

https://dspace.org/

Where formal education meets the informal: co-creating museum palaeosciences learning programmes to enhance teaching and learning in the grade 12 South African life science classroom

Van Wyk, Grizelda

2024
https://hdl.handle.net/10539/37449

Downloaded from a DSpace repository. https://dspace.org/



WHERE FORMAL EDUCATION MEETS THE INFORMAL: CO-CREATING MUSEUM PALAEOSCIENCES LEARNING PROGRAMMES TO ENHANCE TEACHING AND LEARNING IN THE GRADE 12 SOUTH AFRICAN LIFE SCIENCE CLASSROOM

by

Grizelda van Wyk

(1889741)

Thesis

Submitted in fulfilment of the requirements for the degree

Philosophiae Doctor

in

PALAEONTOLOGY

in the Faculty of Science, University of the Witwatersrand, Johannesburg, South Africa

Supervisor:

Dr I.J. McKay

(Former main supervisor)

Dr S Badenhorst

(Main supervisor)

December 2022

In memory of my friend and supervisor

Dr Ian James Mckay

22 March 1963- 13 July 2022

ACKNOWLEDGEMENTS

To my supervisor and friend, Dr. Ian Mckay, thank you so much for all your support and advice. I'm still reeling from the shock of your sudden passing. It was so difficult to finish this thesis without you. I kept on wondering if you would agree with me when I made a statement. It was painful to go through the photos and video clips when I was looking for more footage, or to go back to your emails to find some sources and to see your sarcastic comments (yes, I would laugh again, but tears would always follow). I will never forget our adventure together; we had such fun working with the learners. Thank you for deeming me good enough to do this research with you. I hope I've done your work justice.

To Dr. Shaw Badenhorst, thank you for availing yourself to be my new supervisor during the last five months of this study. Thank you for being patient and motivating me, your words of encouragement gave me hope when I wanted to give up, and the editing; you have helped me so much. Thank you for being my lifeboat these last few months.

To the ESI staff, thank you for inviting all these noisy learners into your workspace; I know sometimes it got a bit out of hand (especially when we were busy with the grade 10 groups). Thank you for supporting us.

Thank you for the ESI, Wits and GDE for granting me permission to do this research. Thank you Wits for giving me ethical clearance. Thank you for all the schools, teachers and learners who participated in this research. I also want to thank the assistants at Wits, for all the help with the logistics and the learners in the museum.

Dr. Lounelle White, you were always available to lend an ear when I was not sure how to resolve a challenge. Thank you for your support and good advice, it meant so much to me. Jy bly maar my 'phone a friend'.

Susan Wiese, the GDE provincial coordinator, thank you for all your inputs and promoting effective human evolution teaching in our province.

To my familie: Fanie, Grizanie, Karleine en Ma Tina, dankie dat julle verstaan het as ek moeg en moedeloos gelyk het. Dat julle geluister het na al my krisisse. Dankie dat julle bereid was om na al my stories van fossiele te luister al is dit nie jul belangstelling

nie. Fanie, baie dankie vir jou ondersteuning deur al die jare van my studies, ek is baie lief vir jou. Dankie Ma en Pa vir julle belangstelling en uitvra oor hoe ver ek is, al het julle nie ‘n idee waarvan ek praat nie. (Ek dink julle het nou al ‘n idee). Dit het baie vir my beteken. Corné, dankie vir jou geduldige luister na al my challenges.

ABSTRACT

This study follows the introduction of a grade 12 human evolution workshop at the University of Witwatersrand, which was later conducted at schools as well. This study used the Cultural Historical Activity Theory as a theoretical framework with socio-culturalism and community of practice as intermediate theories. This was a mixed method study and data were obtained through interviews, observations, pre-and post-tests and a common test in the district. Inductive coding was used to obtain themes. It was found that the learners as well as the teachers found the workshop very beneficial and fun. They especially referred to the hands-on nature of the workshop as the most beneficial part of the workshop. The workshop was aligned to the grade 12 curriculum, and teachers and principals found this part very beneficial. Human evolution is a topic that is found to be very controversial internationally as well as in South Africa and the acceptance of it is low. This workshop managed to increase the acceptance of human evolution amongst the grade 12 learners. The results of the pre-and post-tests indicates a significant improvement of learners' understanding of the content after the workshop. Learners who attended the workshop, also faired significantly better in a common test than learners who did not attend the workshop. Learners' performance improved after the workshop, whether they were from resourced or under-resourced schools. Teachers also commented on the fact that they themselves learnt a lot from the workshop, thus, indicating that it could be used for teacher development. The difference between the university-based workshop and school-based workshops were found to be that the learners enjoyed the workshop at the university more. They were able to visit the museum and link this knowledge to the workshop. The school-based workshops benefited the schools, because no teaching time was lost as the workshops were conducted in the afternoons after schooling has taken place. Principals indicated that there are many challenges to sending learners on field trips, but that they were in favour of sending their learners on field trips if these are aligned to the curriculum.

Table of Contents

LIST OF FIGURES 1
LIST OF TABLES 2
LIST OF ABREVIATIONS 3
1.1. INTRODUCTION 4
1.1.1 CONTEXTUAL BACKGROUND 5
1.1.2. SCHOOL CURRICULUM DEVELOPMENT SINCE 1994 6
1.2. NATURE OF THIS STUDY 8
1.2.1 SCIENCE LEARNING AT INFORMAL SPACES 9
1.2.2. THE SOUTH AFRICAN CONTEXT 10
1.3. PROBLEM STATEMENT 13
1.4. AIMS, RESEARCH QUESTIONS AND HYPOTHESES 13
1.5 DELINEATION OF CHAPTERS 15
2.1 INTRODUCTION 16
2.2 THE HISTORICAL DEVELOPMENT OF CHAT 17
2.2.1 CHAT PRINCIPALS 22
2.3 CHAT FOR THIS RESEARCH STUDY 24
2.4. SUBJECT: GRADE 12 LEARNERS 27
2.5 TOOLS OF THE ACTIVITY SYSTEM 29
2.5.1 SOCIOCULTURAL THEORY, MUSEUMS AND SCAFFOLDING 29
2.5.2 INQUIRY-BASED LEARNING AND THE NATURE OF SCIENCE 32
2.5.3 WORKSHEETS 34
2.5.4 UNIVERSITY LABORATORY AND ARTEFACTS 35
2.5.5 NATURAL HISTORY MUSEUM 38
2.6 RULES 40
2.6.1 THE NATIONAL CURRICULUM STATEMENTS AND 41
EXAMINATION GUIDELINES FOR LIFE SCIENCES 41
2.6.2 THE UNIVERSITY AND SCHOOLS 46
2.7. COMMUNITY 46
2.7.1 UNIVERSITY LECTURER AND STAFF 48
2.7.2 DISTRICT SUBJECT ADVISOR 49
2.7.3 SCHOOLS 51

2.8 DIVISION OF LABOUR 52
2.9 OBJECT 53
2.9.1 LEARNERS' DIFFICULTY WITH THE CONCEPT OF HUMAN 53
EVOLUTION 53
2.9.2 CHALLENGES WITH PHYLOGENETIC TREES/CLADOGRAMS 55
2.9.3 IMPROVEMENT IN GRADE 12 LEARNERS' PERFORMANCE 58
3.1 INTRODUCTION 61
3.2 EPISTEMOLOGY 61
3.5 SAMPLE SELECTION 66
3.5.1 PARTICIPANTS 66
3.5.2 SITE SELECTION 67
3.6 DATA COLLECTION 72
3.6.1 PRE- AND POST-TESTS 76
3.6.2 INTERVIEWS 78
3.6.3 OBSERVATIONS 80
3.7 DATA ANALYSIS 81
3.7.1 QUALITATIVE DATA 82
3.7.2 QUANTITATIVE DATA 84
3.8 VALIDITY 84
3.9 RELIABILITY 86
3.10 ETHICAL CONSIDERATIONS 87
4.1 INTRODUCTION 90
4.2 SUBJECT 90
4.2.1. ENJOYMENT OF THE WORKSHOP 90
4.2.2. INTERVIEWS WITH LEARNERS 91
4.2.2.1. Interviews with learners at Wits 92
4.2.3. OPEN-ENDED QUESTIONS 100
4.2.4 SUMMARY OF CODES FOR SUBJECT 107
4.3 TOOLS 109
4.3.1. OBSERVATIONS MADE BY RESEARCHER DURING THE WORKSHOPS 118
4.3.2. DATA FROM VIDEO FOOTAGE 145
4.4 RULES 158
4.5 COMMUNITY OF PRACTICE 159

