learners indicated that they lacked computers, results showed that 83% of the schools in the urban areas have computers. Schools in the rural areas have computers, but computer illiteracy is high as learners indicated that they need training in the use of computers. A school might have computers, learners` ability to access and being able to use them may be a challenge. Only 33% of the rural learners showed that their teachers were involved with their science projects while 83% of the urban learners indicated that their teachers assisted them. On the theme “parents’ assistance”, 33% of rural learners lacked this support and 83% of urban learners enjoyed family support when they did their science projects.

4.2.3 Unexpected Responses

In figure 4.1 of the rural PMM, the learner drew a face of a person crying. When the researcher asked the participant why she drew that diagram, the response was that she cried during the science fair when the judge told her that her project was "useless and meaningless." The judge barely took a minute at her work. The learner sounded emotional and was depressed. This finding concurs with what Fisanick (as cited by (Keçeci, Zengin, & Alan, 2018) pointed out, that the science fair induces learners to feel nervous and stressed.

Comparing the pre (black ink) and post (red ink) science fair participation PMM, it is apparent that the learners’ knowledge of scientific project requirements is both broader and more comprehensive after the science fair. The participants` understanding of the science fair is clearer as the learners added items (variables, hypothesis, beautiful projects from other schools) and negative aspects like; judges very rude and results unfair.

4.3 Results of the Focus Group Discussions

The focus group discussions have revealed the following themes; poverty, teachers, school, parents/guardians, science fair judges, scientific methods difficult, physics difficult and science fair improvement. The vignettes and findings from the focus group discussions are shown below:

4.3.1 Poverty

According to Flanagan (2013), learners fail to succeed at science fairs because of the lack of resources at their schools and at their homes to do their projects.

Learner RM5 stated,

> *And lastly, I think it is because of lack of resources, because in school we lack resources to do proper research projects too.*

This statement is also supported by Learners RF1 and RM4,

> *Oh, I think I will need more assistance and more resources. I need more money to be able to go and do questionnaires to the people that I want to, I need more money to do research because of lack of resources*.
>
> *My parents do not have money to buy needed stationery, at times there is no electricity, so no lights to work at night.* (RM4)

These rural learners indicated that the lack of resources affects them and without these resources their projects are affected. Their parents cannot assist them because they are poor and do not have the financial resources. This study agreed to findings by Olive (2017) who attributed the poor performance of learners at science fairs due to lack of money to buy the required materials and equipment.

In addition, an urban learner, UM10, stated that,

> *I lack some of the resources to conduct my research project. Like computer or a printer in which I can be able to type out my project and print it out. So I have to go to different places to get those resources and that takes time causes me to limit the amount of work that I have to do for my research.*

Researchers have shown that it is difficult for learners to perform well without resources (Demirel, Baydas, Yilmaz, & Goktas, 2013). It is very important for learners to participate and perform well at science fairs because science fairs offer a platform to career opportunities, enhance communication skills, research skills and scientific knowledge, help learners to connect with experienced researchers and experts in their field of interest. In addition, learners` subject content knowledge is deepened (Jensen & Buckley, 2014; Schmidt & Kelter, 2017).

4.3.2 Teacher

According to the findings of this study, not all the teachers are helping their learners with their projects. Learner RM6 noted,

> …*my teachers are always busy with their school work, at times they help with correcting my English grammar language and spelling mistakes*.

Likewise, an urban learner UM10, added,

> *Some teachers they tell me to see the expo coordinator at school who is always busy with her schoolwork and other projects from learners since she is alone helping us*.

From these learners' statements, it seems that the teachers are very busy with their schoolwork. However, there are some teachers both in the rural and urban schools who assist their learners. Rural Learner RF2 stated,

> *My view of that teachers guides me on how to conduct my project and how to make it better. There is an expo coordinator we work with; we don't go to random teacher*.

Furthermore, Learner RF3 added,

> *In my school, teachers are very much involved in a lot of such projects. But the problem is that is not all teachers. You might find out that it is one, which makes it difficult. But overall, not all teachers in my school are involved in our projects*.

Some teachers use their resources to assist learners as noted by learner RM4,

> *My teachers sometimes give us his laptop to use*.

The same learner was quick to add,

> …*other teachers say science projects are not schoolwork and they are too busy*.

In contrast, an urban school learner, UM12, commented,

> *The teachers at my school are dedicated especially the teacher in charge of the science projects. She is very involved in our project. She always makes sure that we are doing what is required for us. She even had an afternoon activity at school, where she would assist learners who are interested in the science fairs sometimes we would even call her or even text her asking what we can do on our project and she was always open to help us*.

In the same way, an urban school learner, UM11, said the following about his teacher,

> *Oh, okay my teacher when I submit my work, she asked us questions and those questions help me to also question myself on where I can do better, and on where I can improve, so because she encourages me, and checking where I need help checking my progress helping me in a way I can improve. Yeah that*.

From the comments made by the learners, it seems that urban learners are benefiting from more teacher support than the rural learners.

A female urban learner UF9 admitted that she does not want to bother the seemingly busy teacher,

> *Well it's like my teachers do love to help me, but they are always busy and I become shy to always disturb them, yaah but they help me a lot*.

Nevertheless, some learners as noted the desire to have teacher support at their schools. Learner RM5 commented,

> *I don't expect much assistance from them as this is my project. But I expect them to assist us in knowing what exactly is expected for us in doing the project, because we cannot just guess what we have to do because we will do the wrong thing. And I also expect that they could help us in making our projects better if they see the errors and they correct us. And that's the key*.

This lack of support has been confirmed by the study of Akinoglu (2008) (as cited by Betts, 2014) who identified that in many schools, extra coaching for science fair projects is considered as extracurricular activity, an obligatory responsibility. However, there are teachers, as established in this study, who do support their learners by using their resources, laptops and money.

4.3.3 School

In this study, rural learners complain about the lack of school support. Learner RM5 indicated,

> *My research needs a lot of data, so maybe like if the school could provide data. Okay, I can work on that but I would have liked the school to help me on that. And another thing now for my research, I need a like photo copies. Transport us to venues as well. I need to print some of the pictures, and I don't have most of the resources at my house, so the school could help me with that. And also yes,*

> *when I’m doing questionnaires I need to … like ask some people questions and at school is going to be the right place to ask people*.

The learners from both rural and urban schools require their schools to avail rooms or venues where they can plan and complete their projects, undisturbed by other learners. A rural school learner, RF2, said,

> *The school must give us rooms to do our projects without disturbance from other learners. Teachers to help us to make our models and machines and buy charts and markers for us*.

In addition, an urban school learner, UF8, said,

> *The school must give us support by creating a room, space and time for us to do science projects*.

One rural learner, RF3, expressed the need for training by external mentors. She stated,

> *I think if the school could involve more research people from different areas who are specialized or can talk about different areas in science, they can bring them to school so that they can talk about these areas so that we can have a deep understanding on our projects.*

Another learner, RM6, reiterated the need for training and mentor when he said,

> *To buy me material, find me a science mentor and prepare me for science fair*.

These results are in agreement with Alant (2010), as she established that there are very few mentors in rural schools. However, a similar situation occurs in urban schools. For example, an urban learner, UM12, indicated,

> *I think our school should try to make a workshop whereby people get more knowledge about the science fairs. People can come to our school and then they must make a presentation explaining each and every category in the science fair, so that we as the learners get an idea of what is expected of us and what we can do and that this will also help us as learners to understand more about the projects that you are doing so that we can achieve better and so that our minds can think outside the box. They must like maybe have a visual project, just to show us what we can expect, because I think some of the learners they don't really have an idea of what they are expected to do, what categories is all about and they tried and they end up messing things up*.

Similarly, Learner UM11 commented on the need to have a mentor as he said, *They must look for mentors for us, to link us with more knowledgeable mentors who know more than our teachers*.

A rural learner RF3 mentioned the need for an equipped school library when she said,

And also, if, for example, we have a library. But it's not necessarily equipped. It doesn't have enough books on certain topics.

The learner RM4 also expressed the need for computers at their schools when he said,

The expo people must donate computers to us and train us so that we can be able to use them.

In addition, learner UM12 said,

At our school there are computers but we are not always allowed to go inside and use them and this will make me delay in finishing my projects, I need internet which is not always there and the teachers are not always free to help me.

Similarly, another learner UM10 stated,

I lack some of the resources to conduct my research project. Like computer or a printer in which I can be able to type out my project and print it out. So I have to go to different places to get those resources and that takes time causes me to limit the amount of work that I have to do for my research.

Learners without materials and equipment, as well as mentorship, are likely to perform poorly at science fairs (Gifford & Wiygul, 1992). The studies have asserted that learners without resources are disadvantaged because their projects are of poor quality. Due to the lack of laboratory equipment, their scientific investigations are not thorough (Taylor 2011; Grinnell, Dalley, Shepherd, & Reisch, 2018).

Learner RM6 requested,

The school must buy us food when we go for competitions.

The issue of transportation of learners was raised by both rural and urban school learners. Learner RM5 said,

Transport us to venues as well.

Also, Learner UM10 commented,

Our school must transport us to venues, at time we use our money to go to the venue and if they think it’s near they tell us to walk and you get there sweating, they must buy us food and water, lots of water.

Some urban schools do have computers and resources as indicated by learners, UF9 stated,

> *In my school we have resources such as laptops and computers to help us type of projects, but I think that some of the schools in the rural areas don't have equipment to try to type and retype their project or research and information. You see that some of the projects the information has been handwritten not typed due to the lack of equipment to do their project.*

In the same way, learner UF7 said,

> *I need to be using the school library and computer laboratory especially weekends and holidays, the school must buy project materials for us.*

Some findings of this study concur with Bernard (2011) who revealed that learners from urban well-resourced schools have the advantage of over the poor rural school learners from under-sourced schools. However, it has emerged in this study that some urban learners also lack resources to do their science projects.

4.3.4 Parents/Guardian

This study has established that the rural learners expect their parents/guardians to support them with their science projects. Rural school learner RF1 said,

> *I think I would expect my parents to assist with the printing of the papers and reading my file. In order for my report board to look proper. They transport me, they don’t give me any money*.

Similarly, Learner UM12 said,

> *I always need their financial support for printing and making photocopies and laminating my projects display cards*.

Another learner, UF7, wanted her parents to assist her with connectivity. She said,

> *If my parents give money for data bundles that will be nice, or if they can have Wi-Fi at home it will help me, even with other subjects as well*.

Alternatively, Learner UM12 said,

> *If they can get me a mentor like they do with extra classes, that would help me*.

However, Learner RM4 would rather have his parents assist him with editing his work He said,

> *My parents if they can I wanted them to help with my English corrections and appreciate my work even if I lose the competitions.*

Learner RF2 wanted her parents to give her more time at home to complete her science project. She said,

> T*o assist me with ideas help me practice for display. Must give me some space at home and not to send me all over disturbing me*.

However, some learners would require their parents to give them encouragement and love. Learner RM5 said,

> *Okay. Well, I wouldn't expect much from them I would just need encouragement only because it's my research. I'll just need them to edit. So what I need most from my parents is encouragement, nothing more because they can't actually do my research. I need to do my own research. So if my parents are giving me encouragement, that's enough for me the rest I'll just have to work hard enough and if they're like my family is a like my biggest support system. They must understand my project and love me*.

Similarly, learner UF9 said,

> *I need financial support and encouragement from my parents, they must show that they love my work, and help me where they can with my model.*

In the same way, Learner UM11 said,

> *I can manage my project alone but I only want their love, praises support and transporting me to wherever I want to go and look for resources*.

Learner RF3 needed emotional support when she said,

> *You have to put in the effort in order to succeed. The parents can only do so much. But I think financial and emotional support can help. You need money in order to get certain information, in order to print your papers, to create a good place. You do need emotional support from parents*.

Both rural and urban school learners expressed the need of their parents' support, love, encourage and praise.

The learners also expressed that they need their parents to transport them to various venues or offer them money for that purpose. Learner UM10 said, *I think they must make sure that they help me to get the correct resources to conduct my project or some of the times I don't have this. I don't have enough resources to conduct my project which cause me to be frustrated. And another thing is that they might assist me when it comes to the issue of transport. Because when I was doing my project, I had to walk long distances in order to get more information because they were not there, they were at work when I was doing this research. So, I had to walk there was no transport or money that I can take a taxi to go to a certain place to get information regarding this problem. So, it was kind of like tiring to walk long distances looking for information*.

Also, Learner UF8 said,

Oh, I expect my parents to be able to take me to places that I want to do my research because they are my parents and I depend on them.

In the same way, Learner RM6 said,

My parents to transport me or give me taxi money because the school does not transport us.

Learners from under-resourced schools do not get help from their parents and this disadvantaged them against learners from well resourced- schools with supporting parents (Taylor, 2011). Furthermore, learners who enjoy support from parents achieve well (Park & Holloway, as cited in Riggs et al., 2019).

In this study, urban school learners generally commented that parents “give me money for materials, help me with my model, get me a mentor, give me data bundles”. All learners expressed their desires to be assisted by their parents and according to a study learners who receive parental assistance excel at science fairs (Grinnell et al., 2018).

4.3.5 Science Fair Judges

In this study, rural school learners, like RM5, gave positive statements about the science fair judges. He said,

Yes, I think it will be very fair to say that they are doing their best with the time that they are given to judge our projects. I think they're really doing their best. And majority of them seem very knowledgeable in the specific field.

Three urban school learners also commented positively on the work of science fair judges. Learner UF8 said, *They are very fair, and they are able to judge without being bias. My judges were very fair and polite*.

Similarly, Learner UM10 said,

Oh okay. I think most science fair judges are fair and they judge very well…"

In addition, Learner UM11 said,

The judging is very fair. It is very fair because first of all, I don't get to see who judges my project because last year when they were judging our project, we were all out and the judges will be left behind with our projects. And the thing that makes this very fair is that it's more than one judge who looks at my project. So, if more than three people have a say on my project, it means that their results are legit.

However, some learners complained about the work of the science fair judges. A rural school learner, RM5, said

But I would want to comment on the thing that some of them do spend very little time on the specific projects and don't go over your projects in depth so to make you understand the flaws and what you can do to improve on the project.

Also, Learner RM4 said

I think a little more time on each project would go a long way, they just rush past spending few minutes not reading my work.

Learners accused the science fair judges of lacking interest in their projects and intimidating them. Learner UM12 said,

I will say that some I think they're not really interested in my project. Some ask me few questions and others more questions about my project they would seem to be more interested in my project wanting to know more about my project making me feel free to talk to them and giving me more ideas. Whereas some other judges spend little time with me and when they go to other projects they stay a little bit longer time, asking more questions, but when they come to me like they ask few questions and I feel left out sometimes. I like I so scared to death to talk to them. They're more intimidating me rather than making us feel free to talk to them. They must be more interested in our projects regardless of your gender where you come from, whether you're going to a private school or whether you are a girl, they must be more freely to all other learners regardless *of what the project is all about. I think some judges are more interested in projects that has to do with maybe mathematics or science where they have models when it comes to us who are doing investigations like there is no model, they won't be more interested and which makes us feel left out. Next time we want to try projects with models which we are not good at. The new things we are trying we are not good at them we are only good at what they discouraged us to do because of the way they're behaving towards us.*

A rural school learner RF1 added,

They must have a happy face, friendly, asking me good questions and understanding me.

The learners also complain about the way the judges ask their questions. Learner UF9 said,

The judges asked questions that were well above my knowledge and did not explain to me or give me the answers to their questions, they should have given me feedback so that I can upgrade my project, he just went away.

Researchers have shown that learners who do not get formal feedback from the judges are affected and there is a hindrance to their development of science process skills (Rillero, 2011). Learner UM10 concurred,

At some times they only ask one or two questions and it will be maybe about them asking you maybe about your hypothesis. Some sometimes they ask you only what is your problem? Or they sometimes even just want to see how your machine works.

Learner RF3 also accused the science fair judges of segregation and bias. She said, *they do not like projects from poor schools because they don't show too much interest, they quickly move to projects which are beautiful looking models.*

Two rural school learners lamented on their lack of understanding the English language used by the science fair judges. Learner RF2 said,

Some of the judges they talk very fast and it`s difficult to understand their English because they like to use big science words, they expect me to know like them.

In the same way, Learner RM6 said,

English [is] difficult for me, [it is] difficult for me to explain my project in English. They are rude, they don't explain my mistakes they just go away.

For learners are affected by their poor understanding of the English language, these findings are in agreement with other research which established that some rural learners do not understand the English language, and this lack of English skills affects them when they are being interviewed by science fair judges (Karikari & Yawson, 2017).

A learner questioned the competence of the teacher judges. A learner UF7 said,

> *I found out that some judges are not friendly at all, and they are not qualified to judge engineering projects, they are just teachers, we need good trained judges*.

4.3.6 Scientific Skills

Only one rural school learner RM5 agreed that she understood the scientific methods of doing a scientific research. She said,

> *Because I've been into science expo for some time now, I think I have a better understanding. I think I understand the scientific procedure that has to be followed. For me, research plan is formulating hypotheses, you know, data and analysing it. I do understand the scientific method and the guide book. The project guidebook does help a bit. But I also think that guidebook has to be updated over the years*.

In contrast, three urban school learners said that they better understand the scientific methods by completing their research. Learner U12 said,

> *Yes. I understand because in the beginning of the year, they handed out papers explaining the format of the research project. And then we could understand it better*.

Similarly, Learner UF9 said,

> *No problems with scientific methods, I use the templates given and the format*.

In addition, Learner UF8 agreed that she understood the scientific methods from completing her study, but she was quick to say her knowledge was limited. She said,

> *Yes, I do, but just a little not really much*.

One learner, UM11, was not sure of his scientific skills and stated that he had only an idea. In his words, he said,

> *I wouldn't say that I understand but I have an idea of how things must be done. For example, when you collect data you must collect what is measurable and that it must be related to the hypothesis. You cannot do something that is not*

related to the hypothesis because your project will be wrong and that the result either support your hypothesis or contradict your hypothesis. That's what I know about the methods regarding scientific research but other things I don't know.

Learner UM10 specified this area of weakness when he said,

Yes, a little, problems with variables and writing of hypothesis.

Also learner RM6 said,

The variables are difficult, graphs are difficult, hypothesis difficult, difficult to draw graphs with a computer because in the first place we don't have the laptop.

The learners need some training to acquire the necessary skills. An urban school learner, UF7, said,

It is a challenge to me because this is not really taught at school, I think I need to have a bit of training on these scientific methods for me to have the skills.

In the same way, a rural school learner, RF1, said,

The people from the expo need to train us, they need to give us books or show us videos on projects.

This problem is compounded by the fact that some teachers do not teach them, as stated by Learner RM4,

Not that much The science teacher does not teach about science projects, not very much.

Additionally, Learner RF3 stated,

Making beautiful machines or models is not easy because we don't have the money to buy the materials, they don't teach us how to do references or analysis and the hypothesis, we do it on our own.

The learners can get confused and fail to complete the research in a proper scientific way. Learner RF2 said,

…*not too much it's a bit confusing me the order of writing these things*.

Learners expressed their desire to be trained on the scientific research methods. However, there are learners who received the research templates and guidebooks at their schools. These learners stated that they had no problems. Lastly, learners mostly in the rural areas may be aware of the need for good working models but fail to produce them due to lack of resources.

4.3.7 Physics is Difficult

All the participants are doing physics at school under the subject of the physical sciences. Also the participants are all competing under the physics category at the science fair.

The similarities in the two groups are that they both agree that physics is difficult, they all face difficulty in solving problems. Learner UM10 said,

> *I would say I am average learner when it comes to physics, it's a bit difficult, especially solving problems and such staff, too complicated at times*.

Also Learner UF9 commented,

> *The physics questions are tricky and difficult but I like the experiments, our teacher does not do much of the experiments we see in the textbooks, we just mostly do the theory and move on*.

Learner UF7 said,

> *My knowledge in physics is average, but I see when the years goes by maybe next year. It will be more advanced because I'm doing physics*.

Similarly, a rural school learner, RM6, said,

> *Oh. I would not say I know it that much, but I do know the basics. And I have been learning a few parts from my previous grades*.

Learner RF3 added,

> *The teacher does not explain more like in other subjects, the physics questions are difficult to understand them*.

Also, Learner RM4 said,

> *Physics is a natural science that involves the study of matter and its motion, it is hard yes physics is hard*.

In the same way, learner RF1 state,

> *Physics is made difficult by the calculations which are too difficult because you must know the formulas*.

However, there are learners who said that they are skilled in the subjects, and they do not have problems. Learner UM12 said,

> *Well I'm a learner who gets okay, let's talk about my average marks on physics first. Yes. Okay and I am a learner who ranges from 70% plus so I might say that I'm good at physics. I have a good teacher. So that's that one good thing for me as a great teacher who I understand when she's teaching. So I think that contributes a lot to the way I understand physics. I am really good at it because it's also one of the subjects that I love.*

Also, Learner UF8 said,

> *I think that life science is much more difficult than physics because life science is just meaning of things. And then on physics, you have some practical examples which can help you understand better*.

Likewise, Learner UM11 said,

> *Because if I love the subject I work on it every day and I really get good grades. Yeah, and I can also apply most of the things that I learned in class to Everyday Life which means I have a better understanding if I can apply what I learned in class with what I do outside class*.

Also, Learner RF2 said,

> *My knowledge of physics is average on the high school level, but eventually I would like to enhance my learning.*

Similarly, Learner RM5 said,

> *So far it is okay, but I wouldn't say my knowledge is that profound in the subject because I've just recently started it*.

However, one rural school learner noted that the teacher does not explain the subject well. Learner RF3 said,

> *The teacher does not explain more like in other subjects*.