4.5.1. UNIVERSITY LECTURER 159
4.5.2 UNIVERSITY ASSISTANTS 160
4.5.3. DISTRICT SUBJECT ADVISOR (ALSO THE RESEARCHER) 161
4.5.4. TEACHERS 161
4.5.5. PRINCIPALS 164
4.6 DIVISION OF LABOUR 168
4.6.1. UNIVERSITY LECTURER 168
4.6.2. SUBJECT ADVISOR 168
4.6.3. UNIVERSITY STAFF 169
4.7 OBJECT 170
4.7.1. LEARNERS ACCEPTANCE OF HUMAN EVOLUTION 171
4.7.2. CHALLENGES WITH PHYLOGENETIC 177
TREES/CLADOGRAMS 177
4.7.3 PRE-AND POST-TEST RESULTS 178
4.7.4 PRELIMINARY EXAMINATIONS RESULTS COMPARISON 180
4.8 OUTCOME 181
5.1 MAIN FINDINGS 183
5.2 CONTRADICTION CHAT 195
According to Engeström (1987), there are four levels of contradiction within an l. 195
5.3 OUTCOMES OF CHAT 197
5.4 IMPLICATIONS 200
5.5 LIMITATIONS OF THE STUDY 202
5.6 RECOMMENDATIONS FOR FUTURE RESEARCH 203
5.7 MY OWN THOUGHTS 204
5.8 CONCLUSION 205
REFERENCE LIST: 207
Gauteng Province approval letters 233
Wits approval letter 233

LIST OF FIGURES

Figure 2.1	**18**
Figure 2.2	**19**
Figure 2.3	**19**
Figure 2.4	**20**
Figure 2.5	**21**
Figure 2.6	**25**
Figure 2.7	**26**
Figure 2.8	**36**
Figure 2.9	**37**
Figure 2.10	**37**
Figure 2.11	**40**
Figure 2.12	**57**
Figure 3.1	**61**
Figure 3.2	**65**
Figure 3.3	**68**
Figure 3.4	**70**
Figure 3.5	**71**
Figure 3.6	**72**
Figure 3.7	**82**
Figure 4.1	**96**
Figure 4.2	**99**
Figure 4.3	**100**
Figure 4.4	**109**
Figure 4.5	**113**
Figure 4.6	**115**
Figure 4.7	**116**
Figure 4.8	**117**
Figure 4.9	**119**
Figure 4.10	**120**
Figure 4.11	**125**
Figure 4.12	**128**
Figure 4.13	**131**
Figure 4.14	**133**
Figure 4.15	**135**
Figure 4.16	**136**
Figure 4.17	**138**
Figure 4.18	**140**
Figure 4.19	**145**
Figure 4.20	**146**
Figure 4.21	**177**
Figure 4.22	**182**
Figure 5.1	**183**
Figure 5.2	**195**
Figure 5.3	**199**

LIST OF TABLES

Table 2.1	28
Table 2.2	29
Table 2.3	33
Table 2.4	42
Table 2.5	44
Table 2.6	59
Table 3.1	76
Table 4.1	91
Table 4.2	92
Table 4.3	104
Table 4.4	107
Table 4.5	108
Table 4.6	164
Table 4.7	167
Table 4.8	172
Table 4.9	173
Table 4.10	174
Table 4.11	179
Table 4.12	179
Table 4.13	181

LIST OF ABREVIATIONS

CAPS: Curriculum and Assessment Policy Statements

CDE: Centre of Development and Enterprise

CHAT: Cultural-Historical Activity Theory

DBE: Department of Basic Education

DoE: Department of Education

DST: Department of Science and Technology

FET: Further Education and Training band

ELRC: Education Labour Relations Council

ESI: Evolutionary Studies Institute

GDE: Gauteng Department of Education

ISE: Informal Science Education centres

ISL: Informal Sciences Learning institutions

NSC: National Senior Certificate

NDR: National Diagnostic Reports

NHM: Natural History Museums

PUMP: Palaeosciences University Museum Programme

SC: Senior Certificate

TIMS: Trends in International Mathematics and Sciences Study

WITS: University of the Witwatersrand

ZPD: Zone of proximal development

CHAPTER 1
OVERVIEW OF THE STUDY

1.1. INTRODUCTION

This study describes a longitudinal long-term programme conducted by the Evolutionary Studies Institute (ESI) of the University of Witwatersrand (Wits). The research started off as a grade 10 and grade 12 project but it was decided to only concentrate on the grade 12 data for this thesis. The problems addressed by this research were learners' struggle with the concept of human evolution and South African schools' underutilising informal science learning institutions (ISL). The programme covered the topic of human evolution presented as part of a university field trip. This research investigated teaching practice used during field trips as well as schools' management practice with regards to field trips in general. The research took place at Wits as well as schools in one educational district in Gauteng. Gauteng is the smallest of nine provinces in South Africa. Even though it is the smallest province, it's also the most populace province. The researcher in this project is a Life Sciences subject advisor for the Gauteng Department of Education (GDE). The subject Life Sciences includes sub-disciplines such as biochemistry, biotechnology, microbiology, genetics, zoology, botany, entomology, environmental studies, physiology, anatomy, morphology and taxonomy (DBE, 2011). Subject advisors are responsible for curriculum support and delivery in their educational districts.

This study adds to the wealth of existing literature on the interface between the informal education sector e.g., museums and science centres and the formal education sector such as schools (Kenna, 2019; Connealy, 2018; Anderson et al., 2006; Kisiel, 2014; Kisiel, 2005, Cox-Peterson *et al*.,2003). It was the broad aim of this research study to investigate factors promoting and inhibiting collaboration between schools of the GDE and a university museum of palaeosciences, specifically the ESI at Wits. Superficially, such collaboration can benefit both the ESI and the schools through curriculum-related education programmes in the palaeosciences. For example, from the palaeosciences point of view, a fruitful collaboration can create

interest in the South African palaeosciences, more sustainable palaeoscience museums, more jobs in the palaeosciences, as well as attracting top achieving students and funding into the palaeosciences. From the schools' point of view, collaboration could improve the quality of Life Sciences teaching and learner performance. In addition, society will benefit from scientifically literate citizens who are able to contribute knowledgably to debates surrounding climate change, extinction and related topics such vaccination and antibiotic resistance. In practice, however, despite these potential benefits, there are also many obstacles, such as logistics, funding, competing priorities, differences in expectations to name a few, which need to be understood and weighed against the advantages.

1.1.1 CONTEXTUAL BACKGROUND

The South African Strategy for the Palaeosciences (DST, 2011) indicates that palaeosciences should achieve international excellence because of the geographical position and natural heritage of South Africa. South Africa's rich fossil heritage includes the well-known hominin fossils such as *Australopithecus africanus*, *Australopithecus sediba* and *Homo naledi.* Furthermore, the Karoo, a region covering large parts of the Northern and Western Cape provinces, has a rich fossil history from the Mesozoic era and scientists from all over the world study these well-known fossils.

The first goal of the strategy aims to instill a sense of pride and providing the knowledge to make South African citizens informed to engage in palaeoscience matters. South Africa has a very rich and large palaeosciences heritage, and although several museums exhibit this extraordinary fossil and archaeological heritage, public attendance is low in comparison to many western countries.

According to Sanders (2018), this could in part be attributed to the fact that between 1948 and 1994, South Africa was governed by the National Party, who segregated people according to racial criteria. The governing party had strong Calvinistic roots with an anti-evolution stance (van den Heever, 2009). This ideological stance was influenced by factors such as the Anglo-Boer War (also called the South African War, 1899-1902), and the use of concentration camps by the British during the war which resulted in the death of thousands of women and children (Sanders, 2018). The

National Party implemented racial segregation of the South African population, which was called apartheid. In 1967, they implemented the Christian National Education policy which excluded any reference to Darwin and evolution (Christie, 1991). The Christian national policy dictated that white and black children should receive separate education to prepare them for their future superior(white) and inferior(black) economic and social positions in South Africa (Christie, 1991). The Christian national policy rejected any “anti-biblical” concepts such as evolution (Esterhuysen & Smith, 1998).