4.3.8 Science Fair Improvement

The learners observed that some rural schools are being left behind and are not taking part in the science fair competitions. Learner RF3 said, *Oh, what they could do is that they should aim to have many schools involved because I come from Giyani in Limpopo. And in that area, the other public schools are not involved in science fairs and are not taking part at all. But they also have good suggestions. And another thing is that they should also call them for their regional fairs. Now, they only take a few people. So if they could also increase the number of the people they take to the regional competitions the better*.

Also, Learner RM5 said,

Maybe like in my area I stay in a village in Malamulele, right but I go to school in Giyani. If the organization can visit each and every school in every area thus when we can get more creative minds because there might be someone who is more creative but just because they don't know about the science expo, they don't have the platform where they can like expose their creativity. Most of the schools in my area do not know about expo, they need to get more schools involved even public schools, to get more creative minds.

The learners complain about poor communication between the science fair organisers and their schools with regards to the science fairs. Learner RF1 said,

We are always told about the competitions when it's too late, the information come to my school late. They must tell us on time.

A suggestion from Learner RF2, organizers “Can send emails or social media posts to parents and learners.”

Additionally, Learner UF8 said,

The science organisers must communicate directly with schools and if possible communicate with learners via their emails so that the learners are updated on all the events.

Learners would like the science fair organisers to arrange workshops and training sessions for them on science research methods. Learner RM4 said,

We think perhaps more workshops. Training for both teachers and students, I am aware that they do that in certain provinces. But they don't really reach rural communities that you would have like one workshop here and not necessarily where we can engage and find out, get more information on the certain subjects *and perhaps training of judges as well. I'm not really sure we do that, but maybe train judges so that they can have more knowledge*.

Also, Learner UF7 stated,

Learners must be offered workshops and training on science projects and scientific methods of doing projects. Train both teachers and learners.

Learner UF9 commented that the learners should be given more time to walk around the science fair to see other learners` projects. She said,

I think that the amount of time that we were given to go around looking at other projects with other learners must be extended because by going around looking at other Learners projects, we are motivated and it makes our mind to think outside the box so that when next year comes we can do more we can make creative ideas regarding our projects and that the judges must be told that they must be more interested in learners.

Learners would like to receive donations in the form of computers and materials for their use. Learner RM6 said,

We need student science fair handbook that encourages students to develop projects based on something they connect with in their everyday lives. The expo people must donate computers to us and train us so that we can be able to use them. This is why our projects don't look nice because the graphs are not done by computer but by hand and ruler.

The learners also commented on time management during science fairs. Learner RF2 said,

The other thing is that science fair start late and end late in the night this causes us problems with transport back home.

In addition, Learner UM12 said,

Also the time we start the competitions is late and we finish late again.

One urban learner, UM11, suggested that the science fair participants could have media exposure, such as to print media, social media platforms and television. He said,

I think that can be improved by granting exposure to learners, even though they might not make it to the international science fair. They can be given the recognition for their project. like social media platforms? In other countries *projects are televised they are uploaded on YouTube and social media platforms. So I believe from starting small from social media platform. we improve and improve, we might get televised.*

The science fair organisers need to improve on the qualifications and competence of the science fair judges. Learner RM5 identified,

Judges to check on students` projects well not to allow projects taken off the internet. They must use good judges not primary school teachers to judge our secondary school projects, why can't they find qualified judges.

While Learner UM10 said,

Judges must be more interested in the Learners` projects regardless of what they are doing and that they must try to do more, to be more friendly than to intimidate the learners because it makes their interviews to be poor.

Likewise, Learner UM12 said,

They should use competent judges who are not biased at regional expos.

Likewise, Learner UM12 added,

The judges are not all knowledgeable because I found out that at our district competitions primary school teachers were judging our engineering projects and they gave high marks basing on the attractive models without reading or asking deep questions about the projects. I think that was not good.

4.3.9 Word Clouds

A word cloud is the word frequency in a visual format. The word or phrase that appears most frequently in a given text will appear written in large font size in word cloud as shown in the generated image below. The word clouds of the rural school learners (Figure 4.3) and urban school learners (Figure 4.4) show that they are similar and have identical words from the learners` comments.

Figure 4.3. Word cloud for the rural learners.

The text from the FGD transcript of rural school learners shows the biggest word as “difficult”, followed by “scientific”, then “project”. The other words “judges,” “materials,” “schools,” “English,” “poor,” and “money” are also highlighted. These words indicate that they are part of the issues that influence the learners’ performances. A deeper understanding of the highlighted words was found in this study through the use of other research instruments.

The FGD word cloud for urban school learners is shown in Figure 4.4:

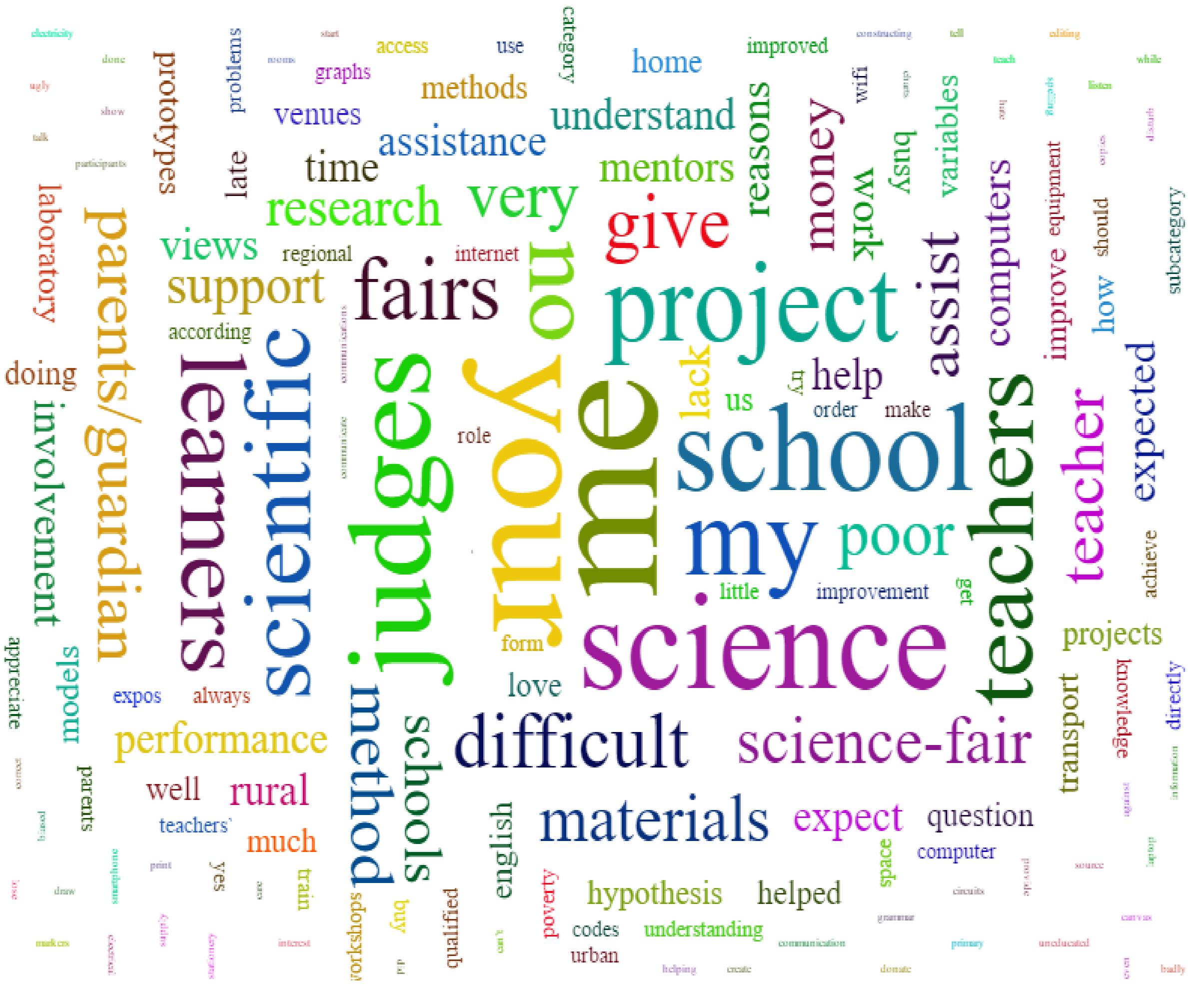

Figure 4.4. Word Cloud for the urban learners

In Figure 4.4, the biggest word is “my school,” followed by “judges,” “science teachers,” “scientific” in diminishing order. The image is in contrast with the one in Figure 4.3 which highlighted the word “difficult.” These images served the purpose of highlighting the words that are of high frequency in the text.

4.3.10 Summary

The two groups agreed on the following suggestions:

- The EEYS must improve on communication with learners and schools on science fairs.
- Learners require some training on scientific research skills development and report writing from EEYS and the DBE.
- The science fairs must start on time and finish on time (to be ensured by EEYS and DBE)
- The EEYS to recruit qualified, competent judges

The two groups differed on their comments as follows:

- The rural learners requested the supply of materials, equipment and computers with training on computer skills from EEYS and DBE.
- The urban schools requested the communication from EEYS to be done by emails.

4.4 Results of the Observation Protocol

The observation protocol was analysed using the level of attention using the three categories: distraction, focus and engagement (Bitgood, 2010) (see Tables 4.4a, 4.4b).

Table 4.4a

Scale Key

Distraction	Very high [1]	High [2]	Moderate [3]	Low [4]	Too low [5]
Focused	Very high [5]	High [4]	Moderate [3]	Low [2]	Too low [1]
Engagement	Very high [5]	High [4]	Moderate [3]	Low [2]	Too low [1]

Table 4.4b

Results of the Level of Attention

Location	Participants	Level of Attention			
		Distraction [5]	Focused [5]	Engagement [5]	Total [15]
Rural participants	RF1	1	1	1	3
	RF2	2	2	1	5
	RF3	3	3	3	9
	RM4	2	2	2	6
	RM5	4	4	3	11
	RM6	1	2	1	4
	Total	13 (43,3%)	14(46,7%)	11 (36,7%)	38
Urban participants	UF7	2	2	1	5
	UF8	2	1	1	4
	UF9	3	4	3	10
	UM10	2	2	2	6
	UM11	3	2	3	8
	UM12	4	4	4	12
	Total	16 (53,3%)	15 (50%)	14 (46,7%)	45

Only two out of six rural school learners (33.33%) had their levels of attention higher than the score of 7,5, Three out of six urban school learners (50%) had their levels of attention higher than 7,5.

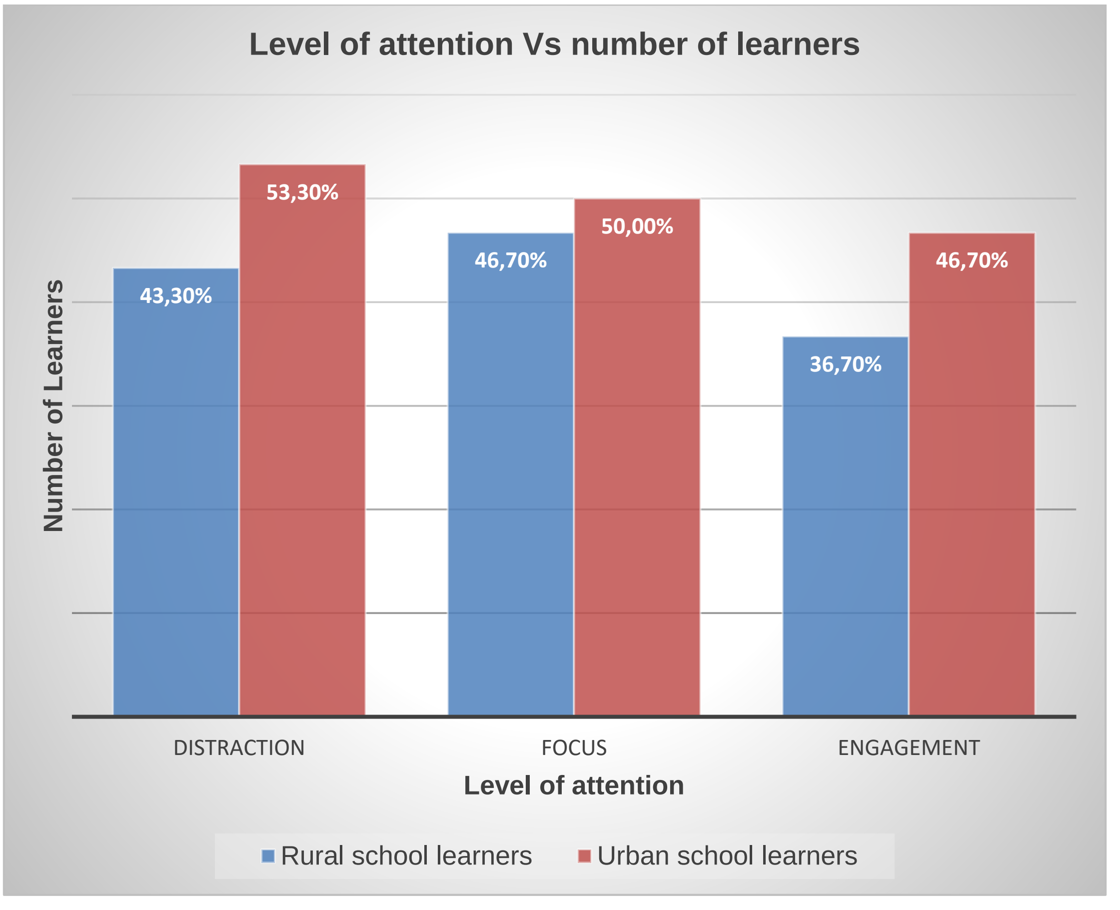

Figure 4.5. The level of attention of learners

Findings of this study, as illustrated in Figure 4.5, revealed that 56,7% (100-43,3) of the rural learners are distracted while 46,7% of the urban learners became distracted during the science fair. Furthermore, 50% of the urban learners where focused onto the science fair activities as opposed to 46,7% of the rural learners. These findings further reveal that 46,7% of the urban learners were engaged with other participants, scientists and judges; whereas, 26,7% of the rural learners were engaged. A possible reason for the difference in terms of engagement might be that of language barrier, most rural learners have challenges in communicating in English language hence they do not engage much with others (see section 4.7.6.1).

Figure 4.6 illustrates the comparisons of individual learners` levels of attention for both groups: rural school learners and urban school learners.

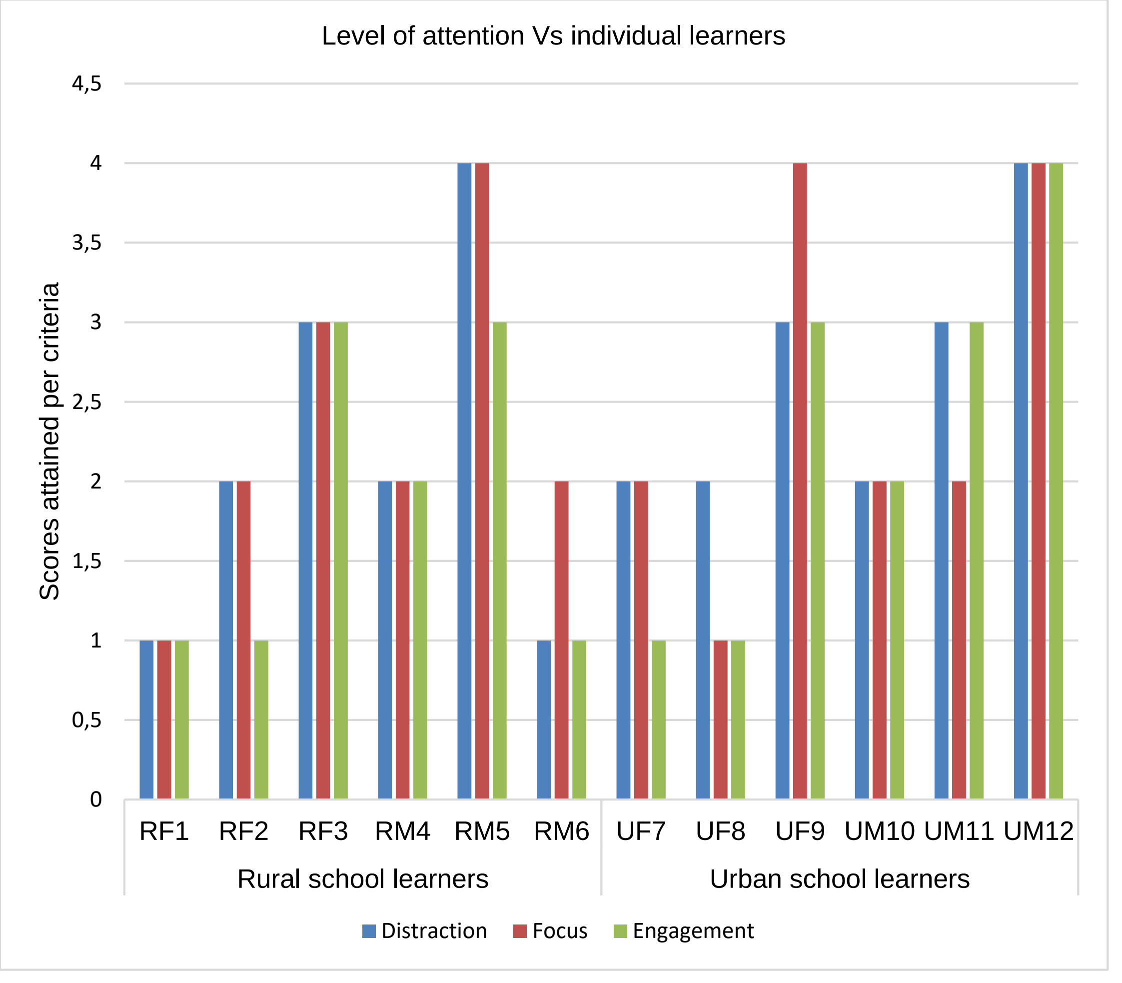

*Figure 4.*6. Level of attention for individual participants

One learner from the rural group scored same marks as two learners from the urban group on the “focus” level of attention. The results reveal that equal numbers (two from each group) scored at the 3-mark level of all the levels of attention.

The level of attention is particularly important as learners who participate at the science fairs need to be actively engaged in the activity, interacting with their peers, the mentors and scientists so as to acquire more knowledge (Alant, 2010; Grinnell et al., 2018; Kahenge, 2013; Ndlovu, 2015). When focused and engaged, learners gain more knowledge from others and improve on their own practices (Mupezeni & Kriek, 2018).

4.5 Results of the Depth of Knowledge (Physics Test)

After grading the scripts, the marks were recorded (see Table 4.5).

Table 4.5

Participants` Marks for the Physics Test

Location	Participants	Depth of Knowledge Levels				
		Level 1 [2]	Level 2 [4]	Level 3 [10]	Level 4 [14]	Total [30]
Rural participants	RF1	0	0	2	3	5
	RF2	0	4	2	5	11
	RF3	2	4	5	7	18
	RM4	2	0	3	5	10
	RM5	2	4	6	8	20
	RM6	0	0	3	3	6
	Total	6	12	21	31	70
Urban participants	UF7	2	4	5	7	18
	UF8	0	0	3	5	8
	UF9	2	4	6	7	19
	UM10	0	4	3	4	11
	UM11	2	4	5	5	16
	UM12	2	4	7	9	22
	Total	8	20	29	37	94

The analysis of individual results in Table 4.5 indicated that although the urban learners` marks were slightly higher than the rural learners` marks, the overall marks show that the urban learners also did not perform well in the test. The knowledge of physics is limited and all the learners during the FGD (see 4.3.7) indicated that the physics subject was difficult for them. Of the rural learners, 33% of them passed the physics test, and 67% of the urban school learners passed.