Furthermore, the 1950 Groups Area Act made it impossible for the majority of the country’s population, namely black people, to visit museums, zoos and other informal learning institutions since they were situated in areas occupied by white people (Leliot, 2017). This means that most South Africans grew up without the opportunity to visit these centres.

1.1.2. SCHOOL CURRICULUM DEVELOPMENT SINCE 1994

In 1994, a new democratically elected government headed by the African National Congress came into power. They aimed to make radical changes to the school curriculum to facilitate social transformation. In 1996 archaeologists had a meeting with the deputy director of curriculum development to discuss the teaching of hominid evolution in classrooms (Esterhuysen & Smith, 1998). Research was carried out to ascertain teachers views on the teaching of these sensitive topics. The research was carried out over a period of 5 months with a sample group of grades 4-7, grades 8 and 11 classes. It was found that hominid evolution could be taught from a young age as a means to instill critical thinking. The researchers also argued that the content could be used to eliminate issues regarding race, as we all come from the same ancestors. The report was forwarded to the Department of Basic Education (DBE).

During the decade that followed, the curriculum was revised, and two new versions were implemented. A decision was made to include palaeosciences in the national curriculum (DoE, 2003). Natural selection as a topic was introduced in the Natural Sciences (grade 5-9) curriculum in 2006 but it was not referred to using this term, to avoid controversy (Sanders, 2018). Natural selection was removed again in 2011

from Natural Sciences in the third curriculum revision, named the Curriculum and Assessment Policy Statements (CAPS) (DBE, 2011).

In Life Sciences, the new curriculum was implemented in 2006 and the focus was more skill-based (Doidge *et al*.,2008). The grade 10 cohort of 2006 wrote the Life Sciences grade 12 Senior Certificate (SC) in 2008. This curriculum contained natural selection and some other evolution concepts. Sanders (2018) indicates that almost 25% of the curriculum was devoted to evolution. In 2009, the curriculum was revised, and the evolution topics were split. Some moved to grades 10 and 11, leaving evolution and natural selection in grade 12. This was implemented in the new grade 10 cohort of 2009. The new CAPS (DBE, 2011) was implemented in grade 10 in 2012 and the cohort wrote their SC in 2014. Currently, CAPS for Life Sciences has four knowledge strands and knowledge strand number 4 is diversity, change and continuity. In grade 10, the knowledge strand number 4 is composed of history of life on Earth, which deals with the different type of fossils, how fossils are formed, fossil dating, the geological timescale, as well as fossil finds from South Africa. In grade 12, knowledge strand number 4 deals with Darwinism, natural selection, speciation and human evolution. Reference is made to biogeography, homologous structures, as well as the fossil, cultural and genetic evidence for evolution, the Out-of-Africa hypothesis and alternative views to evolution (specifically creationism, intelligent design, literalism and theistic evolution). The DBE released examination guidelines in 2014 and revised it in 2017 and 2021, which outlined what content would be examined in the grade 12 National Senor Certificate (NSC) exit examination. The purpose of these examination guidelines is to elucidate the scope of the content to be assessed in the NSC. It aids teachers in preparing the learners adequately for examinations (DBE, 2017). This document excluded the alternatives to evolution, even though it is still stated in the CAPS document. Hence, teachers do not teach it.

When palaeosciences was introduced into the curriculum in 2006 it was new to many teachers, with the result that many still face challenges in teaching this content. Most teachers were not taught evolution before 2006 (Coleman *et al.*, 2015). Subsequently, teachers lacked confidence in teaching the topic (Sanders & Ngxola ,2009). Life Sciences teachers also often have personal objections to teaching evolution, which has a negative impact on the teaching of the topic (Kyriacou *et al*., 2015). There was some anti-evolutionary outcry in the media (van den Heever, 2009)

and some resistance from Christian groups and student organisations when evolution was first introduced in 2006. Hence, the introduction of this topic into the curriculum came with its own problems.

1.2. NATURE OF THIS STUDY

The following topics: Darwinism, history of life on Earth, speciation, natural selection, and human evolution are consistently considered as difficult to teach in South Africa (Kyriacou *et al*., 2015, Sanders and Ngxola, 2009). A programme was launched by the ESI in 2018 to address this challenge. The programme utilised the institute's existing lecture space, preparation laboratory and Kitching Gallery (fossil museum) to invite and promote school visits to its facilities.

The programme was aimed at:

- stimulating interest in the palaeosciences,
- attracting more students, especially from formerly disadvantaged communities, and
- ultimately, attracting more funds into the field.

A secondary aim of the programme was to:

- communicate the palaeosciences to South Africans from all walks of life, thereby promoting inclusivity in this subject,
- as well as investigating and publishing research on best practice in palaeosciences communication to a diverse South African audience.

The collaboration between the ESI and schools started in 2005 and has gained momentum through the years. What started as an initiative where university staff conducted programmes and presented activities, which they thought were appropriate to the needs of learners and teachers, became a two-way process. During this research, the input from teachers and learners were used as feedback into the design of the programmes. At first, the hands-on activities which form part of the workshop were aligned to what is expected in the school syllabus. Later and this will be documented in this research, the activities and programme were modified to

better fulfill the needs, interests and different socio-cultural backgrounds of the learners. It became apparent that one advantage of workshops in a museum context is that learners are exposed to the content that they must learn at school in a more authentic, hands-on manner. The learners were able to experience the fossils in a three-dimensional fashion as opposed to drawings in their textbooks. They could touch objects and interact with them. Some schools got an opportunity to visit the fossil preparation laboratory at the ESI and saw how fossils are extracted from rocks, as well as explore the diversity of fossils in the Kitching Gallery.

1.2.1 SCIENCE LEARNING AT INFORMAL SPACES

Mutjaba *et al.* (2018) indicated that learning rarely, if ever, occurs from a single experience. They argued that science learning takes place over a long time through a myriad of experiences and informal science learning spaces can assist children's learning process. They stated that: "*Museum experiences can help to develop students' scientific skills and understanding of science whilst also helping them to develop an enquiring and critical attitude towards science, to engage with it and to consider the possibility of a career in it"* (Mutjaba *et al*., 2018:4). Science museums should no longer be places with static scientific exhibits, but places where interactive learning takes place. Bell *et al*. (2009) suggested that informal science learning could not be measured the same way that formal school learning is measured. They suggested six strands to measure effective learning at an informal science learning experience, and this included excitement, understanding of scientific facts and participation in scientific activities which was also reiterated by Shaby *et al.* (2019).

Research (Shaby *et al*., 2019); Itzek-Greulich *et al.,* 2017) have shown that field trips to ISL were known to enrich the school curriculum and break the daily school routine because it offered hands-on experiences and developed learners' social and motor skills, as well as fostered learners' motivation to learn. Many researchers argued that the collaboration between schools and museums had positive cognitive and affective outcomes in school learners (Hlengwa & Kholeka, 2019; Williams *et al.,* 2018; Connealy, 2018;Hutson *et al.*, 2011; Anderson *et al*., 2006; Kisiel, 2005). Falk (2016) suggested that ISL supported the development of science identities. The cognitive progress that visitors achieved during visits to the science museums were of

particular interest (Filippoupoliti & Koliopoulos, 2014 According to Andre *et al.* (2017), natural history museums in general had an abundance of information in the form of specimens and cultural and historical artefacts. Furthermore, inquiry-based activities were successful in helping learners to gain knowledge and meaning about the past (Melber, 2003). Wolberg and Goff (2012) identified inquiry as advantageous in supporting learners learning in museums. Learners were encouraged to see, think and wonder when working with a new object and in so doing so, they were exposed to "thinking skills" through guided conversation and questions asked by museum educators and learners. The new information was gained through reasoning, inference, and deduction, which enhanced their learning.

Moreover, learning takes place when people are engaged in social activity, which includes talking and interacting with objects, which is referred to as socio-cultural theory (Vygotsky, 1978). It is important to create a space where learners can work with their peers in groups to stimulate conversation about objects. The interaction with their peers, while engaged in an activity, as well as the scaffolding provided by museum educators and other staff deepens learning (Shaby *et al*., 2019).

Finally, perhaps the most important aspect of this study is that it documents a long-term interaction between different communities of practice (Lave & Wenger, 1991), namely the formal education sector, and the informal education sector, represented by the university museum. The formal education sector in this study is represented by each school visiting the museum and the GDE Life Sciences subject advisor who work closely with the school Life Science teachers to create a shared teaching culture, which includes organising field trips with their learners to life sciences museums.

1.2.2. THE SOUTH AFRICAN CONTEXT

Some notable studies were done on the interaction between schools and South African museums and/or science centres.

Rapule (2007) had an intervention with learners (experimental group) at a science centre in the Potchefstroom area of Northwest province over a six-month period. The

control group did not receive any intervention. Both groups wrote a post-test indicated a significant improvement in the experimental groups' achievement. It indicates that an intervention at a science centre improved learning.

Lelliott (2007) investigated grade 7 and 8 learners' experiences in ISL (informal science learning centres) in astronomy education in South Africa. The focus of his investigation was on the cognitive and affective gains from such visits. Lelliott (2009) emphasised the need for teachers to present pre-museum and post-museum visitor preparatory sessions to learners in order to reinforce learning from an informal learning experience.

Nyamupangedengu (2010) described the use of worksheets in a South African ISL. She found that museums prepare different kinds of worksheets such as a scavenger hunt or structured worksheets that only needs short answers. She identified ways in which these worksheets could be improved. Further, the importance of teachers briefing learners beforehand and mediating the worksheets with learners at informal learning centres, was identified by Nyamupangedengu and Lelliot (2012) as a main factor in a successful learning experience at informal learning centres. This case study also looked at how the type of questions contained in the worksheets could scaffold learning.

It was also found that teachers in the Gauteng province had different motivations and no clear purpose for taking learners to informal learning venues (Mosabala & Lelliot, 2012). They did not interact with the learners during the visits, and they were only there to ensure discipline. They could not find any evidence that teachers used the field trip to reinforce the concepts taught in class. Only minimal reinforcement of the field trip content was found to be done afterwards in class.

Mokgobanama (2011) studied teachers who attended evolution workshops at a science centre. It was found that some teachers had gained knowledge and their attitude towards the teaching of evolution improved. Unfortunately, alternative conceptions about evolution were introduced and reinforced.

Furthermore, of interest in the South African context, is how museums and science centres inadvertently excluded learners from formerly disadvantaged communities as has been described in an international context by Dawson (2014). South African

museums had to transform and confront their colonial past after 1994 (Rall, 2016). They had to incorporate a more integrated approach and celebrate our cultural diversity. Museums had to include formerly excluded members of the public. The Iziko South African museum incorporated adult literacy classes for Xhosa speaking learners, which were coordinated by Xhosa speaking educational officers at their museum. This attracted people to the museum and made it more accessible to the community. Initially the programme made use of Xhosa related cultural displays only, but as it developed other displays were also used. The programme was extended to other museums, such as the West coast fossil park, the South African Astronomical Observatory and the Kirstenbosch Botanical gardens. Language lessons were based on learners' own cultural circumstances and personal experiences. Hence, learning at the museums were totally learner centred.

Dawson's (2014) study focused on how best to include learners from diverse backgrounds in programmes so that they can benefit. This included investigating the use of languages other than English during workshops and code-switching in a strategic way. Fish (2016) found that presenting a science show in Kwa-Zulu-Natal province in the learners' home language isiZulu had a major positive effect on learners' performance in English language-based evaluation.

Cimi, Ngoza & Dold (2020) argued that indigenous learners were only exposed to western ways of science, and they included learners' indigenous knowledge systems into a visit to an herbarium. Learners' prior knowledge was linked to the plants they worked with during the hands-on activities at the herbarium. The link between prior knowledge and the activities they were doing at the herbarium helped the learners with their construction of new knowledge. Learners seemed more interested in learning about the plants.

Speight Vaughn & de Beer (2020) introduced a learning programme to contextualise mathematic teacher's professional development in the Hantam district of the Northern Cape province. This district was situated in a very poor rural area. The people living in this area were from Khoi-San decent and had many traditions linked with nature. The learners were given xylophone-like music pipes ("boom whackers") and sheet music to use during their traditional dances. The musical notes were replaced by mathematical concepts such as fractions. The researchers also found that the

museum incorporated the indigenous knowledge systems of the area, which was regularly utilised by the teachers and surrounding schools. The museum had an indigenous herbal garden where a local community member taught the medicinal value of the plants to learners who visited the museum. They found this to be a very beneficial working relationship which inspired the learners to learn more about their indigenous knowledge and the science behind it. The Kirby-Bauer technique (Mitchell & Cater, 2000) was used in a learning programme for the teachers, and they had to test whether the medicinal plants had antimicrobial properties. It was found that the medicinal plants had antimicrobial properties.

1.3. PROBLEM STATEMENT

In this study, the research problems were identified as grade 12 learners' struggle with the concept of human evolution (DBE, 2019), South African teachers' challenge with the teaching of human evolution (Kyriacou *et al.* 2015), the effectiveness of programmes at science museums (Lelliot, 2009) and the underutilisation of ISL by schools (Kenna, 2019).

Internationally, it was found that there were several deterrents for teachers to make use of ISL, such as logistical challenges of a field trip and disciplinary issues with learners (Kenna, 2019; Kisiel, 2014). Field trips to museums or informal educational centres in South Africa (Leliot, 2009) were not always conducted in a way to optimise learning, The following was found to be problematic during these fieldtrips: teachers did not prepare their learners, no discussions about goals between the school and the centre took place, there was a limited linkage between school curriculum and the programme conducted, demonstrations were done and learners were passive (Tal *et al*., 2014; Leliot, 2009). Interactivity was increasingly seen as essential in children's learning experiences in a museum context (Behrendt & Franklin, 2014; Cheng *et al.,* 2011; Falk & Storksdieck, 2005, Tal *et al*., 2014).

.

1.4. AIMS, RESEARCH QUESTIONS AND HYPOTHESES

The following are the aims, the research questions and the hypotheses of this research.

The aims of this study are:

1. To investigate the factors that impact on a schools' willingness to send their learners on field trips and the relative importance of academic impact of a field trip.
2. To investigate whether a programme at a university-based museum will benefit learners cognitively and affectively.
3. To investigate the socio-cultural factors at work in a programme at a university-based museum.
4. To investigate how a process of continuous reflective practice can improve an education programme at a university-based museum.

The research questions investigated in this study are:

1. How does planning of a field trip, funding, logistics and syllabus coverage influence a school's willingness to send learners on field trips?
2. Does the Palaeosciences University Museum Programme (PUMP) increase the learners' understanding of the knowledge strand "Change, Diversity and Continuity" in Life Sciences?
3. Does the PUMP increase the enjoyment of learners for the Life Sciences' topics contained in the knowledge strand "Change, Diversity and Continuity" and Life Sciences in general?
4. How do teachers perceive the PUMP and how do they integrate it into their teaching programme?
5. How is socio-cultural theory implemented in the PUMP?
6. Will a process of continuous reflective practice improve an education programme at a university-based museum?

The hypotheses of this study are:

1. The planning of a field trip, funding, logistics and a negative impact on the Life Sciences' syllabus coverage deters schools from sending learners on field trips, however, proof of a positive academic impact may outweigh the negative factors.
2. An effective PUMP will increase the enthusiasm and the understanding of learners for the topics of the knowledge strand "Change, Diversity and Continuity" in Life Sciences.

3. Teachers do not prepare learners before a field trip, nor do they follow up afterwards.
4. The most important socio-cultural factor at play in the PUMP is mediation provided during the workshop.
5. Through continuous observations, feedback and reflective practice, it will be possible to improve the PUMP so that learners and teachers receive maximum benefit from participation.

1.5 DELINEATION OF CHAPTERS

Chapter 1 is a broad overview of the research study. The problem statement, aims, research questions and hypotheses are given. Chapter 2 is a comprehensive literature review of the study. The theoretical framework is discussed in detail linking it with existing literature. Chapter 3 outlines and discussed the research design as well as methodology. Sampling, sources of data, data analysis, validity reliability and ethical considerations are discussed. The contextual background of the study is also provided. Chapter 4 outlines the data collected and the data analysis, using the CHAT (cultural historical activity theory) framework. Chapter 5 discusses the main findings of the research. Each research question is discussed in detail using the findings obtained in Chapter 4. The limitations, contributions and recommendations of this study are also discussed in this chapter.