The data from the physics test written by the participants is illustrated in Figure 4.7:

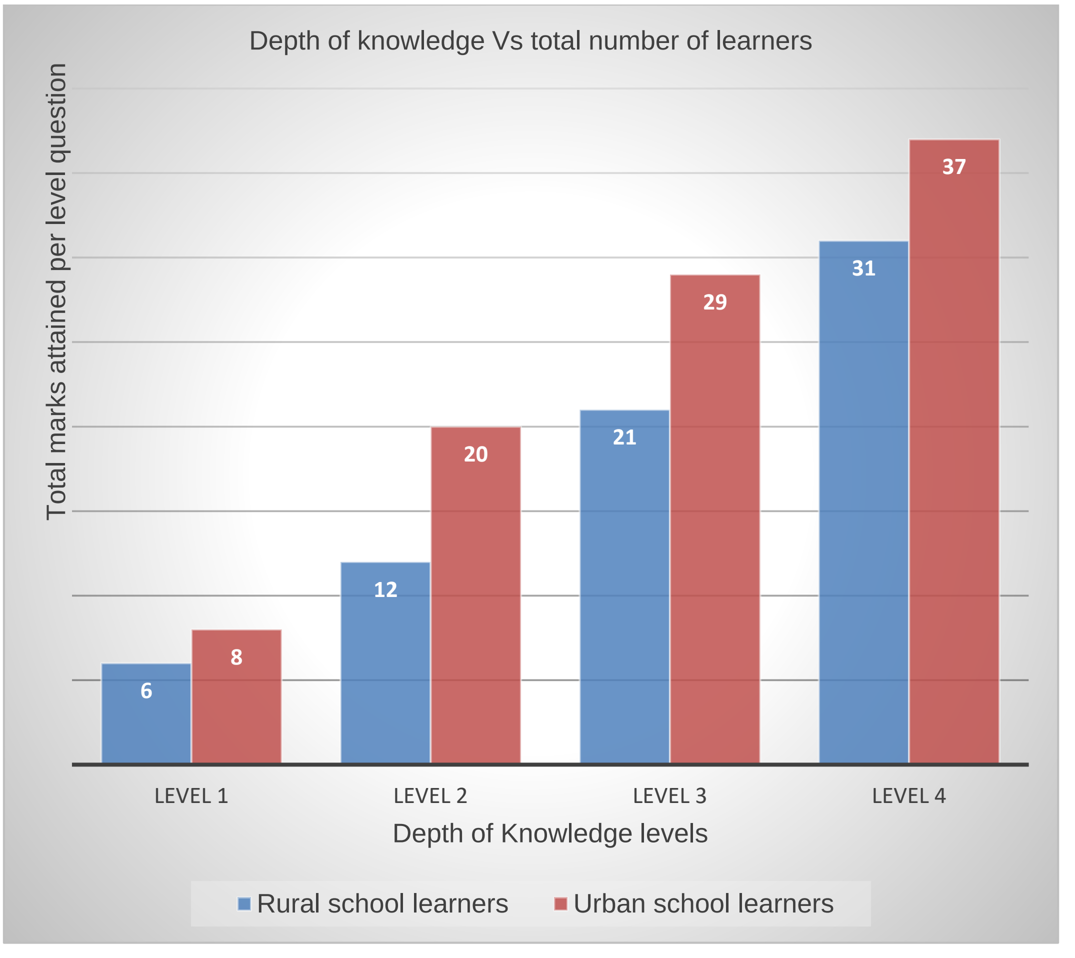

Figure 4.7. Depth of knowledge of all the participants

The findings of the study reveal that for the physics question Level 1, three of six rural learners (50%) got the question correct while four out of six urban learners (66.67%) got the correct answer to this question. It is interesting to note that the total performance of the two groups per level question is not very different. Another way of showing the actual performance of the two groups is by analysing the individual performances of the learner (see figure 4.8):

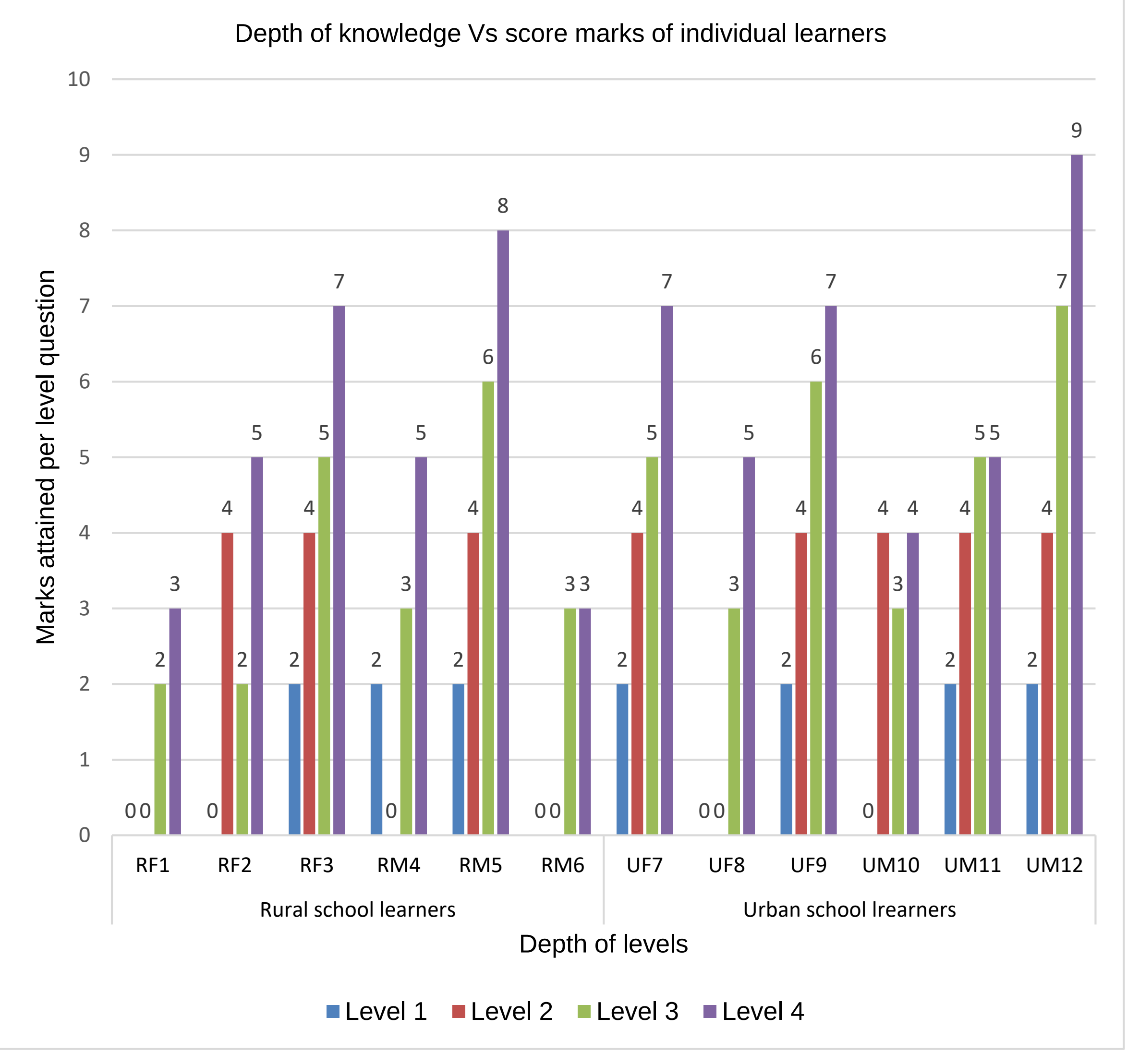

Figure 4.8. Depth of knowledge of learners as shown by the marks scored in the physics test

Figure 4.8 show that for Level 1 question, 50% of the learners from the rural group received zeros, and 33% from the urban group scored zero. In the same Level 1 question, three learners from the rural schools scored two marks each, and four learners from the urban schools scored two marks each as well. For the extended thinking Level 3 question, two learners (33%) passed the question with the highest score of 57%, while for the urban group of three learners (50%) passed the question with the highest score of 64%.

4.6 Results of the Science Fair

In order to understand the performance of the learners, the results of the observation protocol (level of attention), physics test (depth of knowledge) and science fair are illustrated together for comparison. (see Table 4.6)

Table 4.6

Summary Results of Observation and Physics Test

Participant	Observation			Depth of Knowledge				Medal won (gold, silver, bronze)
	Distraction [5]	Focus [5]	Engagement [5]	Level 1 [2]	Level 2 [4]	Level 3 [10]	Level 4 [14]	
RF1	1	1	1	0	0	2	3	None
RF2	2	2	1	0	4	2	5	None
RF3	3	3	3	2	4	5	7	None
RM4	2	2	2	2	0	3	5	None
RM5	4	4	3	2	4	6	8	Bronze
RM6	1	2	1	0	0	3	3	None
Total	13	14	11	6	12	21	31	
UF7	2	2	1	2	4	5	7	None
UF8	2	1	1	0	0	3	5	None
UF9	3	4	3	2	4	6	7	Silver
UM10	2	2	2	0	4	3	4	None
UM11	3	2	3	2	4	5	5	Bronze
UM12	4	4	4	2	4	7	9	Bronze
Total	16	15	14	8	20	29	37	

The results show that no learners, urban nor rural, earned a gold medal. One urban learner earned a silver medal, and one rural learner and two urban learners earned bronze medals. The individual results of the science fairs together with the total marks for the observation protocol (level of attention) and total marks for the physics test (depth of knowledge) are shown in Table 4.7:

Table 4.7

Summary of the Science Fair Results

Learner participant	**Observation Level of attention (%)**	**Physics Test Depth of Knowledge (%)**	**Awards given at science fair**
RF1	20	17	None
RF2	33	37	None
RF3	60	60	None
RM4	40	33	None
RM5	73	67	Bronze
RM6	27	20	None
UF7	33	60	None
UF8	27	27	None
UF9	67	63	Silver
UM10	40	37	None
UM11	53	53	Bronze
UM12	80	73	Bronze

Rural learner, RM5, won a bronze medal and scored 67% in the physics test. The silver medallist, UF9 from the urban group of learners scored 63% in the physics test. The other two bronze winners UM11 and UM12 from the urban group of learners scored 53% and 73% respectively. One learner, RF3, from a rural school scored 60% but did not earn an award in the science fair. The results in table 4.7 indicates a high correlation in understanding the physics subject and performance at science fair in the physics category.

4.7 The Results of the Stakeholders` Interviews

The data gathered from the three stakeholders' interviews were coded to identify categories and themes. In total, nine individuals were interviewed. These individuals were three national managers of each of the stakeholders: EEYS, DTI, and DBE.

There are ten themes emerged from the thematic analysis of the interviews.

4.7.1 Social Characteristics of Learning Found in Science Fairs

Two of the three DBE officials agreed that when learners interact during science fairs, they learn from each other. They also agreed that teachers and learners learn from each other. This study has shown that science fairs support the social characteristics of learning. Social characteristics mean that people can learn informally outside of classroom (Gibbs & Poisat, 2020; Lin & Schunn, 2016). DBE3 stated,

> *Both rural and urban learners have different experiences which they share during these competitions and improve on their projects*.

In addition, DBE2 said,

> *We expect creation of a network of people sharing ideas upgrading each other, learning the developments and creativeness and innovation of others*.

Teachers as they interact with learners also learn, as noted by DBE2,

> *But as the teachers work with the learners they will also acquire various research skills, so they stand to benefit as well*.

However, none of the other stakeholders mentioned the informal learning opportunities offered by science fairs.

4.7.2 Linking Academic Achievement to Science Fairs

When learners participate in science fairs, they gain knowledge which they use in their academic work (Kahenge, 2013; Mupezeni & Kriek 2018; Schmidt & Kelter 2017). This learning is supported by the DBE specialist, DBE1, who stated,

> …*the pass rate of physical science should improve because there is a relationship between research and academic achievement. Learners who are involved in these activities are also good in class and perform well*.

Likewise, DSI2 said,

> *There is a correlation between the learners that participate in these initiative to the improvement of performance in the class*.

In the same way, DSI2 stated,

> *The performance of learners is also linked to the science content knowledge of the learners. As long as the academic performance levels are low, the science*

> *fair projects might still be of low quality. We expect the rural and urban learners to do well but the rural learners are not equal to the task due to many dynamics which include lack of resources and mentorship*.

It is interesting that the EEYS stakeholders did not indicate that the science fair could have an influence on learner performance. EE2 blamed the DBE when he stated "…our education system is designed and geared for assessment and high stakes examinations*"* without giving learners much time to benefit from science fairs.

4.7.3 Teachers Training in Scientific Research Skills

The EEYS stakeholders, teachers, school principal, mentor and one judge expressed the need for teacher training workshops. The DBE official, DBE3, stated,

> *You will see that some teachers even need the skills, to help they must be workshopped and follow ups made to see that they are implementing the skills*.

Also, DBE1 said,

> *Some might not be knowledgeable themselves with the scientific skills to assist so they do not assist not because they don't want but they don't have the research skills*.

The EEYS conduct some workshops with a few teachers and learners. According to EE3,

> *EEYS is an NPO with few workers it is not possible to reach and train all schools in the country.*

Nothing in the data showed that the DBE assisted the EEYS in planning and conducting workshops. It might be much of help if the two organizations planned and executed the workshops together.

4.7.4 Failure of Learners Meeting the Expectations of the Sponsors

According to the stakeholders, in both rural learners and urban learners, the expectations of the sponsors have not been fully met. EE1 observed,

> *We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing and interviews*.

She was quick to add,

> *While some learners from both rural and urban areas produce gold winning research projects and most learners put in a lot of effort, most learners' work do not meet our expectations*.

A DBE member, DBE3, said,

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and other resources*…*The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all*.

The EEYS official, EE2, stated,

> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted*."

In addition, EE3 said,

> *But this is not always the case, some schools mostly in rural areas are under-resourced and the parents are mostly not educated and are poor, all this affect the rural learners*.

A manager, DBE1, noted that some learners present

> *…projects of poor quality, under researched projects, projects with no creativeness and innovation*

A manager from EEYS, EE1, explained,

> *Learners often do not spend time conceptualising and planning their research. They seem to lack the skills to fine tune their ideas so that it is specific and researchable. Learners who do not have parental influence or access to researchers and specialists or means to do research, may produce work that is of poor quality*.

A manager from the DSI, DSI2, stated,

> *Learners, due to poor understanding of basic principles of science concepts, also miss out as they are not able to apply the principles. This is due to teachers doing the bare minimum in class and not pushing them to go beyond the textbook.*

One DSI manager, DSI1, stated,

> *Most urban schools are meeting the expectations mainly because they have the resources. It will be fair for all learners to have resources so that the competitions are even and fair. We do have exceptions in the rural schools were we see good projects but these are scanty*.

The three groups of stakeholders, EEYS, DBE and DSI, agree that their expectations of high quality research projects with innovation and creativity were not met. However, the stakeholders identified possible causes of poor quality projects, such as under-resourced rural schools, failure to apply basic scientific skills, and little access to researcher and scientists especially for rural learners.

4.7.5 Failure of EEYS to Meet Sponsors' Expectations

The sponsors expect the EEYS to reach out to all schools in the urban and rural areas, and this has not been achieved yet. One DBE manager, DBE3, stated,

They must reach out to all schools so that they participate, we only see same schools every year. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all.

In addition, DBE2 stated,

> *EEYS should reach out to be rural schools and not concentrate in schools in town.*

In addition, DSI3 stated,

> *The expectations are not being fully met, for one, the expo is not reaching out to most rural schools*.

There is a contradiction; one DBE manager is of the opinion that EEYS is only involving urban learners and ignoring the rural learners, while a DBE manager noted that not all schools in towns are taking part in expo activities. Despite this contradiction, the DBE and DSI all agree that EEYS is not reaching out to most rural schools.

4.7.6 Stakeholders and Communication

Communication between EEYS and learners via schools is not effective. One DBE manager, DBE1, noted,

> *The schools and learners fail to get information about science fairs on time and hence they rush their work*.

Only one DBE stakeholder, commented on the EEYS`s lack of communication. The DSI may not comment since they are not directly involved with schools as the DBE managers.

4.7.6.1 Stakeholders and Language Barrier

In Limpopo province, the majority of the population speak three languages: Sesotho, Xitsonga and Tshivenda. These home languages are the first language of most learners (Nhlangwini, 2018). English language becomes their second language. A manager, DBE1, stated,

> *They fail to write their reports in perfect English and cannot present their projects before the judges in good English and with confidence*.

Another manager, DBE3, added,

> *Also, poor English, they fail to explain themselves well even if they have a better project.*

One DSI manager, DSI3, said,

> *English language is a barrier to some learners during the judges` interviews. They fail to explain their projects well enough.*

Similarly judge J1 affirmed that,

> *The urban learners are more advanced; they express themselves well in English. The rural learners are not fluent, they are scared, they cannot express themselves well in good English, they are not free, scared and some even cry*.

Two stakeholders and a judge agreed that learners have problems when communicating in English.

4.7.7 Science Curriculum

South African learners who participate in science fairs gain scientific research skills and increase their knowledge in sciences (Kahenge, 2013; Ndlovu, 2014) However, research projects and science fair activities are not fully included in the science curriculum.

An education manager DBE2 opined,

> *Schools should introduce research projects as part of the curriculum coverage*.

In addition, EE2 stated,

> *The examinations do not test inquiry skills so expos become a low priority of teachers and most learners*.

The DSI managers did not comment on the inclusions of research projects in science curriculum. It may be because they are not privy to the curriculum issues as the DBE is.

4.7.8 Science Fair Judges

There is a general consensus that the science fair judges may not have adequate knowledge in order to assess the projects.

A Department of Basic Education manager DBE2 stated,

> *Most judges are not well equipped to judge fairly. Some judges lack the scientific content, but they rush to judge engineering projects or computer science projects in which they have little knowledge thereby short-changing the learners*."

Another manager, DBE1, added,

> *They are not familiar with the scientific methods of investigation. Most judges are teachers and they cannot fairly judge complicated science projects*.

Correspondingly, EE1 explained that,

> *The science fair judges are a heterogeneous group both between regions and within a region. Some judges are experienced, some are highly qualified and experienced in their fields, some are researchers themselves, and some are dedicated to volunteer their services. Unfortunately, some may be inexperienced or not at a level to comprehend some of the research done*.

Similarly, EE3 argued,

> *Judges are trained before they judge at the science fairs. But you can only train someone but if that person does not have the basic scientific skills and content knowledge it will not help much*.

DBE1 also suggested,

> *Judges' should come from different regions or district for this to be fair*.

Furthermore, EE3 said,

> *The judges should be thoroughly trained more than once and encouraged to be fair by not judging their own learners*.

The interviews revealed that EEYS and DBE agree that judges need training, and most of them are not fair and are biased. Since DSI is not directly involved with the judging process those managers could not comment on the issue of judges.

4.7.9 Plagiarism

Plagiarism is an issue at science fairs. DBE3 noted,

> *Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects*.

Likewise, DBE1 said,

> *Learners sometimes copy projects from the internet and from previous years*.

In addition, EE1 said,

> *Often learners reproduce work from the internet or do not submit work in the required formats acceptable in the research field. Very few learners produce research of high quality, most projects are repeats of other projects done or are done very superficially.*

Furthermore, judge J2 said,

> *Some learners are very confident when you interview them, some lack confidence and you may conclude that the project was plagiarized, not their own.*

The DSI did not comment on plagiarism. DBE managers commented because they often come to the science fairs, and see and hear from teachers, judges and learners the issues on plagiarism. EEYS managers commented above since they are directly involved with the learners' project reports.

4.8 Results of Stakeholders' Interviews

Based on the coded transcripts, 14 themes emerged from the data.

4.8.1 Time

In many cases, the lack of time and poor time management are the main reasons for the poor science fair projects (Demirel et al., 2013; Olive, 2017). Stakeholders expressed their opinions about the time spent at school and the time spent at the science fair.

4.8.1.1 Time at School

A rural teacher, TR1, said,

> *They do not have time; they are overloaded with school work. The learners tend to work at the last minute, they only start to work on the projects towards the competition day.*

Also, an urban teacher, TU3, noted,

> *The projects are time demanding and not all learners can manage their tim*e."

In addition, a rural mentor, MR2, stated,

> *The learners have limited time to work on their projects, they have a lot of school work to do*.

Similarly, another urban mentor, MU3, said,

> *Time is always a problem, as soon as the schools finish learners have to leave school since they use common prepaid transport*.

Furthermore, MU4 said,

> *Time is a challenge, learners do not have enough time to do all this after school activities, they have homework and they need to study their subjects as well."*

4.8.1.2 Time at the Science Fair

The EEYS was blamed on the poor management of time during science fairs. A rural school principal SPU3 said that,

> *The science fairs must be well organized and finish on time so that we do not have problems transporting learners at night*.

EEYS manager agreed that time management was a problem when she said, *Some of the organisational issues include keeping to time, venue size, and format of the Awards ceremony.*

A rural parent PR1 complained about finishing the events late as he said,

They must make sure that our children don't travel during the night after their preparations or competitions, the world is now full of bad people.

In addition, judge J1 said,

The time given for judging is not enough, there is little time to read through the whole projects.

The lack of time and poor time management seems to be issues at school and at the fair itself. Stakeholders need to work together in order to determine the best schedule for their learners.

4.8.2 Language Barrier

Interviewees cited the language barrier as another reason for poor learner performance at science fairs. The learners were observed to perform badly during the judges` interviews.

A judge J1 observed,

The urban learners are more advanced; they express themselves well in English. The rural learners are not fluent, they are scared, they cannot express themselves well in good English, they are not free, scared and some even cry.

Similarly, judge J2 said,

Rural learners lack confidence when presenting their projects, they feel inferior.

A rural mentor, MU3, argued,

Learners should be allowed to talk in their language during interviews in order to explain their projects fluently.

Correspondingly, a science fair judge J1 added,

We need to give the vernacular language a chance, the DBE must allow learners to express themselves in their mother language.

Another judge, J3, noted,

The presentation is very poor with most learners due to language barrier. Judges need to be flexible on language usage.

A rural mentor, MR2, stated,

> *The learners especially rural learners they fail to express themselves well during interviews*."

Even though using the English language might be a barrier to learners, using a vernacular language require judges who understand that language. It may be difficult to find judges who are scientifically fluent in all of the home languages. Hiring translators can solve this issue, only if the translator is scientifically fluent in the home languages.

4.8.3 Science Project Reports

At science fairs, the judges read the learners' science project reports and posters awarding marks accordingly using the judges' rubric (see Appendix X). An urban mentor, MU4, noted,

> *Learners do not read more about their projects; their knowledge of the project is limited. When they get to the interviews by judges they are not convincing at all. The use of scientific terms and concepts is very poor*.

In addition, a rural mentor, MU3 said,

> *It is because of this that learners concentrate on constructing models and nothing written, to explain the model*.

Finally, a judge, J2, noted,

> *The discussion and conclusion are not related to the research project. They focus on the model or prototype and not on the science behind the model*.

There may be different reasons for these poorly written reports. One reason may be the learners' lack of scientific knowledge. The learners cannot fully communicate what they do not know. However, another reason may be the language barrier. Because English is the learners' second language, they may not be scientifically fluent. Without scientific fluency, the reports will be inadequate.

4.8.4 Research Projects and the Science Curriculum

Three interviewees suggested that the research projects must be included in the school curriculum. A science fair judge, J1, noted,

> *The school must give learners more projects work in the curriculum like in grade 12 they removed the research components leaving only the experiments."*

An urban school principal, SPU3, added,

> *The DBE must include research projects in the school* curriculum and give the teachers the training needed for them to be competent.

Likewise, a teacher, TR2, argued that science projects will not be taken seriously as long as they are not in the school curriculum. That teacher stated,

> *Most teachers do not consider expo fairs as part of the school curriculum and so to them is a waste of precious time*."