CHAPTER 2
THEORETICAL FRAMEWORK

2.1 INTRODUCTION

A theoretical framework provides the viewpoint of the researcher as well as justification to conduct a study. According to Henning *et al*. (2004), theory positioned the study in the discipline in which it was situated and assisted in defining the research problem. Theory is therefore a lens to view the world. Merriam (1998) stated that theory was the frame that scaffolds a study, and that the theoretical framework was the body of literature which a researcher draws upon to situate research. Moreover, theory also identifies what is known about a topic and what aspects the researcher will focus on.

There are many learning theories that are used in educational research. Some of the main learning theories are cognitive learning, socio-cognitive theory, behaviourism, constructivism, socio-constructivism, and sociocultural theory. Cognitive learning theory (Neisser, 1967) is interested in how learners make sense of new knowledge and learn new things. Socio-cognitive theory (Bandura, 1989) is when learning happens through observing others or modelling behaviour. Behaviourism is interested in how learners behave with regards to their environment (Zhou *et al.*, 2015). Constructivism is interested in learners learning from their own experiences (Piaget,1929) while socio-constructivism (Vygotsky, 1978) explores how people learn through peer-to-peer interaction. Sociocultural theory is based on Vygotsky's emphasis on novice-expert interaction (mediation) and culture in shaping development (Vygotsky, 1978;Rogoff, 1990).

In this research, the third generation of the Cultural-Historical Activity Theory CHAT (Engeström, 1987) was chosen as the theoretical framework. CHAT is situated in sociocultural theory as well as socio-constructivism and offers the opportunity to link educational theory and practice (Roth & Lee, 2007). It is useful in analysing data obtained in classrooms and effecting change when contradictions become evident in

cultural settings. Activity theory is a powerful instrument which is used to analyse human activity its milieu (Roth & Lee, 2007). CHAT was chosen for this research as it was seen as a useful tool to clarify the discrepancies between qualitative and quantitative data within a mixed method design. De Beer & Mentz (2021) stated that it improved the design quality of a study and - the thoroughness of the interpretation. It is a valuable tool in complex settings and could be used in informal as well as formal settings (classrooms and informal learning centres). Fourth generation activity theory accommodates technological advanced activities, where collaboration does not only happen within the activity system but within activity networks (Spinuzzi, 2014) which is why it was not chosen for this research study.

CHAT is best used with "intermediate theories" (Engeström, 2011). If the theoretical lens acts as a lens through which the research is viewed, the intermediate theories act as "filters" when analysing data (de Beer & Mentz, 2021).

Intermediate theories that were used in this study are as follow:

- Sociocultural theory (Vygotsky, 1978)
- Community of practice (Lave & Wenger, 1991)

2.2 THE HISTORICAL DEVELOPMENT OF CHAT

"…*the human mind is not located within the brain, not even bounded by the skin of the individual. The mind is in actions and activities in which humans engage with the world, by means of cultural artefacts such as signs and tools"* (Sannino & Engeström, 2016:44).

CHAT originated in the research on mediation by the Russian psychologist Lev Vygotsky (1978). The Zone of Proximal Development (ZPD) postulates that people could reach a higher level of development by interacting with a more knowledgeable person or persons (Vygotsky, 1978). Hence, people learn by interacting with other, more knowledgeable people. Moreover, higher cognitive functions are changed through collaborative activities. Psychological tools mediate learning and they include aspects such as language, signs and symbols used in learning. Vygotsky proposed a triangular scheme of mediation, which proposed that to get to a response (R) from

a stimulus (S), a mediated act (X) was necessary. This mediated act could be, for example, language, tools, worksheets, and instructions (Figure 2.1).

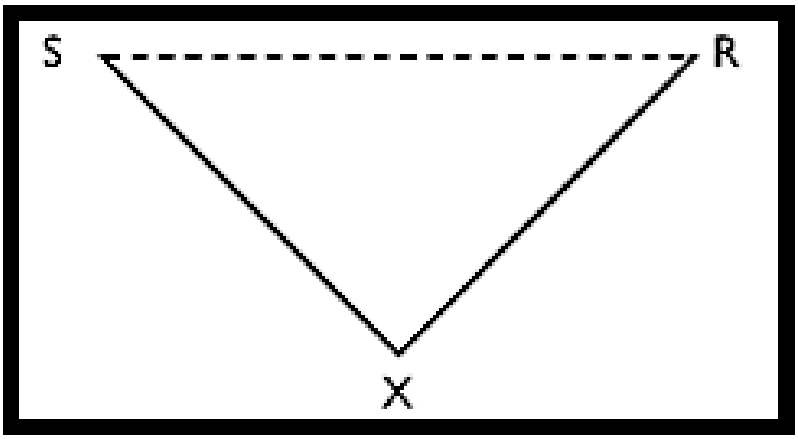


Figure 2.1: Vygotsky's general scheme of mediation (Vygotsky, 1978:62)

According to Engeström (2001), Vygotsky's general scheme of mediation was the basis of the first-generation activity system (Figure 2.2). The goal of the activity was represented by the object. The subject received a stimulus(S), which was acted on (X) to achieve a response, which was the object of the activity. The subject was not necessarily one person, it could also be groups of people. Tools formed part of the mediating act. Examples of the tools were language, machines, computers, writing or speaking. An example is when a mentor with experience and mastery of a specific skill helps people to master the skill using tools. Mediation could be demonstrating the skill, language etc. The skill could be learnt through regular interaction between individual and mentor.

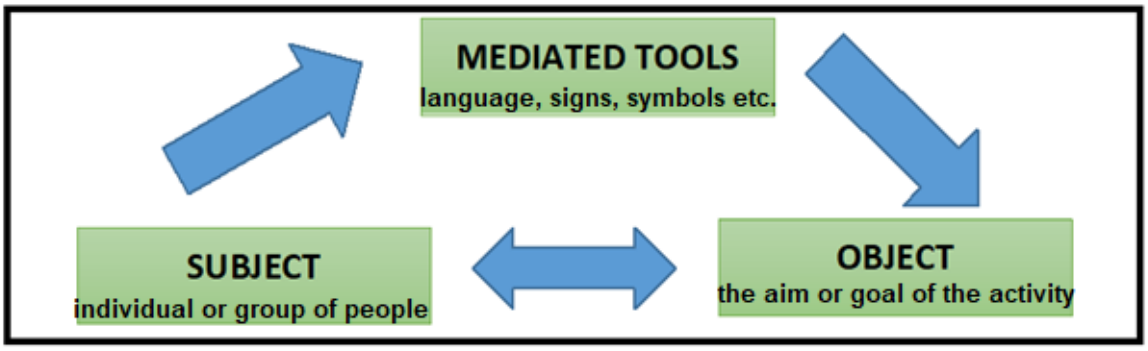


Figure 2.2: Vygotsky's first-generation activity theory (Hardman, 2008:259)

Leont'ev (1981) suggested the second-generation unit of analysis which was activity (Hardman & Amory, 2015). Leont'ev argued that cognitive change or learning in a social context was not explained by Vygotsky's model. Leont'ev linked the social context to the people within the activity centre that learnt collaboratively. He also added division of labour to the activity theory which indicated how activities were shared between members in the activity centre. The division of labour separated the goal-orientated actions and combined them to serve a common object (Sannino & Engeström, 2016). Furthermore, Leont'ev proposed a hierarchical structure of activity (Hardman & Amory, 2015). At the lowest level, he placed the automatic operation that subjects performed with the tools at hand (Figure 2.3 below). The middle level represented the actions taken by individuals to reach their goals. The top level represented the collective activity that represents all the individuals' actions towards the activity motive (Hardman & Amory, 2015).