Some teachers may not be interested in expo activities and/or assisting learners with their projects because it is not in the syllabus. For many teachers, if the activity is not in the syllabus, then it is not important.

4.8.5 Science Clubs

Science clubs contribute to the learners` achievement in science. Learners who participate in science clubs are more likely to be involved in science fairs (Dabney et al., 2012; Nuni, Indoshi, & Odour, 2016). An urban teacher, TU4, stated,

> *Yes, we have a science club and most of the members of the club participate in expo fairs*.

Contrary, a rural teacher, TR2, stated,

> *It was once there but due to lack of resources it just faded away.*

Of interest, another urban teacher, TU3, commented on the existence of a science club at their school,

> *Yes, we do (have a science club) and its mostly run by the learners. The learners need resources and equipment to put their ideas into practice, they cannot use school materials since these are set aside for lessons*.

An urban school principal SPU2 was advocating for a science centre with all the resources for all the learners, as he said,

> *Where do they expect the learners to get the materials, laptops and internet from; they need to offer some form of assistance or create a resource centre.*

Commitment and continuity of the established science club is a challenge. Schools may not want to share their limited resources with a science club, as these materials and equipment are for school lessons. It seems that schools do not see the link between science clubs and the academic achievements of learners.

4.8.6 Parent Meetings/Workshops

Judges have suggested that in order to gain parental support, parents need to be informed about science fairs through meetings or workshops. A science fair judge, J1, explained,

> *Parents need to be workshopped during parents' meetings so that they understand what is expo (science fair). As long as the parents do not understand what is expo, they will not support* it.

Similarly, judge J3 suggested,

> *Learners need the emotional support from home. There must be workshops for learners and parents so that someone can talk to the parents on behalf of learners for them to give support*.

Learners alone cannot convince their parents to support their research projects. They need the school to reinforce their requests. Also, parents need to understand the importance of science research projects before they commit their resources and time.

4.8.7 Science Fair Judges` Competence

During interviews, it was revealed that some science fair judges are perceived to lack competence to judge the science projects.

An urban teacher, TU3, stated,

> *Judges fail to give feedback to learners after judging which the learners need in order to upgrade their projects*."

Additionally, rural mentor, MR1, claimed,

> *Judges are biased towards nice looking projects without actually reading the science behind them*.

Furthermore, DBE2 stated that,

> *Most judges are not well equipped to judge fairly. Some judges lack the scientific content, but they rush to judge engineering projects or computer science projects in which they have little knowledge thereby short-changing the learners.*

Another judge DBE1 agreed that,

> *They are not familiar with the scientific methods of investigation. Most judges are teachers and they cannot fairly judge complicated science projects. They need*

to first read to understand themselves in order to judge but there is no time for that at the science fair.

An EEYS EE1 manager affirmed that,

The science fair judges are a heterogeneous group both between regions and within a region. Some judges are experienced, some are highly qualified and experienced in their fields, some are researchers themselves, and some are dedicated to volunteer their services. Unfortunately, some may be inexperienced or not at a level to comprehend some of the research done.

In the same way, a manager EE3 from EEYS explained that,

Judges are trained before they judge at the science fairs. But you can only train someone but if that person does not have the basic scientific skills and content knowledge it will not help much. Most judges are teachers because they are the ones readily available at times you will find them judging projects far beyond their expertise and this naturally compromises the quality of judging. There are cases of bias which we struggle to end.

The EEYS may need to appoint competent and dedicated judges who are non-biased and being able to guide the learners on the improvements of their projects.

4.8.8 Judges' Favouritism and Bias

There have been allegations of judges` bias and favouritism during the interviews (see section 4.3.5). One science fair judge, J1, said,

The judging process is not fair at all. 2 or 3 judges may assess a project and you will find that all their marks differ very much, after discussion they may still do not agree. Also, the judges influence each other on final scores to advantage their schools or children.

Also, judge, J2, said,

The judging process is not fair. I suggest that the district projects to be judged by judges from other regions to avoid bias. I have observed that learners with good projects are side-lined in favour of poor projects from the judges` schools. This demoralize the learners and in the long run the learners will stop participating."

In addition, judge J3 said,

> *The judging is very poor. The judges lack commitment, with uncontrollable bias and favouritism*.

A rural teacher TR1 explained,

> *The problem is that some judges judge their own learners and give them more marks. Also, the convener or leaders of the judges, changes marks in favour of his/her school. Because of this, winners are mostly from school were the judges and conveners belong due to manipulation of marks. My suggestion is to use the judges from different regions to avoid judges' bias.*

Furthermore, an urban mentor MU4 stated,

> *The judges are never fair because the same judges are mentors of the students at their schools. It is the same judges that are helping learners to do the projects at schools; so they make sure that their learners get top marks so that the school will think that they are doing great work*."

Given all these allegations against the judges, one way of solving the bias issue would be to bring judges from different regions to a science fair. If possible, the EEYS may appoint impartial judges who are likely to act professionally without bias and favouritism.

4.8.9 Judging Time

Two interviewees argued that the time given to judges for judging is too short and the number of projects will be too many. A rural mentor MR2 who is also a judge said,

> *Not all judges are unfair. I am also a judge. The projects are too much for one judge, you will be given 15 projects to judge in a short time which is impossible, you end up just browsing the project reports and giving marks from your head*.

Similarly, a science fair judge, J1, said,

> *The projects at the regional science fairs are too many, in order to come up with best projects, they need to be judged over 2 days not what is currently done in few hours.*"

As compared to the number of science projects that need to be judged, more qualified judges are needed, and/or more time needs to be given for the judges to properly assess the projects. There must be a sufficient number of judges and/or an increase in the judging time. One possibility is to have the science fair span two days. Then, judges may have enough time to thoroughly evaluate the science projects without rushing to finish in a short given time.

4.8.10 Training and Workshops

During the interviews, teachers and learners stated that they need training and workshops on not only the scientific skills but also on the planning and executing the science fair projects (see sections 4.3.8 and 4.7.3). A rural school principal, SPR1 said,

> *They need to support teachers with workshops, training them so that they are confident and have the scientific knowhow*.

Another rural school principal SPR2 agreed,

> *The EEYS cannot just call for projects without assisting the teachers and learners with training on how to do them*.

Similarly, an urban school principal, SPU4, said,

> *The EEYS need to train the teachers and learners on the making of projects from start to finish*.

A judge J2 stated,

> *The DBE to train teachers on scientific research skills and project development*.

A mentor, MR1, expressed,

> *The learners need training workshops so that they understand what they are required to do.*

The teachers agreed to the training. A rural teacher, TR1, said,

> *If they are well planned [workshops] and not interfering with school work, I will appreciate that and attend them.*

Likewise, an urban teacher, TU4, said,

> *I need to know more and gain scientific research skills as well in order to assist the learners. Technology is changing I need to be updated.*

Correspondingly, SPR1 stated,

> *Learners should not depend too much on the teachers, because if the teacher does not research then the learner is limited and affected. Most teachers did not further their education to increase their professional growth*.

Additionally, MR1 noted,

> *Some teachers avoid learners with questions because they are not scientifically knowledgeable and so they too require training workshops on scientific research skills, how to guide learners and how to be good judges*.

Furthermore, J2 stated,

> *EEYS to offer training workshops to teachers and learners on doing projects and scientific skills, to train learners to be confident and to speak fluently. If teachers are not trained and given research skills, they will not be able to assist learners and to judge well.*

These seven interviewees agreed that teachers and learners need training and workshops. They indicated that DBE and EEYS need to give the workshops. EEYS has been conducting these workshops, but they only reach a few schools in the rural areas. DBE, universities, science centres and EEYS could combine their resources and plan together they may reach out to more schools and offer them the training they are requesting.

4.8.11 Communication Mentors' Comments

The EEYS need to improve on their communication channels (see section 4.7.6).

A rural mentor MR2, claimed,

> *Information on science fairs reach the rural schools late*.

Another mentor, MU3, suggested,

> *EEYS must provide resources and invite rural schools to participate, they have to go out to the schools and meet them, sending of circulars and letters is not enough and is not convincing.*

If the EEYS combine the channels of communication to schools used by the DBE, on social media platforms with direct contact to schools via telephones and emails maybe these communication issues can be alleviated.

4.8.12 Transportation Challenges

Learners participating in EEYS science fairs have transport problems when they travel to and fro the venues of competition. A teacher in the rural area TR1 noted,

> *We have learners coming from rural areas were transport is a challenge, each time when we go for competitions, if we finish late they will have transport*

> *challenges getting to their homes. Parents end up discouraging learners participating in expo and the learners stop participating*.

A school principal SPU4, added,

> *The school need assistance in transportation of learners to various venues (from DBE)*.

A mentor MR2 in the rural area said,

> *The school must transport the learners to the venues of the science fair competitions.*

The respondents cannot agree as to who has the responsibility to transport learners: the school, the DBE or the EEYS. The EEYS need to meet with these three entities and determine the appropriate modalities of transporting learners. Learners stated that their parents have misgivings when their children are being transported from the science fairs late at night (see section 4.8.1)

4.8.13 Teachers Awards

It came out during the interviews that as teachers are helping learners with their science projects, they need to be given awards or some form of incentives. A school principal SPR1 said,

> *Teachers need to be given rewards when they do well, when their learners achieve best results in expo*.

Also a judge J2 agreed,

> *Educators and judges are demoralized because they are not given incentives and some have stopped participating, EEYS should work on this*.

It is very important for teachers to be recognized for their extra efforts. Without this recognition, they can become disheartened and demoralized.

4.8.14 Mentorship

The mentors are university students, lecturers, specialists or experts who assist learners with their science projects. They are not necessarily school staff members. They, like the other stakeholders, face challenges when working with the learners. A rural mentor MR1 explained,

Working as an external mentor is difficult because the learners do not respect you as they do their teachers. Some teachers are not interested in assisting you in this regard.

The learners expect the mentor to provide all the requirements including financial assistance which is not possible."

Furthermore, an urban teacher TU3 said,

They must train key school-based mentors who will drive the science fair activities at school level."

Finally, an urban mentor, MU4, stated,

I struggle with learners who want the mentor to do everything for them. They like spoon feeding.

Although mentors are needed to assist the learners, studies have revealed that only a few urban schools have mentors (Akinoglu, 2008, as cited by Betts, 2014; Bernard, 2011). Learners with parents who can afford to hire personal mentors have an advantage over the impoverished learners (Bowen & Stelmach, 2020). One way to ameliorate this issue is for the DBE and the EEYS to train and/or appoint mentors to the rural schools.

4.8.15 Support from School Principals

Some of the school principals offered to support the learners participating in science fairs in different ways in different ways:

The school principal SPR1 said,

> *The school provide the available science equipment to the learners, offer good support to the head of department at school and educators. The schools will also order some laboratory equipment in short supply or that which is not available.*

Also, another principal SPU3 stated that,

> *The school can only give what it has. The school allow teachers to help learners when they are free as long as this does not interfere with their school work. The learners can use school equipment and printers and computers.*

From the statement by SPU3 above, it seems the principal does not consider science projects as school work and of benefit to the learners` scientific knowledge enhancement.

Lastly, SPU4 explained that,

These days the learners use internet to do their research, the school can have an open Wi-Fi which the passwords can be given to those doing research. As a school we also allow the use of our laboratory and its facilities and equipment as long as there is teacher supervision. Those who need photocopying can be assisted by the secretary with no problems.

Some school principals expressed their desire to help the participating learners as shown above.

4.8.16 Parental Support

Some parents have expressed their desire to assist learners with whatever they can afford for the developments of their science fair projects. Some rural parents have indicated that they sometimes help their children as explained by PR1,

I give him money if I have it. If I understand what he is doing I could help but you know these children want to make things that use electricity I don't know that. I allow him to go to meet others where they work together preparing for the competitions.

I think the people who organize these competitions must help learners with the materials needed. Where do they think I will get the materials here in this village? They must make sure that our children don't travel during the night after their preparations or competitions, the world is now full of bad people.

In addition, another parent said,

Well, if she asks for money and the old people grant money is there, I give her some very little because we have to eat in this house you know.

On the other hand, the urban parents assist their children with material needs apart from money as explained by PU3,

I sometimes take the child to the venues by my car or give her money to go there. When they finish late, I always pick her up since she is a girl you know for her safety. I bought her a smart phone which she can use to google and get more information.

Likewise, urban parent PU4 said,

I give him money to go to the internet café and I sometimes give him my laptop to use, but I don't have a printer. I only help with the little I can and encourage him to plan his time well.

From all the parents comments it can be deduced that parents have the desire to help their children to perform well at the science fairs but are limited by their lack of resources.

4.8.17 Stakeholders Expectations from Learners

The stakeholders, DBE, DSI and EEYS have their expectations from the collective body of rural and urban learners. The following participants stated their expectations:

> *The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all. Both rural and urban learners have different experiences which they share during these competitions and improve on their projects.* (DBE3)

> *We expect urban learners to participate more since they have more resources compared to the rural learners, we expect better quality projects from schools in town. In the villages they lack resources and they have to make do with recycling of materials they pick around. However, we expect teachers to be assisting the learners from urban or rural schools. Teachers should assist learners when they can. We expect all learners to compete even though the playing field is uneven in favour of the urban learners.* (DBE1)

> *My expectations are that the rural learners are to be exposed to local and global trends as well as in all competitions including science fairs. I expect them to do equally well despite their circumstances I believe they are also intellectually gifted.* (DBE2)
>
> *We expect EEYS to involve all schools, rural and urban. We expect fairness during competitions no judging biases and all learners to receive same treatment regardless of gender or race*. (DBE2)
>
> *Our expectations are at different levels. At Expo we expect learners from all areas whether rural or urban, to develop and/or practice scientific inquiry skills through research. We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing and interviews. We have several resource and*

> *development programs that assist learners to achieve this. We also expect learners to take safety precautions when doing their research*. (EE1)
>
> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted. Learners from both rural and urban areas often do not meet our expectations, however, this occurs more with the learners from rural areas*. (EE2)
>
> *Most urban schools are meeting the expectations mainly because they have the resources. It will be fair for all learners to have resources so that the competitions are even and fair. We do have exceptions in the rural schools were we see good projects but these are scanty*. (DSI1)

The expectations of the stakeholders are not all met, for example they expect all rural and urban learners to participate in science fairs producing good quality projects. Unfortunately, these expectations are not met.

4.9 Summary of Interviews

4.9.1 Stakeholders

The stakeholders mentioned that as the teachers and learners meet and interact, before and during the science fairs, both groups share ideas and skills thereby learning from each other. This type of social learning has been observed by researchers Mupezeni and Kriek (2018) and Gibbs and Poisat (2020). These stakeholders have linked the academic achievement to science fairs but stressed that the teachers should be properly trained in order to effectively assist the learners.

The learners from the rural and urban areas have failed to meet the expectations of the DSI, EEYS and DBE for producing quality research projects of creativity and innovation. On the other hand, EEYS has failed to meet the expectations of DBE and DSI of reaching out to all schools, especially in the rural areas.

The DBE and DSI managers explained the learners' problem of effectively communicate their research findings in English. They also suggested that research projects should be included in the school science curriculum.

The stakeholders expressed their concern on the issue of plagiarism by learners, especially those in well-resourced school with access to computers and the internet.

4.9.2 Judges

Two judges agreed that there was bias and favouritism practiced by science fair judges for the purposes of advantaging their schools and children. The managers of DSI and DBE confirmed this practice. Both the judges and the managers proposed a solution; the EEYS should use dedicated judges from other regions and appoint trained professional judges.

On the other hand, the judges complained of having to assess many science projects in a very short time because there are not enough of them. The judges proposed that the science fairs should span two days instead of having everything completed in one day.

4.9.3 School Relations (Principals, Teachers, Parents, Mentors)

Learners reported to have little time after school to work on their science research projects. Teachers and mentors agree with the stakeholders that learners have a problem in effectively communicating scientific information in English. They suggested that learners should be allowed to express themselves in their vernacular languages. Some teachers and mentors agreed with the stakeholders, arguing that research projects should be included in the school curriculum. This inclusion may signal to teachers to take research projects seriously.

Rural and urban teachers indicated the need for science clubs in schools, but explained that at one school, the science club once existed but is no longer there. Science clubs need to be supported either by the DBE or EEYS in order to continue to function.

Like the stakeholders, teachers and mentors complained about the inequity and bias practised by science fair judges. All agreed in using neutral well-trained judges. However, the issue of who will train the judges and transport them to other regions for judging remained unanswered. Transporting challenges include moving learners to and from the competition venues.

Although teachers, judges and school principals expressed the need for mentors to assist the learners, they suggested that this training and appointment needs to be the responsibility of the DBE. EEYS sponsors training workshops, but very few mentors attend them. Instead, these workshops should be school sponsored with specific outreach in rural areas.

4.10 Results from Researcher Notebook

The researcher used a notebook to log decisions made and wrote reflections and ideas on the whole research process It would have been easy to forget decisions made at a given time without writing it in the notebook (Engin, 2011).

During the PMM, the researcher noted the outliers in the learners' maps. For example, one outstanding case was that of a drawing made by learner (see section 4.2). The researcher wrote in the notebook, "Follow up on this learner RF1 and find out why she drew a crying picture of a person."

During the FGD, learner participation was documented, and the researcher followed up with a learner who did not say much. The researcher wrote in the notebook, "learner RU4 not saying much check why." It was revealed that this learner had a stammering problem of stammering and was too shy to say much.

During observation protocol, the notebook was useful when documenting the weaknesses of the instrument, such as the amount of time taken to complete the process.

When the physics test was marked, the researcher used the notebook to write the trends of the marks, the highest and the least marks. Finally, the notebook was used during interviews to formulate follow-up questions to vague answers.

4.11 Chapter Summary

Chapter 4 started with an introduction of the chapter, followed by the description of the results of the personal meaning mapping (PMM). Results of the focus group discussion (FGD) followed. The science fair competitions results were also documented. Findings from the observation protocol, physics test, thematic analysis of the interviews and the researcher notebook notes were presented. The discussions, recommendations and conclusions will be done in the following chapter.

Chapter 5: Discussion, Recommendations, and Conclusions

5.1 Introduction

Chapter 5 presents a discussion of the key findings from the research and links the literature to the research results. The purpose of this study was to explore the dynamics influencing the learners` performance at science fairs in the Limpopo province of South Africa. A qualitative approach was embraced by integrating a variety of research instruments. The study has offered insights into the dynamics that influence the performance of the science fairs by rural and urban learners as well as the expectations of the teachers, principals, mentors, parents, judges and stakeholders such as the managers of the Department of Science and Innovation, organisers of the Eskom Expo for Young Scientists and the managers of the Department of Basic Education.

In the preceding chapter, the results of the data collected were presented. Within this chapter, research questions are answered, and how the theoretical framework influenced the interpretation of the findings. Lastly, the potential contributions of this study and the recommendations for future research will be presented.

5.2 Addressing the Research Questions

The main research question of this study is:

What are the dynamics influencing the performance of learners at science fair competitions in the Limpopo province?

The sub-research questions were:

1. How do the constructs of CHAT uncover the dynamics contributing to the difference of rural and urban school learners' performance at science fair competitions?
2. How do the tensions in the constructs of CHAT reveal the disparity between urban and rural science fair learners?
3. What is the effect on the performance of learners competing at science fairs in the Physics category, in terms of the level of attention and depth of knowledge in physics?

This study has revealed dynamics influencing the performance of learners at science fair competitions and these have been analysed and themes emerged.

In order to answer the main research question, similarities and differences from themes arising from 3 main sources of information namely; learners (using FGD), stakeholders (interviews of DBE, DSI, and EEYS managers), other people (interviews of teachers, school principals, mentors, judges and parents) were compared.

5.2.1 Learners

5.2.1.1 Lack of Resources

Learners revealed that they are unable to produce good quality science projects due to lack of resources. For example, both rural and learners stated,

> *And lastly, I think it is because of lack of resources, because in school we lack resources to do proper research projects too.* (RM5)

> *Oh, I think I will need more assistance and more resources. I need more money to be able to go and do questionnaires to the people that I want to, I need more money to do research because of lack of resources*. (RF1)

> *My parents do not have money to buy needed stationery, at times there is no electricity, so no lights to work at night.* (RM4)

Learners from under-resourced schools do not have computers, printers, stationery and laboratory equipment to complete their projects. Furthermore, some rural learners do not have electricity at home. Rural learners gave feedback on their situations,

> *My research needs a lot of data, so maybe like if the school could provide data. Okay, I can work on that but I would have liked the school to help me on that. And another thing now for my research, I need a like photo copies. Transport us to venues as well. I need to print some of the pictures, and I don't have most of the resources at my house, so the school could help me with that. And also yes, when I'm doing questionnaires I need to … like ask some people questions and at school is going to be the right place to ask people*. (RM5)

> *The school must give us rooms to do our projects without disturbance from other learners. Teachers to help us to make our models and machines and buy charts and markers for us*. (RF2)

> *I think if the school could involve more research people from different areas who are specialized or can talk about different areas in science, they can bring them to school so that they can talk about these areas so that we can have a deep understanding on our projects… And also, if, for example, we have a library. But it's not necessarily equipped. It doesn't have enough books on certain topics*. (RF3)

To buy me material, find me a science mentor and prepare me for science fair. (RM6)

Rural schools, which are under-resourced, are unable to assist their learners with computers, stationery, printing of project reports and mentors (Demirel et al., 2013; Ndlovu, 2015).

Not all learners from urban areas are from wealthy families, so these urban learners lack financial support from parents. For example, one urban learner stated,

I lack some of the resources to conduct my research project. Like computer or a printer in which I can be able to type out my project and print it out. So I have to go to different places to get those resources and that takes time causes me to limit the amount of work that I have to do for my research. (UM10)

However, urban schools are well-resourced, so urban students have better opportunities for adequate support.