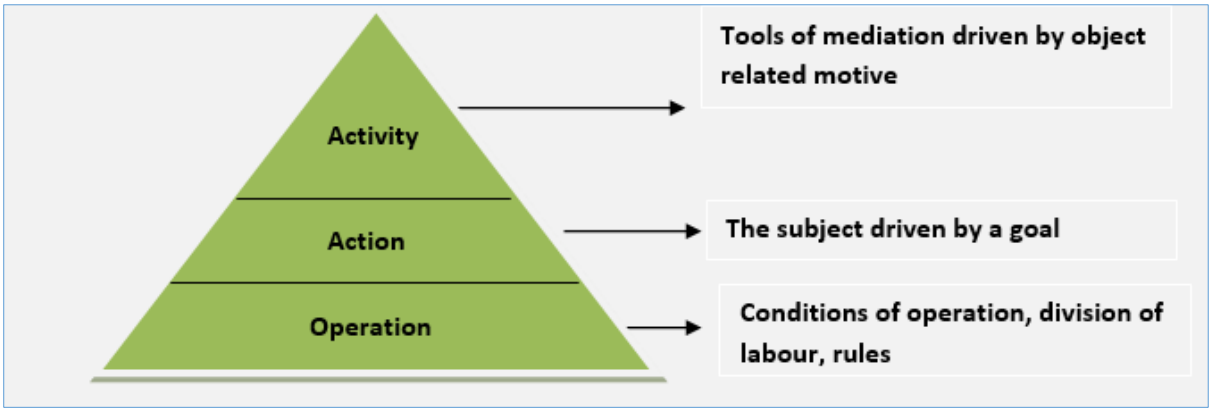


Figure 2.3: The second-generation activity theory as proposed by Leont'ev 1981 (Hardman, 2008:70)

The third-generation activity theory came about when Engeström (1987) added a cultural dimension to the construct and created an activity centre (Figure 2.4). An activity system was a system where an activity was done to achieve a certain object (goal). A mediating artefact was used to obtain the object. The object was represented by a circle indicating that its dynamic and could change (Hardman, 2008). The bottom left triangle indicated the influence of rules on the subject and the community (Hardman & Armory, 2015). The bottom righthand side triangle indicated the influence of the division of labour on the community and the object. The activity system is a basic unit of analysis and could be used in a classroom, a workplace, or even in society where people want to bring about change.

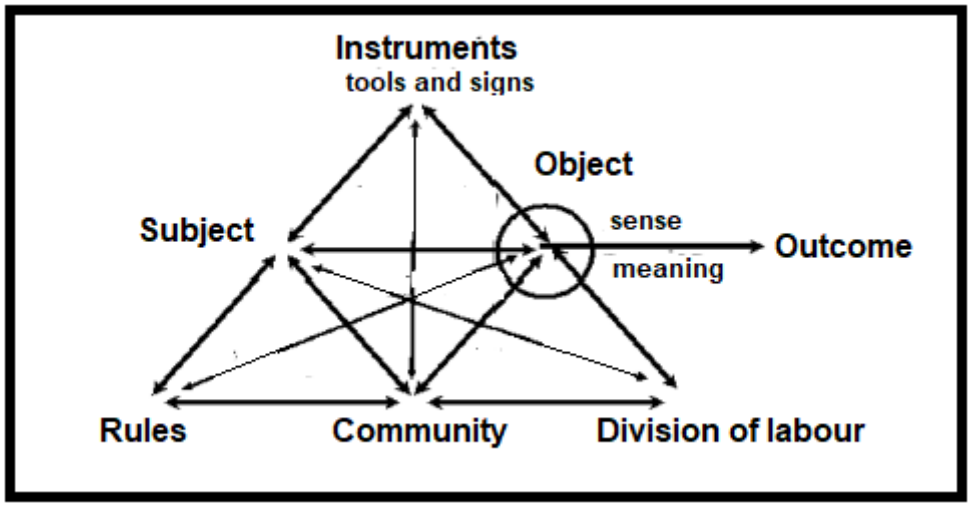


Figure 2.4 The structure of an activity system (Engeström 1987: 78)

The activity theory was further developed into a system with two interacting activity centres with a shared object (Engeström, 2001). This system was known as the third generation CHAT (Figure 2.5). According to Engeström, the internal contradictions within the activity centres drove transformation within the activity centres. The contradictions within and between two activity centres, working on the same object, could be compared. Further, one activity centre was insensitive to cultural diversity whereas two activity centres represented different viewpoints and traditions (Engeström, 2001). The multiple viewpoints caused conflict and subsequent change.

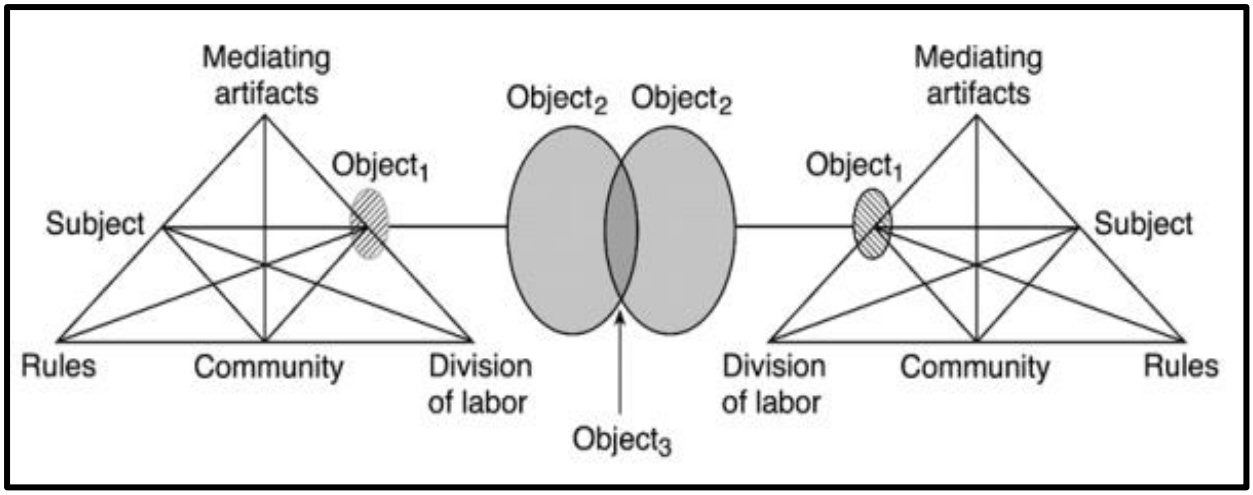


Figure 2.5: The third generation CHAT (Engeström, 2001:136)

The activity theory was explained by Sannino and Engeström (2016) as follows:

- the subject referred to the individual or group whose point of view were used as the perspective of the analysis. The object referred to the goal of the activity. It was usually a problem or learning challenge that was addressed with the activity. At the end of the activity, the researcher could determine whether the object had been achieved, and this would be the outcomes of the activity. The outcomes (changes in the activity system) we mediated with the help of tools and signs. The community was composed of the individuals and groups who shared the same object. The horizontal division of duties and the vertical division of power and status was represented by division of labour. The rules referred to norms, conventions, standards, and regulation within the activity system,
- the circle around the object depicted in Figure 2.4 indicated the ambiguity of the object. It could be a person making sense of something or learning something new in an activity system. It could also be societal change, where change was brought about in a community through an activity. It could also be a generalised object (e.g., people want more service delivery from their local government, they organise themselves into an activity system to achieve this object). It could also be a specific object, such as a teacher wanting learners to understand a certain topic in a subject better. The generalised object was linked to societal meaning, while a specific object was linked to personal

meaning. The object was what the activity was focused on but was durable and constantly under construction. It could be different for each participant, depending on their own history, and

- historicity was the context that each participant brought to the activity system. Historicity was how people's background influenced their actions. Culture or context in which people grew up caused them to do things or to think in a certain way, and this was what each participant brought to an activity system.

According to Engeström (2001) the analysis of activity should take place in the context/milieu it took place. The type of activities, the participants and their goals as well as the object of the activity represented the context/milieu. The rules were chosen by the community, and it dictated how the activities took place (Jonassen & Rohrer-Murphy, 1999). According to Leont'ev (1981), human activity was a system of social relations, and it was dependent on the efforts of a community. The community members decided which members will perform a specific function, thus dividing the labour. This division of functions was also influenced by the rules, and it could cause conflict which would cause changes within the activity system. For example, this could result in a change in learners understanding of a concept. Furthermore, there were also contextual differences between different activity systems and no community would be the same.

2.2.1 CHAT PRINCIPALS

Engeström (1987) developed the five principles underlying CHAT. These are:

Principle 1

Activity is used to analyse an activity system. Hence, a researcher will use the activity system to see whether the object was met using certain activities mediated by tools.

Principle 2

Activity systems are different from each other, and they represent different opinions. Activity systems could be composed of people with different backgrounds, cultures, and worldviews. Activity systems differ from other activity systems because there are

different contexts in each activity system. Different communities have different artefacts, views, traditions etc. The multiple voices are a source of conflict, innovation, and change. It demands actions of translation and negotiation. When people in the activity system differ, they need to discuss and find solutions, and these solutions, lead to change.

Principle 3

Historicity implies that activity centres have a historical background. The background of the activity should thus be studied. An example of this is an activity system in an office environment, where workers need to learn a new skill (e.g., operating a new computer programme). When there are challenges while doing a certain activity, or conflict between colleagues, the researcher should consider the background of the group and where certain issues originated. For example, the researcher should refer to the history of how the people were trained in the past, to consider why they have a challenge with the specific activity.

Principle 4

Tensions are a source of transformation. These tensions create fertile ground for change. Considering the example of the office workers again, tension can be used in a positive way. The problem can be discussed between everyone in the community and a solution can be proposed. This leads to a positive change in the activity system.

Principle 5

Activity systems enable transformation over a period. Tension may cause participants to interrogate a scenario and subsequently implementing change. An activity system could possibly change a persons' worldview about a certain subject leading to transformation in their own life. It could also work in a larger societal sphere, where people working together to make a change in society forming an activity system, overcome tensions (differences/challenges within the activity system) and find a better way to approach a problem and achieve their object (goal), hence, transforming society.

CHAT has been used in various social research endeavours in South Africa, including education. More recent studies include De Beer and Mentz (2021) who found it a great tool to use in mixed method research. It helped to analyse the dichotomous

data generated from qualitative and quantitative methods and to open the “black box” (Timans, *et al*., 2019). CHAT was found to be very useful in researching indigenous knowledge systems to decolonise science education in South Africa (De Beer & Kriek, 2021). The use of foldscopes in a Life Sciences classroom was compared to conventional teaching using the CHAT framework (Jackson *et al*., 2020). The drop in learner motivation after a case-based intervention was understood using the CHAT framework (Krugel, 2019). Hardman (2015) used CHAT to understand how pedagogical practices changed in the presence of computers in four disadvantaged schools. CHAT was used to study the professional learning of science teachers (Oswald, 2019; Van Wyk & De Beer, 2019).

2.3 CHAT FOR THIS RESEARCH STUDY

At first, the activity theory (Engeström, 1987) was used as the theoretical framework, but the programme was changed in response to data that were obtained during interviews. After reflection it was decided to change the format of the programme and the third generation CHAT was used to analyse data (Figure 2.6). It is composed of an activity centre 1, that represents the fieldtrip to the university museum and an activity centre 2, that represents the workshop conducted at the schools.

A brief description of CHAT for this research is delineated below:

- Subject

The subject of this activity system was the Grade 12 learners who attended the workshop at the university-museum. These learners came from schools within one educational district, namely the Gauteng province.

- Community

The university lecturer and his assistants, the district Life Sciences subject advisor, teachers and the principals of the schools comprised the community of this activity centre.

- Rules

They were comprised of the rules of the university, the rules that governed each school when learners attended an excursion, and the rules and regulations of the GDE when learners went on fieldtrips. In the second activity centre the rules of the university changed to the code of behaviour on the school's premises.

- Tools

The socio-cultural theory, inquiry-based learning and the nature of science, the university laboratory with fossils and fossil replicas, the museum and the worksheet that the learners had to work with comprise the tools of the systems.

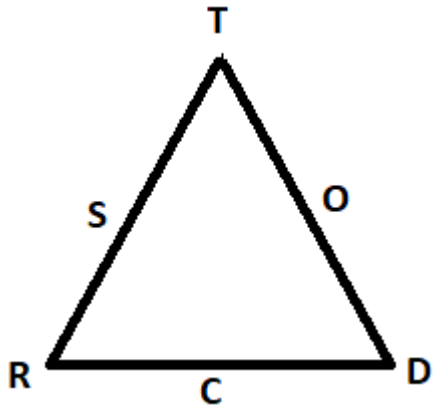
- Division of Labour

The duties were shared between the university lecturer and his assistants, the subject advisor and the teachers.

- Object

The improvement of the grade 12 Life Sciences learners' performance in the topic human evolution was the main objective of this study.

The logo in Figure 2.6 below will be used throughout the thesis to highlight the link a section has to CHAT.



Key:

T= tools

O= object

D= division of labour

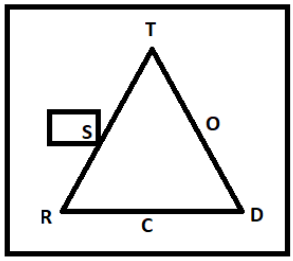
C = community

R = rules

S= subject

Figure 2.6: The CHAT logo used to indicate the link between a certain section and the CHAT framework

Figure 2.7: The third generation CHAT for this research study



2.4. SUBJECT: GRADE 12 LEARNERS

The components of the CHAT system will now be discussed in detail. The grade 12 learners attending this workshop were the subject of this system. South Africa is a diverse country with eleven official languages. It is also a country steeped in a history of inequality. Apartheid divided the nation according to race and black African people were extremely disadvantaged by this policy (van der Berg, 2008). Twenty-eight years after the end of Apartheid, the socio-economic disparities are still visible in society. Most Black people living in townships and rural areas are still plagued by poverty (Amnesty International, 2020; Fish, 2016; van der Berg, 2008). Schools in these areas have a poor culture of learning and teaching and are often under-resourced (De Beer & Ramnarain, 2012; Taylor, 2008). The Centre for Development and Enterprise (CDE, 2020) states that South African schools still have huge inequalities and the vast majority of learners going to public schools are disadvantaged. Grade 12 learners taking mathematics dropped by 14 000 in 2019 and the pass rate dropped to 54.6% in that year (CDE, 2020:3). South Africa had also participated in the Trends in International Mathematics and Sciences Study (TIMSS) since 1995, and consistently ranked at the bottom of the participating countries. Countries like Kenya and Tanzania, who has a lower GDP per capita than South Africa, have continuously out-performed South Africa in these tests (CDE, 2020).

A study in Gauteng (Miji & Makgato, 2006) found that the factors impacting on learners' performance in physical sciences and mathematics were related to poor teaching strategies, poor teacher content knowledge, non-use of laboratories, not completing the yearly syllabus as well as learners' lack of motivation. Other more indirect factors were the lack of parent involvement in their children's education and general language usage (Miji & Makgato, 2006). Another study in Gauteng found that lack of learner discipline and motivation, teacher discipline, commitment, and morale as well as ineffective policies and poor parent involvement were responsible for poor

results (Van der Westhuyzen *et al.,* 2002). De Beer (2016) found that the three major factors that causes poor performance of South African science learners were that there were not enough well qualified science and mathematics teachers, the affective outcomes were neglected in an examination-driven school system and that many schools lacked appropriate materials and equipment for effective teaching. Table 2.1 indicates learners' performance in the Life Sciences exit examinations (the National Senior Certificate (NSC) over the last five years in South Africa and Gauteng province.

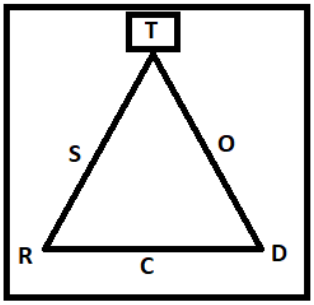
	South Africa		**Gauteng province**	
Year	**Number wrote**	**Percentage achieved at 30% and above**	**Number wrote**	**Percentage achieved at 30% and above**
2016	245 157	70,5	50868	83
2017	236584	74,4	47991	84
2018	236 584	76,3	46340	85,9
2019	217 729	72,3	46850	79,1
2020	226 700	71,00	49718	76,5
2021	274 584	71,5	56343	77,2

Table 2.1: The achievement of Grade 12 learners in the Life Sciences NCS in South Africa and Gauteng province since 2016 (information from the NSC School subject report (DBE, 2017, 2018, 2019, 2019, 2020, 2021, 2022)

The National Diagnostic Reports (NDR) published by the DBE, gives detail on how Grade 12 learners in South Africa performed in the questions relating to human evolution in Life Sciences Paper 2 (Table 2.2). It should be noted that the NDR stated that learners sometimes knew the content but did not understand the question or how they should answer the question. Overall, learners did not perform well in the questions regarding human evolution. Palaeosciences forms part of the grade 12 Life Sciences curriculum and this research was regarded as an apt way to improve learners understanding of these concepts.