5.2.1.2 Science Fair Judges

Rural learners have claimed that some science fair judges were rude and unfriendly, biased towards beautiful looking projects. For example, some rural learners complained about the work of the science fair judges. A rural school learner, RM5, said,

But I would want to comment on the thing that some of them do spend very little time on the specific projects and don't go over your projects in depth so to make you understand the flaws and what you can do to improve on the project.

Also, Learner RM4 said,

I think a little more time on each project would go a long way, they just rush past spending few minutes not reading my work.

These comments suggest that learners with projects of sound science may be overlooked because they are not attractive due to poor resources. As a result, they may be poorly judged and given unfairly low marks. Science fair judges often consider the appearance of the project and not the science behind it (Saunders, 2013). The science fair judges failed to give learners feedback and this may jeopardise the upgrading of the learners' projects in future. Judges who fail to offer learners formal feedback do not offer feedback and opportunities for learners to continue discussing their results after science fairs (Ho-Shing, 2017, Rillero, 2011).

One rural school learner cried and was emotionally affected when a judge told her that her project was useless (see Figure 4.1). Negative statements by science fair judges affect the learners emotionally and may lead to the learner's poor performance during the presentation of their projects. The humiliation and embarrassment of learners by science fair judges causes the learners to perform poorly during the judges` interviews (Saunders, 2013). The data analysis showed that 25% of the learners at science fairs are shy and nervous, which can affect their communication with the science fair judges, implying that they will perform badly during their presentation of their findings. Science fair arena induces learners to feel anxious and stressed, thus affecting their performance (Keçeci et al., 2018).

The findings of this study imply that that both rural school learners and urban school learners require training on how to plan and complete research projects and report writing. Numerous learners gave feedback on this issue:

> *Yes, a little, problems with variables and writing of hypothesis*. (UM10)

> *The variables are difficult, graphs are difficult, hypothesis difficult, difficult to draw graphs with a computer because in the first place we don't have the laptop.* (UM6)

> *It is a challenge to me because this is not really taught at school, I think I need to have a bit of training on these scientific methods for me to have the skills*. (UF7)

> *The people from the expo need to train us, they need to give us books or show us videos on projects*. (RF1)

> *Not that much The science teacher does not teach about science projects, not very much.* (RM4)

> *Making beautiful machines or models is not easy because we don't have the money to buy the materials, they don't teach us how to do references or analysis and the hypothesis, we do it on our own*. (RF3)

> …*not too much it's a bit confusing me the order of writing these things*. (RF2)

5.2.1.3 Physics Knowledge

Learners expressed their desire to be trained on the scientific research methods. However, there are learners who received the research templates and guidebooks at their schools. These learners stated that they had no problems. These claims agree with studies that show learner performance at science fairs is enhanced when the learners are trained and equipped with scientific research skills (Koomen et al., 2017; Türkmen, 2019). Scientific methods and practical skills are necessary when learners plan and complete their science projects (Jackson et al., 2018).

This study revealed that 16.7% of the learners performed poorly at the science fairs iregardless of the support they received from the parents, teachers and school. Possible reasons for this contrary result may be lack of scientific skills required, techinical skills and insufficient content knowledge of the science subject. Even if the learners get the support required to do the work, they may still perfom badly if the learners do not know how to utilise the resources given (Betts, 2014).

The results indicate that participants from rural and urban schools found the physics subject too difficult. Both groups agree that physics is difficult, that they all face difficulty in solving problems:

> *I would say I am average learner when it comes to physics, it's a bit difficult, especially solving problems and such staff, too complicated at times*. (UM10)

> *The physics questions are tricky and difficult but I like the experiments, our teacher does not do much of the experiments we see in the textbooks, we just mostly do the theory and move on*. (UF9)

> *My knowledge in physics is average, but I see when the years goes by maybe next year. It will be more advanced because I'm doing physics*. (UF7)

> *Oh. I would not say I know it that much, but I do know the basics. And I have been learning a few parts from my previous grades*. (RM6)

> *The teacher does not explain more like in other subjects, the physics questions are difficult to understand them*. (RF3)

> *Physics is a natural science that involves the study of matter and its motion, it is hard yes physics is hard*. (RM4)

> *Physics is made difficult by the calculations which are too difficult because you must know the formulas*. (RF1)

However, there are learners who said that they do not have problems:

> *Well I'm a learner who gets okay, let's talk about my average marks on physics first. Yes. Okay and I am a learner who ranges from 70% plus so I might say that I'm good at physics. I have a good teacher. So that's that one good thing for me as a great teacher who I understand when she's teaching. So I think that contributes a lot to the way I understand physics. I am really good at it because it's also one of the subjects that I love.* (UM12)
>
> *I think that life science is much more difficult than physics because life science is just meaning of things. And then on physics, you have some practical examples which can help you understand better*. (UF8)
>
> *Because if I love the subject I work on it every day and I really get good grades. Yeah, and I can also apply most of the things that I learned in class to Everyday Life which means I have a better understanding if I can apply what I learned in class with what I do outside class*. (UM11)
>
> *My knowledge of physics is average on the high school level, but eventually I would like to enhance my learning.* (RF2)
>
> *So far it is okay, but I wouldn't say my knowledge is that profound in the subject because I've just recently started it*. (RM5)

This study has shown that there is no correlation between passing physics tests and performing well in the science fair. A plausible explanation may be that for learners to produce winning projects in the physics category, they require physics content knowledge, in addition to scientific skills, materials and equipment. The lack of experiments at schools affects the understanding of the physics subject by learners leading to their poor performance in physics tests (Musasia, Abacha & Biyoyo, 2012). These claims concur to similar findings stating that learners perform badly in physical sciences due to lack of practical work and knowledge construction (Bhaw & Kriek, 2020a; Welsh et al., 2020).

The implications of the findings in this study are that the learners completing science fairs may also do well in their science studies at school. Science fair activities enhance the academic achievement for all the students (Camacho & Fuligni, 2015). Stakeholders identified this relationship:

> *…the pass rate of physical science should improve because there is a relationship between research and academic achievement. Learners who are involved in these activities are also good in class and perform well*. (DBE1)

> *There is a correlation between the learners that participate in these initiative to the improvement of performance in the class*. *The performance of learners is also linked to the science content knowledge of the learners. As long as the academic performance levels are low, the science fair projects might still be of low quality. We expect the rural and urban learners to do well but the rural learners are not equal to the task due to many dynamics which include lack of resources and mentorship*. (DSI2)

It is interesting that the EEYS stakeholders did not indicate that the science fair could have an influence on learner performance. EE2 blamed the DBE when he stated "…our education system is designed and geared for assessment and high stakes examinations*"* without giving learners much time to benefit from science fairs.

5.2.1.4 Plagiarism

The study has revealed that plagiarism is rampant with science fair participants especially urban school learners with access to computers and internet. The science fair judges may identify plagiarised materials in learners' research reports by using some computer software. However, this method of identifying plagiarism might not be useful in some rural areas where there is poor internet connectivity. For example, stakeholders commented:

> *Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects*. (DBE3)

> *Learners sometimes copy projects from the internet and from previous years*. (DBE1)

> *Often learners reproduce work from the internet or do not submit work in the required formats acceptable in the research field. Very few learners produce research of high quality, most projects are repeats of other projects done or are done very superficially.* (EE1)

5.2.1.5 Scientific Communication

The poor understanding of the English language, and failure to communicate effectively in English by the learners presents difficulties in presenting the research findings to the science fair judges. Poor presentation of research findings could imply poor performance in the science fairs. Judges and mentors identified this issue:

> *The urban learners are more advanced; they express themselves well in English. The rural learners are not fluent, they are scared, they cannot express themselves well in good English, they are not free, scared and some even cry. We need to give the vernacular language a chance, the DBE must allow learners to express themselves in their mother language*. (J1)
>
> *Rural learners lack confidence when presenting their projects, they feel inferior*. (J2)
>
> *Learners should be allowed to talk in their language during interviews in order to explain their projects fluently*. (MU3)
>
> *The presentation is very poor with most learners due to language barrier. Judges need to be flexible on language usage*. (J3)
>
> *The learners especially rural learners they fail to express themselves well during interviews*. (MR2)

These claims are in agreement with the findings of other studies which postulated that learners with poor verbal and written communication skills, lacking in English language proficiency present their research results poorly before science fair judges (Alant, 2010; Fisanick, 2010; Karikari & Yawson, 2017; Schmidt & Kelter, 2017; Wharton, 2019). In this study the judges and mentors revealed that most rural learners have difficult in expressing themselves in English.

The DBE manager, judges and some teachers suggested the use of vernacular language at science fairs during interviews, so learners can express themselves well. Using vernacular language can be an option, but some judges do not speak the vernacular language.

This study has established that reports submitted by learners to the science fair judges do not follow the scientific method, and do not use scientific terms and concepts appropriately. A model is displayed with little explanation and no linking of results to discussion and conclusion. Mentors and judges stated:

> *Learners do not read more about their projects; their knowledge of the project is limited. When they get to the interviews by judges they are not convincing at all. The use of scientific terms and concepts is very poor*. (MU4)

It is because of this that learners concentrate on constructing models and nothing written, to explain the model. (MU3)

The discussion and conclusion are not related to the research project. They focus on the model or prototype and not on the science behind the model. (J2)

Learners should participate in training and workshops organised by EEYS and DBE.

5.2.2 Stakeholders

Stakeholders include DBE, DSI, and EEYS managers.

The stakeholders agree that the rural learners are disadvantaged at science fairs due to lack of resouces and equipmet they require to develop their projects. The teachers, mentors and school principals also say poverty affects more rural learners than the urban learners. For example,

Judges fail to give feedback to learners after judging which the learners need in order to upgrade their projects. (TU3)

Judges are biased towards nice looking projects without actually reading the science behind them. (MR1)

Other studies have confirmed that learners from under-resourced schools are not as likely to perform as high as the learners from well-resourced schools (Flanagan, 2013; Ngcoza et al., 2016; Olive, 2017).

When the sponsors the DBE and EEYS were interviewed, they stated that some judges were neither qualified nor competent to judge effectively. These judges fail to give participants feedback (see section 4.8.7). The claim affirms the findings of Ho-Shing (2017) who observed that the judges do not identify the mistakes of the learners and/or offer advice on how to improve on their projects.

The EEYS organisers explained that their organisation was an NPO with few workers. As a result, they cannot reach out to all schools in the country to conduct learners` and teachers` trainings. The manager EE3 stated,

EEYS is an NPO with few workers it is not possible to reach and train all schools in the country.

The findings of this study suggest that the organizers of the science fairs, EEYS, may need to improve on their communication channels to rural schools since get information on science fairs later than urban schools. Learners have stated, *We are always told about the competitions when it's too late, the information come to my school late. They must tell us on time*. (RF1)

We think perhaps more workshops. Training for both teachers and students, I am aware that they do that in certain provinces. But they don't really reach rural communities that you would have like one workshop here and not necessarily where we can engage and find out, get more information on the certain subjects and perhaps training of judges as well. I'm not really sure we do that, but maybe train judges so that they can have more knowledge. (RM4)

The science organisers must communicate directly with schools and if possible communicate with learners via their emails so that the learners are updated on all the events. (UF8)

Another issue is to improve on their time management; at some venues where the science fairs are tardy and finish late into the evening. In addition, learners do not have time to look at the other projects. As learners have stated,

The other thing is that science fair start late and end late in the night this causes us problems with transport back home. (RF2)

Also the time we start the competitions is late and we finish late again. (UM12)

I think that the amount of time that we were given to go around looking at other projects with other learners must be extended because by going around looking at other Learners projects, we are motivated and it makes our mind to think outside the box so that when next year comes we can do more we can make creative ideas regarding our projects and that the judges must be told that they must be more interested in learners. (UF9)

The rural learners further requested the donation of computers and training workshops. As one learner stated,

We need student science fair handbook that encourages students to develop projects based on something they connect with in their everyday lives. The expo people must donate computers to us and train us so that we can be able to use them. This is why our projects don't look nice because the graphs are not done by computer but by hand and ruler. (RM6)

Furthermore, EEYS may consider recruiting and training judges making them competent, discouraging them from being biased. The learners perceived the judges as being unfair and intimidating, when they stated,

> *Judges to check on students` projects well not to allow projects taken off the internet. They must use good judges not primary school teachers to judge our secondary school projects, why can't they find qualified judges*. (RM5)

> *Judges must be more interested in the Learners` projects regardless of what they are doing and that they must try to do more, to be more friendly than to intimidate the learners because it makes their interviews to be poor*. (UM10)

> *They should use competent judges who are not biased at regional expos*…*The judges are not all knowledgeable because I found out that at our district competitions primary school teachers were judging our engineering projects and they gave high marks basing on the attractive models without reading or asking deep questions about the projects. I think that was not good*. (UM12)

These findings support prior study that showed judges to demean and humiliate learners (Saunders, 2013). This study also revealed that the judges are biased and favour learners from well-resourced schools with flashy colourful projects. These findings concur with a prior study that asserted that some judges are biased towards beautiful looking projects (Atkins, 2014)

The interviews with the DBE and DSI revealed that EEYS is not able to cover the majority of the schools especially those in the rural areas. For example,

> *EEYS should reach out to be rural schools and not concentrate in schools in town.* (DBE2)

> *The expectations are not being fully met, for one, the expo is not reaching out to most rural schools*. (DSI3)

These comments may suggest that rural schools are not benefiting from science fair activities as well as being inspired to follow STEM courses. EEYS' rationale for not reaching all schools is because of its size. It is a small non-profit organization with limited funding from sponsors. Currently, it has only 17 employees and rely mostly on volunteers (https://exposcience.co.za/about-us/our-team/). Similar studies have shown that EEYS is not reaching out to all rural schools. As a result, they are not doing much to inspire rural learners to focus on science subjects that can lead them to STEM careers (Miller et al., 2018; Ndlovu, 2014; Taylor, 2011).

The DBE, DSI, and EEYS expect the learners to produce projects with sound scientific knowledge. Most learners in the rural and urban areas are failing to meet these expectations. Numerous stakeholders commented on this situation:

> *We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing and interviews*…*While some learners from both rural and urban areas produce gold winning research projects and most learners put in a lot of effort, most learners' work do not meet our expectations*… *Learners often do not spend time conceptualising and planning their research. They seem to lack the skills to fine tune their ideas so that it is specific and researchable. Learners who do not have parental influence or access to researchers and specialists or means to do research, may produce work that is of poor quality*. (EE1)

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and other resources*…*The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all*. (DBE3)

> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted*. (EE2)

> *But this is not always the case, some schools mostly in rural areas are under-resourced and the parents are mostly not educated and are poor, all this affect the rural learners*. (EE3)

> *…projects of poor quality, under researched projects, projects with no creativeness and innovation* (DBE1)

> *Learners, due to poor understanding of basic principles of science concepts, also miss out as they are not able to apply the principles. This is due to teachers doing the bare minimum in class and not pushing them to go beyond the textbook.* (DSI2)
>
> *Most urban schools are meeting the expectations mainly because they have the resources. It will be fair for all learners to have resources so that the competitions are even and fair. We do have exceptions in the rural schools were we see good projects but these are scanty*. (DSI1)

This study has established that EEYS has not met the expectations of the sponsors of reaching out to learners in the urban and rural areas to participate in science fairs. For instance, DBE and DSI commented on this situation:

> *They must reach out to all schools so that they participate, we only see same schools every year. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all*. (DBE3)
>
> *EEYS should reach out to be rural schools and not concentrate in schools in town.* (DBE2)
>
> *The expectations are not being fully met, for one, the expo is not reaching out to most rural schools*. (DSI3)

As a small non-profit organization, EEYS can only cover few schools in the country. This finding confirms what has been claimed by Taylor (2011) that EEYS is not reaching out to learners from impoverished backgrounds in townships and rural areas.

5.2.3 Other People

This group of people includes teachers, school principals, mentors, judges and parents.

The results indicate that teachers in rural schools do not assist their learners with the development of their science projects. Rural learners are aware of this lack of help:

> …*my teachers are always busy with their school work, at times they help with correcting my English grammar language and spelling mistakes*. (RM6)

My view of that teachers guides me on how to conduct my project and how to make it better. There is an expo coordinator we work with; we don't go to random teacher. (RF2)

In my school, teachers are very much involved in a lot of such projects. But the problem is that is not all teachers. You might find out that it is one, which makes it difficult. But overall, not all teachers in my school are involved in our projects. (RF3)

The study revealed that rural and urban teachers are overwhelmed with their school workload and are too busy to assist the learners with their science projects. Bailey and Colley (2014) made the same claim that teachers are heavily under pressure to cover the school syllabus, and they consider the science fairs as an extra burden.

By contrast, there are teachers who assist learners with their science projects by giving their own time and resources such as laptop computers and their personal funds.

When some rural and urban school principals were interviewed they stated that they will support the learner with the resources available at the school:

The school provide the available science equipment to the learners, offer good support to the head of department at school and educators. The schools will also order some laboratory equipment in short supply or that which is not available. (SPR1)

The school can only give what it has. The school allow teachers to help learners when they are free as long as this does not interfere with their school work. The learners can use school equipment and printers and computers. (SPU3)

These days the learners use internet to do their research, the school can have an open Wi-Fi which the passwords can be given to those doing research. As a school we also allow the use of our laboratory and its facilities and equipment as long as there is teacher supervision. Those who need photocopying can be assisted by the secretary with no problems. (SPU4)

The study has established that although both rural and urban learners need assistance from their parents, rural learners require more help because their schools are under-resourced. Urban learners state that their parents give me money for materials, help me with my model, get me a mentor, give me data bundles." The data suggest that the learners who receive support from their parents/guardians perform well at science fairs

(Bowen & Stelmach, 2020; Grinnell et al., 2018; Pittinsky, 2020; Taylor, 2011). Part of the findings of this study demonstrated that the urban learners who were supported by their parents did not perform well at science fairs (see section 4.6). Despite the support, they received from their parents, they failed the physics test. This is in contrast to Park et al., (2013) (as cited in Riggs, 2019), who claimed that parental support enhances academic achievements. This study has established that the learners fail due to their lack of subject knowledge or the depth of knowledge of the physics content.

Rural parents want to support the learners with whatever they can afford as seen in their comments:

> *I give him money if I have it. If I understand what he is doing I could help but you know these children want to make things that use electricity I don't know that. I allow him to go to meet others where they work together preparing for the competitions.* (PR1)
>
> *Well, if she asks for money and the old people grant money is there, I give her some very little because we have to eat in this house you know*. (PR2)

Also, parents want all activities to end on time so that learners avoid travelling at night for their safety (see section 4.8.16), parents said,

> *They must make sure that our children don't travel during the night after their preparations or competitions, the world is now full of bad people. (PR1)*
>
> *When they finish late, I always pick her up since she is a girl you know for her safety.* (PU3)

When the urban parent was interviewed, he stated that he drives the learner to science fair venue and supply the child with a smart phone for internet and money.

When the judges were interviewed, they stated that parents need to be informed or trained at meetings on science fairs so that they, the parents, understand and appreciate science projects since the parents will eventually assist the learners. For example, judges have stated,

> *Parents need to be workshopped during parents' meetings so that they understand what is expo (science fair). As long as the parents do not understand what is expo, they will not support it*. (J1)
>
> *Learners need the emotional support from home. There must be workshops for learners and parents so that someone can talk to the parents on behalf of learners for them to give support*. (J3)

This study further reveals that the judges lack adequate training and proper qualifications and this may suggest that the results of the science fair competitions are compromised. Teachers and mentors have stated,

> *Judges fail to give feedback to learners after judging which the learners need in order to upgrade their projects*. (TU3)

> *Judges are biased towards nice looking projects without actually reading the science behind them*. (MR1)

> *The problem is that some judges judge their own learners and give them more marks. Also, the convener or leaders of the judges, changes marks in favour of his/her school. Because of this, winners are mostly from school were the judges and conveners belong due to manipulation of marks. My suggestion is to use the judges from different regions to avoid judges' bias.* (TR1)

> *The judges are never fair because the same judges are mentors of the students at their schools. It is the same judges that are helping learners to do the projects at schools; so they make sure that their learners get top marks so that the school will think that they are doing great work*. (MU4)

This claim is in agreement with a study by Atkins (2014), which established that science fair organisers have difficulties in recruiting science fair judges, and when they find them they often offer them minimum training.

When the science fair judges were interviewed (see section 4.8.8) they all agreed that favouritism, bias and conniving of judges to favour their school was practiced during the judging process. Further findings of this study were that the judging time (see section 4.8.9) was too short, judges were not managing large numbers of projects; they sometimes rushed through the process.

Some teachers are not effectively assisting learners with the research projects because the teachers lack the scientific research skills. DBE managers identified this issue:

> *You will see that some teachers even need the skills, to help they must be workshopped and follow ups made to see that they are implementing the skills*. (DBE3)

> *Some might not be knowledgeable themselves with the scientific skills to assist so they do not assist not because they don't want but they don't have the research skills*. (DBE1)

The need for teacher training is supported by research studies by Baki and Bütüner (2009), Park and Ertmer (2008), and Pektas (2009) (as cited in Demirel et al., 2013). These researchers have stated that some teachers lack the scientific research skills to guide the learners with the process of developing a research project for a science fair.

There is poor communication between the EEYS and the schools (see section 4.7.8). The learners, who get the information from the school in some instances, receive science fair invitations and dates for competitions late disadvantaging the learners who would want to participate in science fairs. As a DBE manager stated,

> *The schools and learners fail to get information about science fairs on time and hence they rush their work*. (DBE1)

The suggested solution is that the information on science fairs should be posted on social media, newspapers, and if possible, sent directly to learners.

Learners and teachers have difficult in managing the little time they have and utilise it effectively for science fair projects. Teachers have stated,

> *They do not have time; they are overloaded with school work. The learners tend to work at the last minute, they only start to work on the projects towards the competition day.* (TR1)
>
> *The projects are time demanding and not all learners can manage their tim*e. (TU3)

The judges complain of being given little time to judge a large number of projects resulting in compromising of proper assessment of projects as explained by judges J1 and J2 below,

> *The time given for judging is not enough, there is little time to read through the whole projects. The projects at the regional science fairs are too many, in order to come up with best projects, they need to be judged over 2 days not what is currently done in few hours.* (J1)
> *The judging must start at school level to circuit level and elimination done at these levels until the projects are upgraded to meet minimum required standards.*
> *The number of judges is always very low at the science fair events; when the judges get tired they will start looking for exciting projects to judge properly as for the rest they will rush through.* (J3)

Not all judges are unfair. I am also a judge. The projects are too much for one judge, you be given 15 projects to judge in a short time which is impossible, you end up just browsing the project reports and giving marks from your head. (MR2)

The findings of this study concur with Demirel et al. (2013) and Olive (2017). These researchers learned that learners have limited time, which is not enough to produce sound science projects. The judges and teachers would rather have the science fair being held over two days than in few hours within one day.

The findings of the research are that, a judge, a school principal and a teacher want the school curriculum to have research component. They claim that the projects will not be taken seriously if this topic is not part of the learners' routine instruction:

The school must give learners more projects work in the curriculum like in grade 12 they removed the research components leaving only the experiments. (J1)

The DBE must include research projects in the school curriculum and give the teachers the training needed for them to be competent. (SPU3)

Most teachers do not consider expo fairs as part of the school curriculum and so to them is a waste of precious time. (TR2)

When research projects are a requirement of the science curriculum, the teachers will be forced to teach learners how to effectively plan and execute a research project, and the DBE would be required to provide the necessary equipment and materials which the learners need.

Some schools do not have science clubs; others had the science clubs in the past and they discontinued. Those schools with science clubs have most of their members developing science projects and participating in science fairs. As one teacher stated,

Yes, we have a science club and most of the members of the club participate in expo fairs. (TU4)

The findings of this study concur with Cicek (2012) and Sahin et al. (2014) who claimed that science clubs offer a platform for development of science fair projects. The DBE and other stakeholders may consider establishing science clubs at schools, as these clubs give learners a place to develop their science projects. Then, they are more likely to participate in science fairs (Dabney et al., 2012; Nuni, Indoshi, & Odour, 2016).

Teachers, judges, school principals, and mentors stressed that teachers and learners require workshops on how to develop science projects and on how to improve their scientific research skills in order to gain confidence and knowledge to assist the learners. Numerous people commented about this issue:

> *They need to support teachers with workshops, training them so that they are confident and have the scientific knowhow*. (SPR1)
>
> *The EEYS cannot just call for projects without assisting the teachers and learners with training on how to do them*. (SPR2)
>
> *The EEYS need to train the teachers and learners on the making of projects from start to finish*. (SPU4)
>
> *The DBE to train teachers on scientific research skills and project development*. (J2)

This lack of teacher training with the scientific research skills and assessment skills suggest that their assistance to learners on science projects is substandard. Studies by Rillero (2011) and Atkins (2014) also asserted that teachers require some training in order for them to be effective and helpful with science projects. In agreement, Tortop (2014) identified that schools should allow teachers to undego training workshops in order to be able to mentor the learners. Therefore, all the stakeholders; DBE, DSI and EEYS should work together and organise training workshops for the teachers and lrearners.

The teachers may be given some awards or incentives by DBE and EEYS when their learners win at science fairs. These commendations can help to motivate and appreciate the help the teachers give to learners. A principal and judge stated,

> *Teachers need to be given rewards when they do well, when their learners achieve best results in expo*. (SPR1)
>
> *Educators and judges are demoralized because they are not given incentives and some have stopped participating, EEYS should work on this*. (J2)

While giving incentives to teachers can motivate them, it is also beneficial to explain to the teachers that the gains obtained by learners when they participate in science fairs, such as scientific skills, science content knowledge, can be more valuable (Koomen et al., 2017; Mupezeni & Kriek, 2018; Ulusoy, 2016).

Learners who plan and complete science projects require qualified mentors to assist and guide them. This mentorship is especially important to the learners in rural schools. As one rural mentor stated,

> *Working as an external mentor is difficult because the learners do not respect you as they do their teachers. Some teachers are not interested in assisting you in this regard. The learners expect the mentor to provide all the requirements including financial assistance which is not possible*. (MR1)

This claim concurs with Bernard (2011) who affirms that urban learners have an advantage over rural learners because the urban learners have more access to qualified mentors. Similarly, Alant (2010) affirmed that rural school learners do not have mentors to assist them with their projects. Also, Akınoğlu (2008) (as cited by Betts, 2014) observed that if schools acknowledge the importance of science fairs, they will engage mentors to assist their learners.

5.2.3.1 Interaction amongst the Three Groups

The findings of the study reveal that teachers, mentors and learners learn new ideas and research skills as they interact with each other; teacher-teacher, teacher-learner, learner-learner. DBE managers identified this interaction:

> *Both rural and urban learners have different experiences which they share during these competitions and improve on their projects*. (DBE3)

> *We expect creation of a network of people sharing ideas upgrading each other, learning the developments and creativeness and innovation of others*. *But as the teachers work with the learners they will also acquire various research skills, so they stand to benefit as well*. (DBE2)

Learners and teachers acquire knowledge outside classroom (Lin & Schunn, 2016). They also learn from each other in a relaxed non-threatening environment for free (Cheng & Jin, 2015; Griffiths, 2014; Kisiel 2013; Pittman, 2016; Rennie, 2014). Teachers learn from other experienced teachers during science fairs, thus increasing their knowledge and scientific skills (Taylor, 2015).

5.3 Addressing the First Sub-Research Question

The first sub-research question of this study is:

1. How do the constructs of CHAT uncover the dynamics contributing to the difference of rural and urban school learners' performance at science fair competitions?

In order to answer this question, it is necessary to indicate that there are two activity systems, the rural and the urban (see Figure 5.1). These two activity systems, rural school learners and the urban school learners, are interrelated. Each informs the other which makes the object exist, the science fair competition. The CHAT framework used in this study pivots on three main notions: a) learners (humans) act communally, learn by practicing, and communicate verbally or by actions; b) learners create, use and adapt equipment and materials to learn and communicate; c) the community is key to the whole process, forms of learning (developing of projects), ways of communication and actions. Some rural and township schools are under-resourced due to apartheid, and this is now affecting the performance of some learners.

The qualitative data from the PMM, FGD, observation protocol, interviews and researcher notebook notes triangulated to validate these findings.

Figure 5.1 below shows the CHAT framework indicating two contrasted CHAT activity systems the rural learners on the left, and the urban learners on the right.

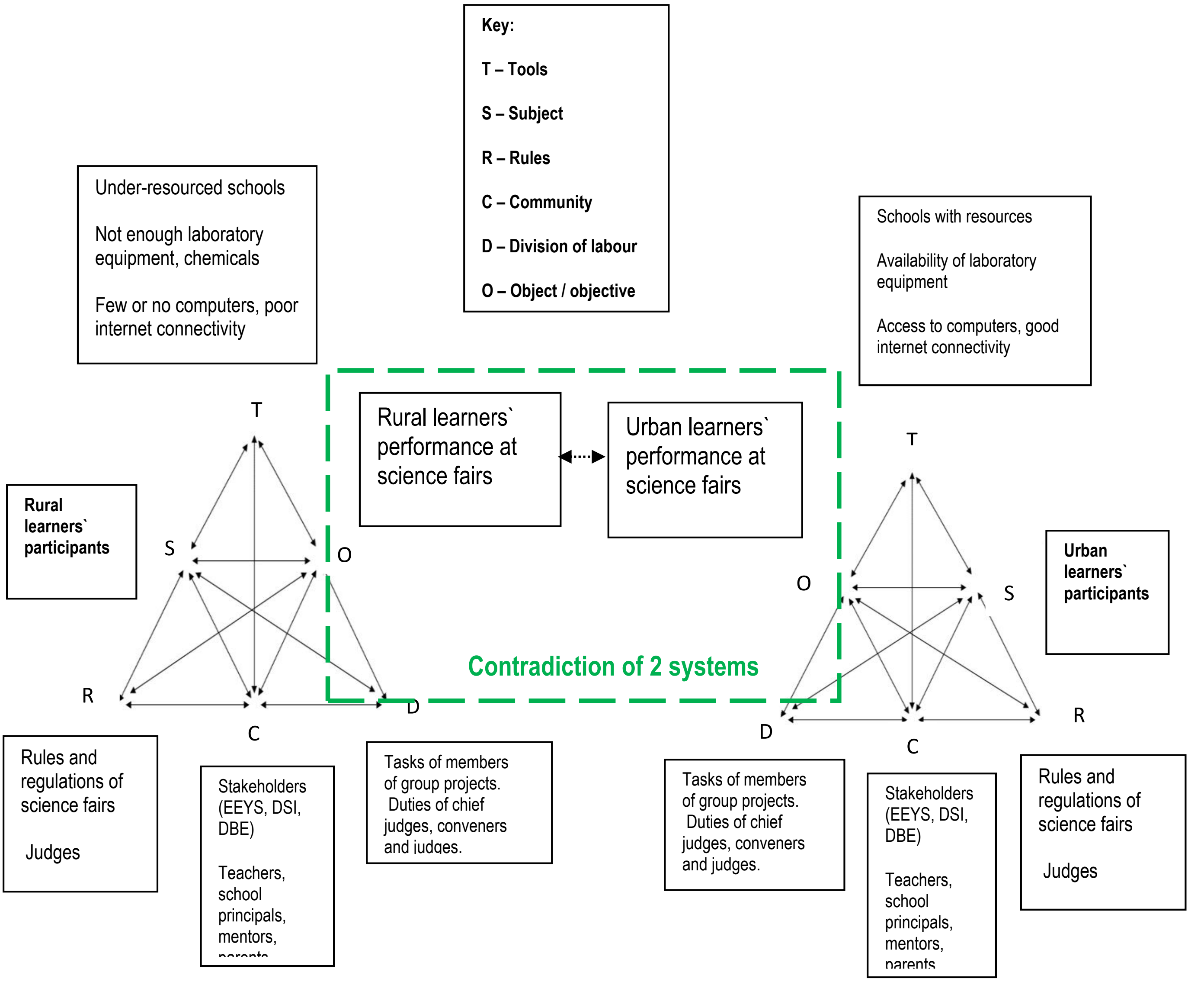

Figure 5.1: The two contrasted CHAT activity systems: (a) the rural learners on the left, and (b) the urban learners on the right.

There are tensions between nodes of the facets of the CHAT triangle framework (see Figure 2.3). One construct, community, has the following tensions: community-rules, community-division of labour, community-object, community-subject and community-tools. First, tensions for urban and rural learners are explained. Then, there is an explanation of the disparities in terms of tensions.

5.3.1 Subject-Community

There are tensions between the expectations of science fair stakeholders, EEYS, DBE, DSI, and what the learners can achieve. The stakeholders expect the rural and urban learners to produce research projects of a high standard and to perform well at science fairs. The learners have not been able to achieve this due to various dynamics highlighted in this study. For example,

> *We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing…While some learners from both rural and urban areas produce gold winning research projects and most learners put in a lot of effort, most learners' work do not meet our expectations*. (EE1)

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and other resources*…*The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all*. (DBE3)

> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted*. (EE2)

> *Learners, due to poor understanding of basic principles of science concepts, also miss out as they are not able to apply the principles. This is due to teachers doing the bare minimum in class and not pushing them to go beyond the textbook.* (DSI2)

There are tensions between the learners and teachers, parents, school principals, and mentors. One source of the tensions is time. For instance,

> *They do not have time; they are overloaded with school work. The learners tend to work at the last minute, they only start to work on the projects towards the competition day.* ITR1)

> *The projects are time demanding and not all learners can manage their tim*e. (TU3)

> *The learners have limited time to work on their projects, they have a lot of school work to do*. (MR2)
>
> *Time is always a problem, as soon as the schools finish learners have to leave school since they use common prepaid transport*. (MU3)
>
> *Time is a challenge, learners do not have enough time to do all this after school activities, they have homework and they need to study their subjects as well.* (MU4)

The findings show that the rural learners do not receive much support from their parents due to poverty and the parents' lack of science literacy. The rural learners` performance at the science fairs (Table 4.6) has shown that they are not as successful as urban learners who enjoy support of parents. Rural learners with limited resources, are competing at the same level as the urban school learners from well resourced-schools. These conditions put rural learners at a disadvantage (Kahenge, 2013; Grinneli et al., 2018; Smith, 2013; Taylor 2011).

Within the community, there are tensions between the parent and teacher, and there are tensions between the stakeholders, EEYS and DSI/DBE

The tensions between the parents and the learner focus on the issues of time and money. The parent is afraid that by attending science fairs the learner might not pay attention to the academic school work. On the other side, the learner wants to participate in the science fairs,

> *The boy always complains of time, there is school work, other competitions and this science fair, it's too much and I am afraid that this might affect his academic performance.* (PU4)
>
> *Some parents do not allow learners to participate because they think they might not end up performing well at school.* (TU3)

There is tension between parents and learners, due to poverty and science literacy. Some parents are unable to support their children with the required materials. Learners gave the following statements with regards to this support:

> *I think I would expect my parents to assist with the printing of the papers and reading my file. In order for my report board to look proper. They transport me, they don't give me any money*. (RF1)
>
> *I always need their financial support for printing and making photocopies and laminating my projects display cards*. (UM12)

To assist me with ideas help me practice for display. Must give me some space at home and not to send me all over disturbing me. (RF2)

In addition, judges gave similar statements:

Parents need to be workshopped during parents' meetings so that they understand what is expo (science fair). As long as the parents do not understand what is expo, they will not support it. (J1)

Learners need the emotional support from home. There must be workshops for learners and parents so that someone can talk to the parents on behalf of learners for them to give support. (J3)

The findings in this study show that most rural parents are not supporting learners and this concurs with other previous studies (Betts, 2014; Finnerty, 2013; Kahenge, 2013). DBE and DSI expect the EEYS to reach out to all learners including those in the rural areas. However, the EEYS is only an NPO, with limited resources and employees, so it is not possible for it to reach all the schools;

EEYS is an NPO with few workers it is not possible to reach and train all schools in the country. (EE3)

5.3.2 Subject-Object

Tensions arise between the science fair and the rural school learners (see Table 4.4b). During the science fairs, rural learners' level of attention is low and characterised by distraction, less focused and less engaged. The urban learners performed slightly better than the rural learners on the physics test, which was set to measure the depth of knowledge of the learners. The rural learners did not do well in the science fair competition as compared to the urban learners. They did not perform well because they were not able to: formulae hypothesis, identify variables, report writing, use of scientific terms, and/or present their research results during judges' interviews.

b) There are tensions between the science fair and the urban school learners (see Table 4.5). The depth of knowledge and level of attention of urban learners is better than that of rural learners. Urban learners are able to express themselves well in English, and their research reports are clearly written.

5.3.3 Subject-Tools

Tensions exist between the rural learners, urban learners and the availability of resources to use for their projects. For example, rural and urban learners stated, *And lastly, I think it is because of lack of resources, because in school we lack resources to do proper research projects too.* (RM5)

Oh, I think I will need more assistance and more resources. I need more money to be able to go and do questionnaires to the people that I want to, I need more money to do research because of lack of resources…We are always told about the competitions when it's too late, the information come to my school late. They must tell us on time. (RF1)

My parents do not have money to buy needed stationery, at times there is no electricity, so no lights to work at night. (RM4)

I lack some of the resources to conduct my research project. Like computer or a printer in which I can be able to type out my project and print it out. So I have to go to different places to get those resources and that takes time causes me to limit the amount of work that I have to do for my research. (UM10)

My research needs a lot of data, so maybe like if the school could provide data. Okay, I can work on that but I would have liked the school to help me on that. And another thing now for my research, I need a like photo copies. Transport us to venues as well. I need to print some of the pictures, and I don't have most of the resources at my house, so the school could help me with that. And also yes, when I'm doing questionnaires I need to … like ask some people questions and at school is going to be the right place to ask people. (RM5)

The school must give us rooms to do our projects without disturbance from other learners. Teachers to help us to make our models and machines and buy charts and markers for us. (RF2)

The school must give us support by creating a room, space and time for us to do science projects. (UF8)

The results of the study suggest that the learners might desire to excel in the science fairs but are frustrated and hindered by the lack of resources. This situation creates a tension between the learners and the tools/resources.

5.3.4 Subject-Rules

Tensions exist between the learners and the EEYS rules and regulations, in a bid to perform well some learners plagiarise their projects from the internet. Stakeholders stated, *Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects*. (DBE3)

Learners sometimes copy projects from the internet and from previous years. (DBE1)

Often learners reproduce work from the internet or do not submit work in the required formats acceptable in the research field. Very few learners produce research of high quality, most projects are repeats of other projects done or are done very superficially. (EE1)

In the study the EEYS management, the DBE managers and school principal confirmed that some learners resort to plagiarism and thereby break the rules of the science fairs. The subjects (learners) find themselves in confrontation with the judges who are the enforcers of the rules. The differences amongst the rural and the urban learners was that the urban learners were reported to be the most violators of the plagiarism rules because of their access to the computers and internet. Both rural and urban learners feel that the judges are biased and lack adequate training. They stated,

Judges must be more interested in the Learners` projects regardless of what they are doing and that they must try to do more, to be more friendly than to intimidate the learners because it makes their interviews to be poor. (UM10)

They should use competent judges who are not biased at regional expos. *The judges are not all knowledgeable because I found out that at our district competitions primary school teachers were judging our engineering projects and they gave high marks basing on the attractive models without reading or asking deep questions about the projects. I think that was not good*. (UM12)

5.3.5 Subject-Division of Labour

There is tension between what is expected from the teachers in terms of extra work required by the learners in the form of assistance with their projects. The learners should do the work sharing tasks amongst themselves, and the teacher’s role is to encourage them. As learners stated,

…*my teachers are always busy with their school work, at times they help with correcting my English grammar language and spelling mistakes*. (RM6)

Some teachers they tell me to see the expo coordinator at school who is always busy with her schoolwork and other projects from learners since she is alone helping us. (UM10)

My view of that teachers guides me on how to conduct my project and how to make it better. There is an expo coordinator we work with; we don't go to random teacher. (RF2)

In my school, teachers are very much involved in a lot of such projects. But the problem is that is not all teachers. You might find out that it is one, which makes it difficult. But overall, not all teachers in my school are involved in our projects. (RF3)

This assertion supports the findings by Bailey and Colley (2014) who established that the teachers are overloaded with their normal school work and have no/little time for helping learners with their projects. In both rural and urban areas, there are teachers who are assisting and committed to the learners, and others who are also not helping learners with their projects.

5.3.6 Tools-Community

The materials, equipment, computers and printers (tools) are needed by the learners for use and being provided by stakeholders, school, teachers and parents (community). The tension arises when members of the community fail to provide the needed tools, leading to the poor performance of learners at science fairs. Rural and urban learners stated,

My research needs a lot of data, so maybe like if the school could provide data. Okay, I can work on that but I would have liked the school to help me on that. And another thing now for my research, I need a like photo copies. Transport us to venues as well. I need to print some of the pictures, and I don't have most of the resources at my house, so the school could help me with that. And also yes, when I'm doing questionnaires I need to … like ask some people questions and at school is going to be the right place to ask people. (RM5)

The school must give us rooms to do our projects without disturbance from other learners. Teachers to help us to make our models and machines and buy charts and markers for us. (RF2)

> *The school must give us support by creating a room, space and time for us to do science projects*. (UF8)

In terms of support, the lack of resources has been documented as disadvantaging learners (Flanagan, 2013; Gifford & Wiygul, 1992; Ndlovu 2015). The learners, teachers and school principals have indicated that the tools should be provided by the DBE and the EEYS as shown in the following comments:

> *The school should support the learners financially and motivating them. They should buy equipment for the learners to use in their projects.* (TR2)
>
> *The school should assist with chemicals, electrical devices and equipment for the learners to use. The school should give teachers who participate in science fairs some incentives as well because this is out of school work.* (TU4)
>
> *The DBE can supply laboratory equipment schools. The DBE must give learners transport and feed them when they go for science fairs. The schools do not have money. These learners need computers and printers as well, the DBE must supply these and internet.* (SPR1)
>
> *The DBE should pay for all the expenses, transport, printing and buy the materials and electrical devices that the learners may require. The DBE should also recognize with incentives teachers taking part in these activities.* (SPR2)
>
> *The DBE has a tendency of leaving everything to schools and expect results without themselves giving any input for the learners to use the internet. The DBE must provide science kits and upgrade our school laboratories. They need to provide us with access to free Wi-Fi and data. The school need assistance in transportation of learners to various venues.* (SPU4)

From the previous comments, it is clear that some teachers and the school principals desire the DBE to provide the resources to schools.

5.3.7 Tools-Object

There is tension between the resources and the performance of learners at the science fair. This tension exists for urban and rural learners,

> *I lack some of the resources to conduct my research project. Like computer or a printer in which I can be able to type out my project and print it out. So I have to go to different places to get those resources and that takes time causes me to limit the amount of work that I have to do for my research.* (UM10)

We think perhaps more workshops. Training for both teachers and students, I am aware that they do that in certain provinces. But they don't really reach rural communities that you would have like one workshop here and not necessarily where we can engage and find out, get more information on the certain subjects and perhaps training of judges as well. I'm not really sure we do that, but maybe train judges so that they can have more knowledge. (RM4)

These findings agree with studies that argued that under-resourced schools are disadvantaged and will perform poorly at science fairs (Demirel et al., 2013; Flanagan, 2013; Olive, 2017).

5.3.8 Rules-Object

The judges are representing the rules, and there are tensions between them and the science fair event (object). The science fair is considered successful if the judges conduct themselves professionally and fairly treat all learners without bias. They are run by regulations (enforced by judges) which the learners have to follow. These rules include copying or repeating other people`s projects. However, science fair participants have stated that the judges are not qualified for this job. Learners notice the lack of qualifications. For example,

Judges to check on students` projects well not to allow projects taken off the internet. They must use good judges not primary school teachers to judge our secondary school projects, why can't they find qualified judges. (RM5)

Judges must be more interested in the Learners` projects regardless of what they are doing and that they must try to do more, to be more friendly than to intimidate the learners because it makes their interviews to be poor. (UM10)

They should use competent judges who are not biased at regional expos…*The judges are not all knowledgeable because I found out that at our district competitions primary school teachers were judging our engineering projects and they gave high marks basing on the attractive models without reading or asking deep questions about the projects. I think that was not good*. (UM12)

The findings of this study about judges` bias, not being properly trained and failing to provide feedback to learners concurs with the findings of Karikari and Yawson (2017). These researchers stated that judges should be interested in the science behind the project and not the outward appearance of the model. Also, judges should try and give learners feedback after assessing their projects to enable them to upgrade the projects.

5.3.9 Rules-Community

Tension exists between the judges` professional conduct and the rules of the science fair, in regards to fairness and favouritism. Learners stated that the judges lack interest in the projects that are not in the judge's field and/or attractive. For example,

> *I will say that some I think they're not really interested in my project. Some ask me few questions and others more questions about my project they would seem to be more interested in my project wanting to know more about my project making me feel free to talk to them and giving me more ideas. Whereas some other judges spend little time with me and when they go to other projects they stay a little bit longer time, asking more questions, but when they come to me like they ask few questions and I feel left out sometimes. I like I so scared to death to talk to them. They're more intimidating me rather than making us feel free to talk to them. They must be more interested in our projects regardless of your gender where you come from, whether you're going to a private school or whether you are a girl, they must be more freely to all other learners regardless of what the project is all about. I think some judges are more interested in projects that has to do with maybe mathematics or science where they have models when it comes to us who are doing investigations like there is no model, they won't be more interested and which makes us feel left out. Next time we want to try projects with models which we are not good at. The new things we are trying we are not good at them we are only good at what they discouraged us to do because of the way they're behaving towards us.* (UM12)

> *They do not like projects from poor schools because they don't show too much interest, they quickly move to projects which are beautiful looking models.* (RF3)

Teachers and mentors have commented on this situation:

> *Judges fail to give feedback to learners after judging which the learners need in order to upgrade their projects*. (TU3)

> *Judges are biased towards nice looking projects without actually reading the science behind them*. (MR1)

In addition, tensions arose between rules (ethics and regulations) of the science fair and the community (family members and biased judges) who cheated. For example,

> *Often learners reproduce work from the internet or do not submit work in the required formats acceptable in the research field.* (EE1)
>
> *The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects.* (DBE3)

Other studies have revealed these tensions as well (Karikari & Yawson, 2017; Ramugondo & Kronenberg, 2015; Rillero, 2011; Saunders, 2013). These tensions exist because the parents desire their children to perform well at science fairs; they then hire other experts and professionals to do the projects of their children in violation of science fair regulations.

5.3.10 Object-Community

There are tensions between the expectations of teachers, the school, parents and the sponsors with the deliverables of science fair. On tension is between the stakeholders and the learners. As the stakeholders stated,

> *We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing and interviews*…*While some learners from both rural and urban areas produce gold winning research projects and most learners put in a lot of effort, most learners' work do not meet our expectations*. (EE1)

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and other resources*…*The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all*. (DBE3)

> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted*. (EE2)

Mentors have also acknowledged tensions. They stated,

> *Learners do not read more about their projects; their knowledge of the project is limited. When they get to the interviews by judges they are not convincing at all. The use of scientific terms and concepts is very poor*. (MU4)
>
> *It is because of this that learners concentrate on constructing models and nothing written, to explain the model*. (MU3)

Learners who are involved in science clubs also participate in science fairs (Nuni et al., 2016). In some schools, the science clubs were established but later abandoned due to lack of resources. Rural teachers indicate that they don't have it due to resources. Urban teachers indicated that the science clubs exist, but the schools are not prepared to share their resources with the clubs. Thus, a science club without support and resources eventually ceases to function. Therefore, the success of a science fair (object) requires the support of the DBE, EEYS and DSI.

5.3.11 Division of Labour-Object

When division of labour is seen as a division of time and efforts, learners encounter challenges in managing their time. Some learners struggle to get time for the development of their science projects as noted by mentors MU3 and MU4,

> *Time is always a problem, as soon as the schools finish learners have to leave school since they use common prepaid transport. (MU3)*
> *Time is a challenge, learners do not have enough time to do all this after school activities, they have homework and they need to study their subjects as well.* (MU4)

Learners might need parental and school assistance to help them manage their time and to help them form a balance between school work and science fair projects.

5.4 Addressing the Second Sub-Research Question

The second sub-research question of this study is:

How do the tensions in the constructs of CHAT reveal the disparity between urban and rural science fair learners?

5.4.1 Subject-Community

There are tensions between the expectations of science fair sponsors and partners EEYS, DBE, DSI and what the learners can provide.

EEYS expects the learners to be inspired as young scientists and researchers capable of identifying a problem, analysing data and effectively communicate their results to the peers and public. They expect all learners from both rural and urban areas to practice scientific inquiry skills through research and produce high quality research projects. The tension arises when the learners from all areas develop projects that reflect only basic inquiry skills, with a lack of originality, a lack of deep critical thinking, and inadequate literature reviews. Most rural learners produce poor quality projects. EEYS officials stated,

> *Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted*. (EE2)

> *But this is not always the case, some schools mostly in rural areas are under-resourced and the parents are mostly not educated and are poor, all this affect the rural learners*. (EE3)

> *Learners often do not spend time conceptualising and planning their research. They seem to lack the skills to fine tune their ideas so that it is specific and researchable. Learners who do not have parental influence or access to researchers and specialists or means to do research, may produce work that is of poor quality*. (EE1)

The DBE expects all learners to have an understanding of scientific, technological and environmental knowledge and must be able to use it in different environments or contexts. The DBE desire all learners to do well but expect urban learners to produce better projects since they have more resources when compared to the rural learners. The majority of rural learners` research projects are of poor standard compared to the urban learner’s projects. DBE managers stated,

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and*

other resources…The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all. (DBE3)

…projects of poor quality, under researched projects, projects with no creativeness and innovation. (DBE1)

The DSI expects the all learners to design and execute excellent original research projects, showing sound science procedures. Learners are expected to acquire problem solving skills and make academic improvements. The tension arises because most of the rural learners are failing to meet the expectations due to lack of resources. The science fair activities are not largely being transformed to academic improvement. DSI managers stated,

Learners, due to poor understanding of basic principles of science concepts, also miss out as they are not able to apply the principles. This is due to teachers doing the bare minimum in class and not pushing them to go beyond the textbook. (DSI2)

Most urban schools are meeting the expectations mainly because they have the resources. It will be fair for all learners to have resources so that the competitions are even and fair. We do have exceptions in the rural schools were we see good projects but these are scanty. (DSI1)

Teachers, school principals, mentors and parents are expected to work together (community) to assist the learners (subject) in the development of science projects. The study has revealed that the community has limitations when assisting the learners due to lack of time, resources, commitment and scientific research skills. As DBE managers stated,

You will see that some teachers even need the skills, to help they must be workshopped and follow ups made to see that they are implementing the skills. (DBE3)

Some might not be knowledgeable themselves with the scientific skills to assist so they do not assist not because they don't want but they don't have the research skills. (DBE1)

5.4.2 Tools-Community

The rural school learners expect material support from EEYS for them to produce quality projects. The EEYS does not supply equipment to schools which the learners, this creates a tension because the EEYS still expects quality research projects from the same learners. Rural learners have stated,

> *Oh, what they could do is that they should aim to have many schools involved because I come from Giyani in Limpopo. And in that area, the other public schools are not involved in science fairs and are not taking part at all. But they also have good suggestions. And another thing is that they should also call them for their regional fairs. Now, they only take a few people. So if they could also increase the number of the people they take to the regional competitions the better*. (RF3)

> *Maybe like in my area I stay in a village in Malamulele, right but I go to school in Giyani. If the organization can visit each and every school in every area thus when we can get more creative minds because there might be someone who is more creative but just because they don't know about the science expo, they don't have the platform where they can like expose their creativity. Most of the schools in my area do not know about expo, they need to get more schools involved even public schools, to get more creative minds.* (RM5)

The DBE expect rural learners to perform well at science fairs but they have not placed resources like computers, laboratory equipment at these schools. Tensions exist caused by what the community (DBE, teachers, school principals, parents) expects and the availability of tools (computers, printers, laboratory chemicals and equipment). Both DBE and EEYS officials have stated,

> *In an ideal situation all schools should be equally resourced and equally exposed to the science engagements going on. Anyway, rural learners are unfortunate in that their schools are under resourced as a result their projects are not as good as those coming from town schools. We expect learners from town to produce good projects and well written reports since they are exposed to the internet and other resources…The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are*

participating and very few schools in the villages are participating, so the expectation of involving most schools is not being met at all. (DBE3)

But this is not always the case, some schools mostly in rural areas are under-resourced and the parents are mostly not educated and are poor, all this affect the rural learners. (EE3)

5.4.3 Rules-Community

The DBE and the DSI expects equal opportunities to all learners and requires the EEYS to reach all of them, including those in the rural areas. This expectation creates tensions because the EEYS does not have the capacity to access all learners. DBE and DSI managers stated,

EEYS should reach out to be rural schools and not concentrate in schools in town. (DBE2)

The expectations are not being fully met, for one, the expo is not reaching out to most rural schools. (DSI3)

Also the judges who are the enforcers of the rules are accused by the learners and the community of bias. As they stated,

They do not like projects from poor schools because they don't show too much interest, they quickly move to projects which are beautiful looking models. (RF3)

Some of the judges they talk very fast and it`s difficult to understand their English because they like to use big science words, they expect me to know like them. (RF2)

English [is] difficult for me, [it is] difficult for me to explain my project in English. They are rude, they don't explain my mistakes they just go away. (RM6)

5.4.4 Rural and Urban Activity System-Stakeholders

Stakeholders expect South African learners to excel at science fairs and then attend universities regardless of the school where they attended. This expectation creates a tension between the collective body of learners and the stakeholders, as the expectations of stakeholders are not always met:

The expectations are not all met. Even learners from the towns they are not producing the good projects, they take advantage of the internet to plagiarise projects. The other thing is that not all schools in towns are participating and very *few schools in the villages are participating, so the expectation of involving most schools is not being met at all.* (DBE3)

We expect urban learners to participate more since they have more resources compared to the rural learners, we expect better quality projects from schools in town. In the villages they lack resources and they have to make do with recycling of materials they pick around. However, we expect teachers to be assisting the learners from urban or rural schools. Teachers should assist learners when they can. We expect all learners to compete even though the playing field is uneven in favour of the urban learners. (DBE1)

My expectations are that the rural learners are to be exposed to local and global trends as well as in all competitions including science fairs. I expect them to do equally well despite their circumstances I believe they are also intellectually gifted. (DBE2)

We expect EEYS to involve all schools, rural and urban. We expect fairness during competitions no judging biases and all learners to receive same treatment regardless of gender or race. (DBE2)

Our expectations are at different levels. At Expo we expect learners from all areas whether rural or urban, to develop and/or practice scientific inquiry skills through research. We expect learners to work in a problem solving mode that will help develop their critical and logical thinking. We expect learners to conduct their research in an ethical manner and present their findings using Expo guidelines both in writing and interviews. We have several resource and development programs that assist learners to achieve this. We also expect learners to take safety precautions when doing their research. (EE1)

Some of the expectations that are not met include: developing only basic inquiry skills, lack of originality, lack of deep critical thinking, inadequate literature reviews, and very little diversity in the types of projects submitted. Learners from both rural and urban areas often do not meet our expectations, however, this occurs more with the learners from rural areas. (EE2)

Most urban schools are meeting the expectations mainly because they have the resources. It will be fair for all learners to have resources so that the competitions are even and fair. We do have exceptions in the rural schools were we see good projects but these are scanty. (DSI1)

Evidently there is a tension between the expectations of the stakeholders and the rural and urban learners. The learners are not all meeting the expectations of the stakeholders.

5.5 Addressing the Third Sub-Research Question

The third sub-research question of this study is:

> What is the effect on the performance of learners competing at science fairs in the Physics category, in terms of the level of attention and depth of knowledge in physics?

5.5.1 Level of Attention

The level of attention measures the concentration of an individual on an activity (Bitgood, 2010). This level of attention is assessed by amount of distraction, focus and engagement of the individual in a given task or activity being undertaken.

Mentors and judges have commented on the learners' level of knowledge and attention.

> *Learners do not read more about their projects; their knowledge of the project is limited. When they get to the interviews by judges they are not convincing at all. The use of scientific terms and concepts is very poor*. (MU4)

> *It is because of this that learners concentrate on constructing models and nothing written, to explain the model*. (MU3)

> *The discussion and conclusion are not related to the research project. They focus on the model or prototype and not on the science behind the model*. (J2)

The findings indicate that the level of attention of rural learners is 33.3% as compared to 66.7% of urban learners (Table 4.6). Furthermore, data revealed that the majority of rural learners, 66.7%, were distracted, not focused and lacked engagement during the science fairs. Learner RF1 wrote on the PMM that other girls had beautiful hair and were putting on new uniforms (see Figure 4.1). Instead of focusing on the science projects, this learner was busy observing and admiring superficial qualities, thereby getting distracted and losing focus and engagement. Likewise, a learner may not engage with mentors and other learners when the learner is too shy.

The only rural learner RM5 who got an award at the science fair scored a high level of attention score of 73% and scored 66,7% on the depth of knowledge. Correspondingly, the following scores 67%, 53% and 80% were obtained by the urban learners (UF9, UM11 and UM12) in the level of attention respectively. These findings suggest that learners who have high levels of attention during science fairs are likely to perform better at science fair competition. There is also an outlier, learner RF3 who performed well in terms of level of attention but did not perform well at the science fair competition.

During science fairs, the level of engagement by rural learners was 36.7% while for urban learners was 46.7%. This might be due to language barrier (section 4.8.2) as commented by one judge (J1) who said rural learners are not fluent, they are scared, they cannot express themselves well in good English, they are even scared. For the learners and especially rural learners to be more engaged mentor (MU3) and judges (J1, J3) suggested that learners should be allowed to express themselves in their mother language.

Two learners (RM5-73% and UM12-80%) who scored high on level of attention earned bronze medals at the science fair. In contrast, learner (UF9) who scored 67% on level of attention won a silver medal. One possible explanation of these results is that science fair competitions depend on other dynamics such as judges (Atkins, 2014; Rillero, 2011). Therefore, it is possible that the judge gave him undeserved higher marks.

5.5.2 Depth of Knowledge in Physics

Rural learners performed poorly in the physics test when compared to the urban learners. (see Table 4.5 and Figure 4.7). There does not seem to be a link between passing of the physics test and winning at science fairs. These findings suggest that other dynamics might have influenced the performance of the learners at science fairs, like poor quality projects, poor performance of the learners during judges` interview or judges bias. Learner RF3 who passed the physics test and failed to score high mark in the science fair had complained during the FGD that judges did not like projects from poor schools and they did not show interest in her project, they quickly moved on to projects which were looking beautiful. As she stated,

> *They do not like projects from poor schools because they don’t show too much interest, they quickly move to projects which are beautiful looking models.* (RF3)

These results agree with the findings revealed by Atkins (2014) who observed that some judges only focus on the outward appearance and beauty of the projects which contributes to poor and unfair assessment of the projects. The same rural learner stated that she does not have the money to buy the needed materials. She stated,

> *Making beautiful machines or models is not easy because we don't have the money to buy the materials, they don't teach us how to do references or analysis and the hypothesis, we do it on our own*. (RF3)

Her comments suggest that this learner performed badly not because she did not understand physics but because the project was poorly constructed due to her lack of resources. These findings are supported by the claims made by other researchers that learners from under-resourced schools and poor backgrounds are likely to perform poorly at science fairs (Ndlovu, 2015; Olive 2017).

Another outlier in the results would be learner UF7. She passed the physics test but did not earn any award at the science fair. This learner stated three comments which may explain this anomaly. Firstly, she admitted to being a shy person especially when talking to unfamiliar people. She affirmed that she gave less information to the judges concerning her project. Secondly, the learner stated that the judges were not only unfriendly but they were also teachers who were not qualified to judge engineering projects. These findings concur with Atkins (2014) who claimed that the training of science fair judges was minimal. Thirdly, the learner affirmed that the scientific methods of doing research were a challenge since these methods were not taught at school. Therefore, she expressed her desire to have additional training for her to acquire the required skills. These findings are in agreement with the claims made by other researchers who said learners perform poorly at science fairs because they have difficulties in presenting their projects before the judge (Demirel, Baydas, Yilmaz, & Goktas, 2013).

The urban school learners performed better compared to rural school learners. (see Table 4.7). The rural learners` group won 1 bronze medal, and the urban learners` group won 1 silver medal and 2 bronze medals. The poor performance of the 2 groups of learners in the physics test might suggest that the learners lack content knowledge of the physics subject which may be one of the causes for their poor performance at the science fair in the physics category. Also, rural learners are disadvantaged due to their under-resourced schools and lack of support from parents. Judges have stated,

> *Parents need to be workshopped during parents' meetings so that they understand what is expo (science fair). As long as the parents do not understand what is expo, they will not support* it. (J1)

Learners need the emotional support from home. There must be workshops for learners and parents so that someone can talk to the parents on behalf of learners for them to give support. (j3)

5.6 Contributions of the Study

This study has made unique contributions in showing the differences between urban and rural school learners as follows:

a) This study used the Level of Attention criteria: distraction, focus, and engagement in order to observe the learners during science fairs.
b) This study used the Depth of Knowledge to assess the learners' understanding of physics and how their knowledge influenced their performance in the science fair under the physics category.
c) This study introduced the personal meaning mapping (PMM) to the study of science fairs.
d) Result of this study revealed that learners and teachers gain knowledge as they interact informally before and during science fairs, and they learn from one another. As a result, they exhibit the social characteristics of learning of science fair. Therefore, more learners and teachers need to attend and participate in science fairs to possibly expand their knowledge.
e) Findings of this research add knowledge in terms of the dynamics affecting the performance of learners at science fairs in South Africa.
f) Expectations of the science fair sponsors and partners (EEYS, DSI, DBE) were established.
g) In addition to students, this study sought the opinions of teachers, school principals, parents, mentors and science fair judges on science fairs.

It is recommended that learners and teachers attend training workshops on scientific research skills and on how to plan and complete award-winning research projects. Furthermore, science fair organizers could better reach out to rural schools, communicate with potential participants timeously, and to finish the science fairs within a suitable time limit. This study also suggests that the science fair judges be trained and encouraged to be professional during the judging process.

5.7 Recommendation for Future Research

Grounded on the findings of this study, the following recommendations for future research are made:

- A similar study using a larger sample of learners.
- A study on the impact of science fairs on the academic performance of learners in South Africa.
- A study on the impact of science clubs in schools with regards to learners` participation in science fairs.
- To explore the views and reasons of learners and teachers who stopped participating in the science fairs.

5.8 Conclusion

This research has identified dynamics influencing the performances of learners at science fairs. The study determined the following findings:

- The EEYS has not achieved the expectations of the sponsors and partners the DSI and DBE of reaching out to all schools, in towns and in rural areas. The EEYS would require the assistance of DBE and DSI to reach out to more schools.
- Parents need to be made aware of the importance of science fairs first before seeking their approval and support.
- The link between science fairs and academic performance need to be highlighted in order for teachers and learners to participate in science fair activities.
- The stakeholders and teachers would like the science curriculum to include the project research components in it.
- Teachers, judges, mentors, school principals and stakeholders have suggested that the learners should be allowed to express themselves in vernacular language during the presentation of their research findings at science fairs.
- Science clubs contribute to the learners` participation in science fairs.
- Judges` bias and favouritism may be minimised if well trained judges are appointed and not allowed to assess their own learners' projects.

Furthermore, the results indicated the science fair judges have a negative influence on the results of the science fairs due to their lack of training, proper qualifications, lack of feedback, bias, and at times rudeness to the learner participants. Based on a qualitative analysis, it can be concluded that the role of teachers, schools, judges, mentors and parents influence the performance of learners. In addition, the learners` poor content knowledge (depth of knowledge) of the physics subject influenced the results of those participating in science fairs under the category of physics. Also, the learners' level of attention during the science fairs could influence the outcome of the results. This study confirmed that rural learners from under-resourced schools perform poorly compared to those learners from urban schools. Moreover, all learners need additional training on scientific research skills. Also, the EEYS is encouraged to increase its efforts to reach out to the under-resourced schools which are mostly in the rural areas.

The CHAT framework was found an appropriate structure for analyzing the dynamics influencing learners` performance at science fairs. The approach focused on the dynamic relationships among learners, materials and equipment (tools), members of the community, the impact of historical events and cultures.

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Appendix A: EEYS Category List

EEYS Category list

1. AGRICULTURAL SCIENCES(AGR)
• Animal Husbandry
• Aquaculture
• Crop Sciences

2. ANIMAL SCIENCES(ANI)
• Animal Behaviour
• Animal Genetics
• Animal Physiology
• Aquatic Animals
• Entomology
• Zoology
• Wildlife Management

3. BIOMEDICAL AND MEDICAL SCIENCES(BIO)
• Diseases and Illnesses
• Food Science and Technology
• Health Care
• Human Genetics
• Human Physiology
• Medical Science
• Microbiology
• Pharmacology
• Sports Sciences
• Veterinary Sciences

4. CHEMISTRY AND BIOCHEMISTRY(CHB)
• Analytical chemistry
• Biochemistry
• Inorganic Chemistry
• Organic Chemistry
• Polymer Chemistry

5. COMPUTER SCIENCES AND SOFTWARE DEVELOPMENT(COM)
• Data Management
• Data Sciences
• Networking
• Software Systems

6. EARTH SCIENCES(EAR)
• Atmospheric Sciences
• Climate Sciences
• Geography
• Geology
• Limnology
• Oceanography
• Soil Sciences
• Water Sciences

7. ENERGY(ENP)
• Energy Productivity
• Non-renewable energy

8. NGINEERING(ENG)
• Biomedical
• Chemical Engineering/Process Engineering
• Civil & Industrial
• Electrical, Electronics and embedded systems
• Mechanical & Aeronautical
• Mining & Metallurgical

9. ENVIRONMENTAL STUDIES(EVS)
• Ecology
• Environmental Management
• Sustainable Development
• Sustainability

10. MATHEMATICS(MAT)
• Algebra
• Game Theory
• Geometry
• Number theory
• Statistics and probability

11. PLANT SCIENCES(PLA)
• Aquatic Plants
• Botany
• Plant Genetics
• Plant Pathology
• Plant Physiology
• Taxonomy

12. PHYSICS, ASTRONOMY & SPACE SCIENCES(PHY)
• Material Sciences
• Mater and Materials
• Mechanics
• Mechatronics and Robotics
• Optics
• Theoretical physics
• Astronomy and Space Sciences

13. SOCIAL SCIENCES(SOC)
• Anthropology
• Education Studies
• Human Behaviour
• Human settlements
Psychology

Appendix B: Letter by Department of Education Director-General

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Private Bag X895, Pretoria, 0001, Sol Plaatje House, 222 Struben Street, Pretoria, 0002, South Africa
Tel.: (012) 357 3000, Fax (012) 323 0601, www.education.gov.za

Ref no: C-1098-27/06/2014
Enquires: Dr JJ Joshua
Tel: 012 357 4182
Email:Joshua.j@dbe.gov.za

Mr M Matthews
Administrator: Education
Limpopo Province
Private Bag X9489
POLOKWANE
0700

By fax: 015 290 9416

Dear Mr Matthews

PARTICIPATION IN THE ESKOM EXPO FOR YOUNG SCIENTISTS

The Education Sector is experiencing low learner participation and success rate in the areas of Science, Technology, Engineering and Mathematics (STEM). This situation is partly attributed to the lack of confidence and self-efficacy among learners caused by the perceived abstract nature the STEM subjects.

The Eskom Expo for Young Scientists (Eskom Expo) is South Africa's primary and only existing science fair for school learners. Eskom Expo provides opportunities for learners to apply the theoretical knowledge they have learned in class and to strengthen their research skills through scientific investigations. There are currently 31 regions affiliated to Eskom Expo throughout the country. In addition, successful learners have an opportunity to exhibit their projects at international science expos.

The Department of Basic Education (DBE) sits on the board of directors of Eskom Expo to provide strategic direction in keeping with our national strategy and priorities. The DBE, therefore, requests your office to encourage all STEM learners to participate in the Eskom Expo. I have attached a list of names of provincial Expo co-ordinators and regional directors who may be contacted to assist schools with Expo dates and logistical issues.

Yours sincerely

MR SG PADAYACHEE
ACTING DIRECTOR-GENERAL
DATE: 02/07/2014

Appendix C: Physics Test (Depth of Knowledge Levels).

Physics questions measuring Depth of Knowledge for grade 10 learners in Limpopo

Level 1 question.

1. The gradient of a velocity versus time graph is equivalent to the …

A acceleration.

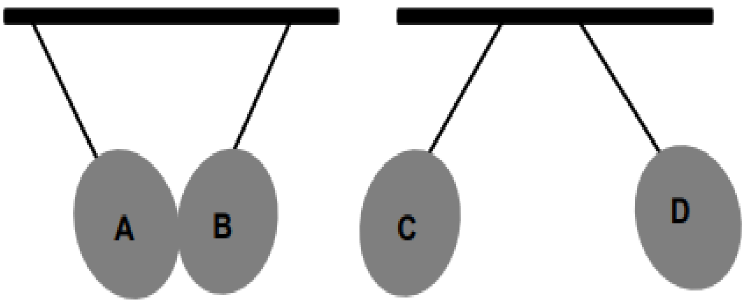
B displacement.

C deceleration.

D total distance covered. [2]

Level 2 question

Four identical balloons, each carrying a charge, are suspended from a ceiling, as shown in the diagram below.



Balloon B is negatively charged. Deduce the correct combination regarding the charges A, B and C (negative or positive) on the balloons?

A = …………

B = …………..

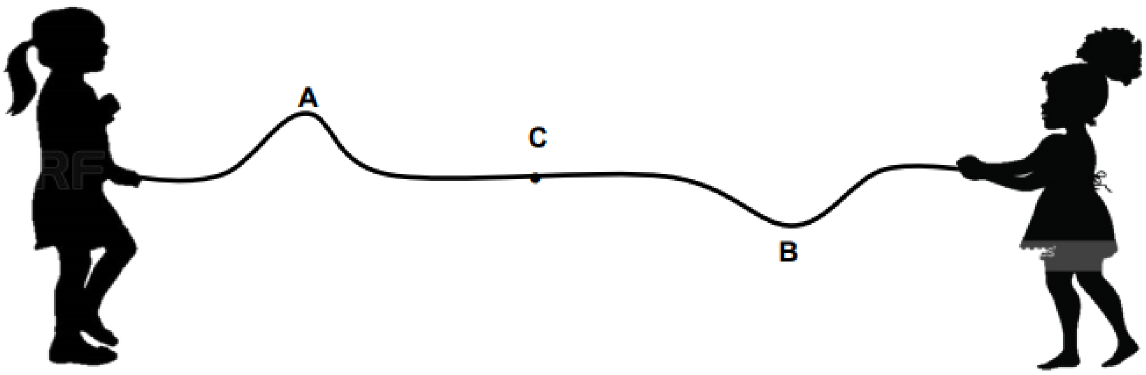
C = …………..

D = …………… [4]

Level 3 question

Two girls, standing at opposite ends of a rope, each makes a pulse of the same speed.

Pulse A, with an amplitude of 4 cm, moves to the right and pulse B, with an amplitude of -6 cm, moves to the left. The pulses meet at point C.



6.1 State the phenomenon observed when the two pulses meet at point C. (2)

6.2 Draw a labelled diagram to show the resultant pulse when the two pulses meet at point C. Label the pulses clearly. (3)

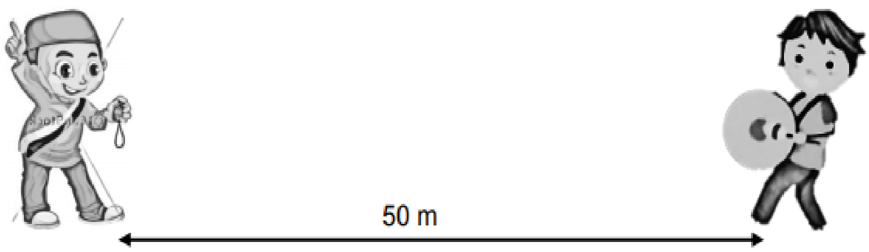
6.3 Name the type of interference that takes place when the pulses meet. (2)

6.4 Determine the resultant amplitude of the pulses at point C. (2)

6.5 How will the amplitude of pulse A be affected after passing point C? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1) [10]

Level 4 question

Experiments were done to investigate the effect of temperature on the speed of sound. One person beat a drum while another person, who was standing 50 m away from the sound source, recorded the time travelled by the sound.



They performed the experiment at different temperatures at different times of the day. They recorded their findings in the table below:

TEMPERATURE (°C)	TIME (s)
0	0,151
5	0,150
10	0,148
15	0,147
20	0,146
25	0,145

4.1 For the investigation, write down the:

4.1.1 Investigative question (2)

4.1.2 Independent variable (3)

4.1.3 Dependent variable (3)

4.2 Calculate the speed of sound at 20 °C. (3)

4.3 Write down a conclusion for the investigation. (3)

The person who beat the drum, noticed that the sound reflected back after a while.

4.4 Name the term used to describe the reflection of sound waves. (2)
[14]

Appendix D: Observation Protocol Sample

Activity name or summary **Participant RF1**	Observer comments
Learner distracted	The learner was highly distracted.
Learner focused	The focus of the learner to all activities around her was too low.
Learner engaged	The learner was not communicating with other participants, did not move around to see other learners` projects, she was sullen and very quiet.
Enthusiastic during judge interviews	Did not show any signs of enthusiasm.
Self-confidence and body language	She lacked self-confidence and did not express any body language during the judge interviews

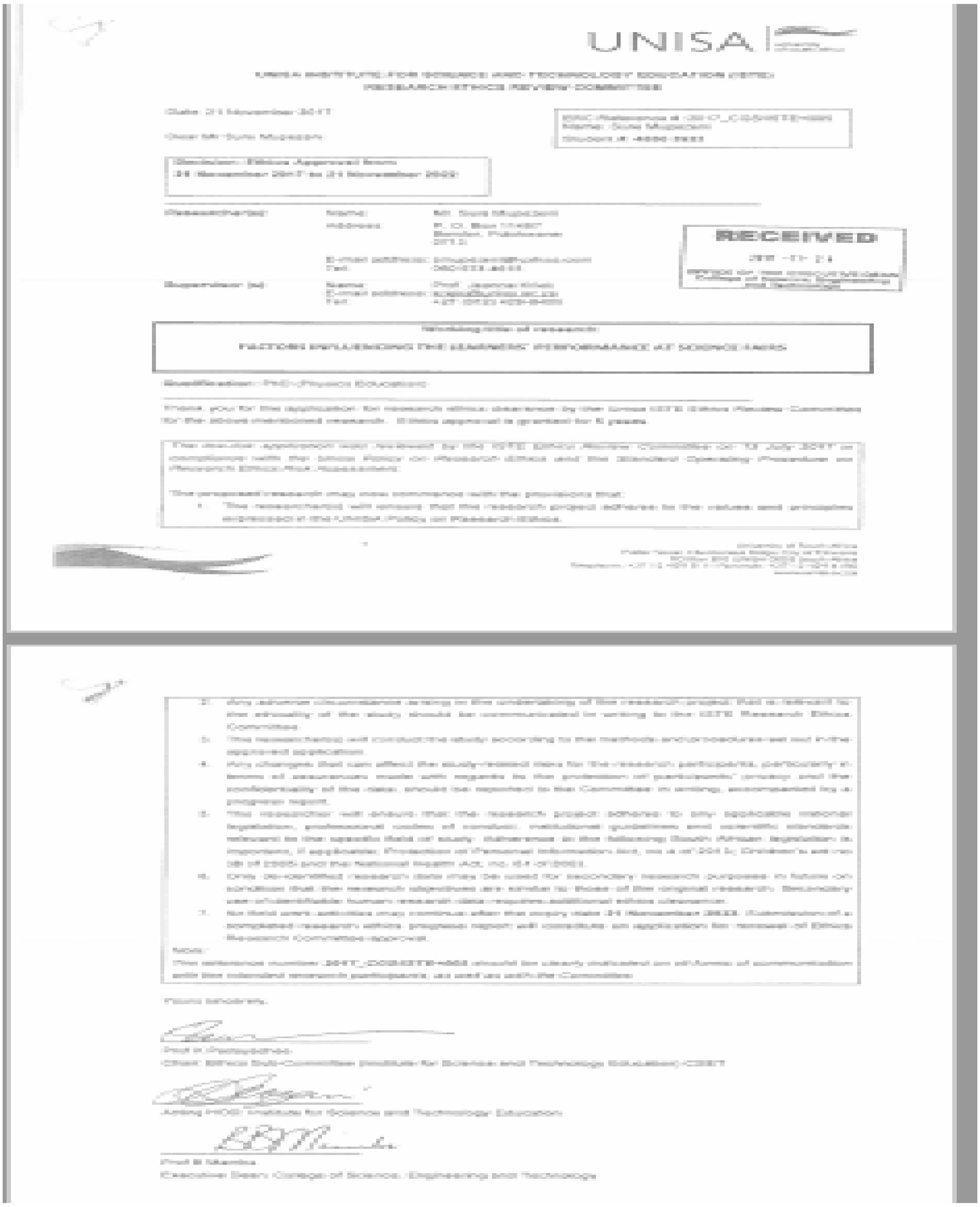
Activity name or summary **Participant UM11**	Observer comments
Learner distracted	The was not distracted his behaviour was moderate.
Learner focused	He focus was low
Learner engaged	The learner engaged only to the 2 learners next to him, did not move about to engage with more learners,
Enthusiastic during judge interviews	He showed minimum enthusiasm during the interview with the judge.
Self-confidence and body language	He was only nodding or shaking his head, he was not moving or pointing to his projects and display board.

Distraction	Very high [1]	High [2]	Moderate [3]	Low [4]	Too low [5]
Focused	Very high [5]	High [4]	Moderate [3]	Low [2]	Too low [1]
Engagement	Very high [5]	High [4]	Moderate [3]	Low [2]	Too low [1]

Location	**Participants**	**Level of attention**			
		Distraction [5]	**Focused [5]**	**Engagement [5]**	**TOTAL [15]**

Rural participant	RF1	1	1	1	3
Urban participant	UM11	3	2	3	8

Appendix E: Ethics Clearance Certificate



Appendix F: Permission Letter from Department of Education

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

Ref: 2/2/2 Enq: MC Makola PhD Tel No: 015 290 9448 E-mail: MakolaMC@edu.limpopo.gov.za

Mupezeni S
Eskom Expo
P O Box 26045
Gauteng
1462

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"THE INFLUENCE OF ESKOM EXPO ON LEARNERS"**
3. The following conditions should be considered:

3.1 The research should not have any financial implications for Limpopo Department of Education.

3.2 Arrangements should be made with the Circuit Office and the schools concerned.

3.3 The conduct of research should not anyhow disrupt the academic programs at the schools.

3.4 The research should not be conducted during the time of Examinations especially the fourth term.

Request for permission to Conduct Research: Mupezeni S

CONFIDENTIAL

Cnr. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE, 0700
Tel: 015 290 7600, Fax: 015 297 6920/4220/4494

The heartland of southern Africa - development is about people!

Appendix G: Permission Letter from EEYS

Eskom EXPO FOR YOUNG SCIENTISTS

LIMPOPO PROVINCIAL GOVERNMENT
EDUCATION

15-08-2016

The CEO
Mr P Chetty
Eskom Expo for Young Scientists
P. O Box 26045
East Rand, 1462

REF: REQUEST FOR PERMISSION TO CONDUCT RESEARCH DURING EXPO SCIENCE FAIRS

I a student of UNISA and I have passed my proposal stage of my PhD studies. I am requesting for permission to gather data for my research during Eskom Expo science fairs. The research will not interfere with the proceedings of expo and with the work of the researcher as the data gathering is done on learners' free time. The details are:

Title of research: The influence of Eskom Expo for Young Scientists on learners in South Africa.
Institutute: UNISA
Supervisor: Prof Jeanne Kriek

I will avail to you the findings of my research.

Regards
Sure Mupezeni
Provincial Coordinator.
Eskom Expo. Limpopo Province
sure@exposcience.co.za
www.exposcience.co.za
084 336 3655 and 060 678 4615

APPROVED

Limpopo Province: 52 Carlu Park, Kierieklapper Ave, Welgelegen, Polokwane,0699
www.exposcience.co.za

Appendix H: Science Fair Judges` Rubric

PROJECT ASSESSMENT FORM

Name(s) of learner(s)						Grade	Project number
PROJECT TITLE							
1. Intro (10)	2. Method (20)	3. Results & Discussion (20)	4. Limitations, Further research, Conclusion (10)	5. Originality, Creativity, value (10)	6. Presentation (30)	Initial Score (100)	Final Score after Discussion (100)
JUDGE'S NAME: SIGNATURE				CONVENER'S NAME: SIGNATURE			

SCORE: 0 or 1 or 2 for each of the items listed below:
0 = Not done/no evidence/incorrect
1 = Average or 50% correct or partially achieved
2 = Very good or well done

1. INTRODUCTION (10 marks)

1.1	Literature Review/Background research is relevant and from adequate sources	
1.2	Literature Review/Background research is from credible sources	
1.3	Problem/issue/phenomena identified	
1.4	Purpose/Aim of the study is clear	
1.5	Hypothesis is correct and stated as a testable/falsifiable statement	
	TOTAL (10)	

2. METHOD (20 marks)

2.1	Method/data collection approach is appropriate for the study	
2.2	Variables (control/fixed, independent, dependent) correctly stated	
2.3	Materials/apparatus listed or evident in the Procedure	
2.4	Procedure written correctly	
2.5	Procedure is clear, logical and repeatable	
2.6	Data collected is relevant to the study	
2.7	Sufficient data collected for the purposes of the study	
2.8	Number of trials/tests/replications adequate	
2.9	Evidence of measures to collect accurate data and minimise errors	
2.10	Correct units used for data collected e.g. length in cm	
	TOTAL (20)	

1. **RESULTS & DISCUSSION (20 marks)**

3.1	Data represented correctly (e.g. Tables, Diagrams, Graphs)	
3.2	Data has been correctly and sufficiently analysed	
3.3	Patterns/trends/outliers identified	
3.4	Results discussed fully and correctly	
3.5	Results and discussion are linked to the aim of the study and the problem has been addressed	
3.6	All claims made are justified with data	
3.7	Data used to accept or reject/falsify the Hypothesis	
3.8	Discussion is substantive and logical	
3.9	Discussion cites literature, compares findings to other studies	
3.10	Significance/value of the study is explained	
	TOTAL (20)	

4.1	Limitations and errors stated	
4.2	States how the study can be improved	
4.3	Recommendations for further research made	
4.4	Conclusions(s)/Summary of the findings stated	

4.5	Hypothesis is accepted or rejected	
	TOTAL (10)	

4. LIMITATIONS, FURTHER RESEARCH, CONCLUSION (10 marks)

2. ORIGINALITY, CREATIVITY AND VALUE (10 marks)

5.1	No evidence of plagiarism of ideas, text, images	
5.2	Knowledgeable about the field of study beyond the scope of the school curriculum	
5.3	Study that: Finds a new solution to a problem OR Improves on an existing solution OR Uses new methodology OR an improved method OR contributes to new knowledge	
5.4	Creative and resourceful e.g. uses available resources	
5.5	Shows mastery of the scientific investigative method	
	TOTAL (10)	

3. PRESENTATION (30 marks)

Written		
6.1	Research Plan written in third person, future tense	
6.2	Journal/Data Book is present with data, notes	
6.3	Abstract is concise, substantial, written in third person, past tense	
6.4	**Project Report** has main sections: Introduction, Aim, Hypothesis, Variables, Method, Results, Discussion, Limitations, Conclusion, Further Research, References, Acknowledgements	
6.5	**Project Report** written with correct content under headings	
6.6	**Project Report** AND **Poster** have correctly labelled Tables, Graphs, and Diagrams. Illustrations and Photographs are correctly referenced and/or acknowledged	
6.7	**Poster** has main sections: Introduction, Aim, Hypothesis, Variables, Method, Results, Discussion, Limitations, Conclusion, Further Research, Acknowledgements	
6.8	**Poster** is a logical summary of the Project Report	
Interview		
6.9	Explains the Problem/issue/phenomenon logically	
6.10	Understands scientific concepts, terminology, theories, principles related to the study	
6.11	Explains the research method logically, clearly and concisely	

6.12	Explains the results correctly and fully	
6.13	Makes justifiable claims based on the scope of the research study	
6.14	Both members of group project understand and contribute/Learner understands the research fully	
6.15	Research study was done by the learner(s)	
	TOTAL (30)	

Please provide additional information (attach additional writing paper to this judging sheet, if necessary):

1. If this work was not done by the learner(s), and/or ideas, text, images were plagiarised, please explain and provide evidence of this.

2. What improvements can you recommend?

3. Who could mentor this project? Name and contact details

4. Other Comments.

Appendix I: Language Edit Certificate

Comp Ed II, Inc. 1226 S. Blue Island Ave. Suite 202.

Chicago, IL 60608, USA

1-773-972-3052 (telephone), 1-312-243-0394 (fax)

Comped2inc@gmail.com

To Whom It May Concern:

This letter is to certify that the accompanying thesis submitted in fulfillment of the requirement of the PhD titled: Dynamics Influencing Learners` Performance at Science Fairs in Limpopo Province of South Africa by Mr. Sure Mupezeni, has been edited and is of suitably high standard in terms of language, syntax, grammar, mechanics, and presentation.

Please be aware that we are a service in the United States. Any miscellaneous issues with spacing and formatting may be the result of electronic transference from the United Sates to South Africa and /or differences in texting programs (i.e. Microsoft Word SA vs. Microsoft Word US).

Sincerely yours,

B. Seo 24 Feb 2021

Byung-In Seo, Ph.D.
Literacy and English Language Specialist

Appendix J: Turnitin Report

Thesis: Dynamics influencing learners` performance at science fairs in Limpopo province of South Africa.

ORIGINALITY REPORT

6%	5%	4%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.ejmste.com Internet Source	2%
2	aisel.aisnet.org Internet Source	<1%
3	repository.up.ac.za Internet Source	<1%
4	Sure Mupezeni, Jeanne Kriek. "Out-of-school Activity: A Comparison of the Experiences of Rural and Urban Participants in Science Fairs in the Limpopo Province, South Africa", Eurasia Journal of Mathematics, Science and Technology Education, 2018 Publication	<1%
5	scholarship.shu.edu Internet Source	<1%
6	uir.unisa.ac.za Internet Source	<1%
7	researcharchive.vuw.ac.nz	