Year	Learners Performance
2016	The essay question was on human evolution, namely the out of Africa hypothesis and the learners obtained an average mark of 24% for this question
2017	The question was on human evolution and the overall performance of learners in this question was 54%
2018	The questions were on different jaw shapes and how it related to change in diet. The learners obtained 42% overall in this question
2019	One question was on human-primate comparison where the learners obtained 52% overall. Another question was on bipedalism and the learners obtained 44% overall
2020	The learners obtained an average of 40% for the question on evolution. Which was the lowest of all the topics. They achieved 23% for the question on human evolution
2021	The learners obtained an average of 53% for the evolution question and 51% for the human evolution question

Table 2.2. A summary of South African learners' achievement in the questions pertaining to evolution in Life Sciences Paper 2 from 2016 to 2021 (DBE, 2017,2018, 2019, 2020,2021,2022)



2.5 TOOLS OF THE ACTIVITY SYSTEM

2.5.1 SOCIOCULTURAL THEORY, MUSEUMS AND SCAFFOLDING

Worldwide museums are environments of informal learning that are accessible to the public and focus on interactivity (Andre *et al.,* 2017; Falk & Dierking, 2000). Learning

in a museum context is embedded in a process where learners, knowledgeable others and the media at hand are interacting with each other (Henderson & Atencio, 2007). It results in learning that is both dialogical and hands-on. This type of learning is based on the ZPD (Vygotsky,1978) and form the basis of sociocultural theory. These interactions become internalised and part of people's psychological makeup in the form of higher order mental processes.

It follows from sociocultural theory that effective learning is most likely to take place where learners work in groups, solving problems and handling objects under the guidance of an experienced facilitator (Ash & Rahm, 2012). Sociocultural theory was used in the education programme of the ESI, a palaeosciences research institute, where a workshop programme was reinforced by a visit to a fossil preparation laboratory and palaeoscience museum. According to Kozulin (1998) people learnt using cognitive tools such as images, symbols, and models. These tools provided mediation in the learning process. Objects in informal settings like museums could become part of thinking by mediating group interaction (Rowe, 2002). During this research, the learners had to search for the information and discuss possible solutions to the questions asked. Rowe and Bachman (2012) identified the tools associated with scientific thinking as arguments based on evidence, inductive and deductive reasoning and identifying and manipulating variables. These skills appeared as part of communication between individuals in a socially meaningful activity, which was a focus of these activities at the museum. It follows that the tools in this programme were the museum artefacts, language and the worksheet.

According to Emmerson (2019), mediation was at the epicentre of sociocultural theory. Mediation, or scaffolding, was the process where learners were moved from their current level of development to a potentially higher level of development, by interacting with a more knowledgeable other (Vygotsky, 1978). This happened when a mentor or mediator stepped in and scaffolded the learning process by asking the learners questions and in so doing, leading them to the solutions. Mediation was also a basic principle of CHAT.

In this programme, there was at least one mentor moving between groups and helping the learners when they struggled with the concepts. The answers were not merely given but mediated through a range of prompts in the form of leading

questions. Benjamin *et al.,* (2010) found open-ended “wh” questions (Why?, What?) during learner mediator interactions to be very effective. Moreover, they found that the conversational instruction linked with hands-on activities resulted in the improvement of learners’ abilities to report on the focused content directly after and even two weeks after the intervention. According to May and Ash (2012), informal settings had the potential to offer rich learning contexts where naturalistic scaffolding occurred between participants. Mediation did not only occur between the learners and mentor, but also between the group members. The characteristics of mediation defined in this research study included:

a) several learners involved in joint activity;

b) learners engaging with artefacts asking questions, debating possible answers and interacting with each other; and

c) learners interacting with a mentor.

The worksheet with questions for each part of the activity was another tool that mediated learning. Concept-orientated worksheets (Braund & Lelliot, 2017) were used, and they contained higher order questions which encouraged discussion. Questions mediated learning by scaffolding the concepts. Another form of scaffolding used was the feedback session at the end of the workshop, where learners asked questions to seek clarity on some of the concepts that they did not understand. An overarching form of scaffolding which took place during this programme was between the:

- learners, with their different cultural backgrounds,
- the teachers and departmental officials with their knowledge of curriculum and assessment requirements; and
- the facilitators and designers of the informal learning programme.

By receiving continuous feedback from these various representatives of the formal educations sector (learners, teachers, and officials), the designers and facilitators of the programme were able to change the design of the programme so to better accommodate the needs of the various education role-players.

2.5.2 INQUIRY-BASED LEARNING AND THE NATURE OF SCIENCE

Educationalists agree that learning takes place when learners are active participants in their own learning and the question is not if, but how learners should be involved in their learning (Lazonder & Harmsen, 2016; Vygotsky, 1978). Inquiry-based methodology allow learners to learn through investigations. Hmelo-Silver *et al*. (2007) stated that contemporary inquiry-based methods are powerful methods for learning, because they employ extensive scaffolding. Inquiry-based learning is rooted in the work of Dewey (1859-1952) and was very popular during the nineteen sixties of the 20th century. Hermann (1969) found that the effectiveness of inquiry-based methods were dependant on the guidance learners receive during an inquiry. This was reiterated forty-two years later by Alfieri *et al.* (2011), who found that across domains and settings, inquiry-based methods with no or minimal guidance were less effective than explicit instruction. When learners received adequate guidance during inquiry, they learnt more than learners who were taught by using only transmission of content. A meta-analysis study (Lazonder & Harmsen, 2016) also indicated that inquiry-based activities should employ guidance to assist learners to accomplish the task and learn from the activity. Too much guidance challenged the nature of inquiry-based learning, but less specific forms of guidance lead to positive outcomes. In South Africa, Stott (2019) found that a weeklong inquiry-based intervention gave learners from poor schools a statistically significant learning gain. Potgieter *et al*. (2021) found inquiry-based learning effective in teaching grade 10-12 learners at a science centre in Limpopo.

Inquiry-based methods enable learners to learn about a topic through self-directed investigations. By “acting like a scientist,” learners not only learn science content but also science processes (Abd-El-Khalick *et al.,* 2004). Duschl *et al.* (2007:47) stated that science is “*a set of processes which involves logical reasoning about evidence, theory change, and participation in the culture of scientific practices*.” It therefore follows that science is composed of subject knowledge as well as skills, practices, and values inherent to science. Science processes (Lederman *et al.,* 2002) are activities where learners have to collect data, interpret the data and then deduce a conclusion from their data. Following are the tenets of the nature of science

(Aikenhead & Ogawa 2007; Beauchamp, 2011; Dekkers, 2006; Lederman *et al.,* 2002) formed part of this study:

The Tenet	Explanation of the Tenet	Application to this study
The empirical nature of science	Experiments should be conducted before science claims could be made	Learners had to gather data based on their observations and measurements
The tentative nature of science	Scientific knowledge is not cast in stone, it is continuously transformed through new discoveries	During the feedback session learners were told how knowledge changed as new skeletons was discovered
The observational and inferential nature of science	Observation differs from deducting and inferring from data. Learners should know what the differences are	Learners had to make inferences at the end of the session which were discussed/debated during the feedback session
The theory laden nature of science	Science should be pursued in an objective manner. It is possible that a scientists' theoretical viewpoint could influence the findings of an investigation.	In this research, the cultural and religious background of a person researching a scientific phenomenon was highlighted
The social and cultural nature of science	Science is conducted by humans which makes it imbedded within a context. This context represents a certain social and cultural milieu.	Cultural tools had to be identified during the workshop. The social and cultural context were discussed when the feedback on the tools were done. The fact that human evolution is unacceptable for some cultures were also discuss during the feedback session

Table 2.3: How the tenants of the nature of science relates to this research

The inquiry-based activities chosen for this research required learners to observe and measure skulls of different organisms. This was not the traditional scientific method of setting of a hypothesis, controlling variables, doing a practical investigation, and inferring a conclusion. They had to observe and make inferences about skull features such as size of brow ridges, prognathous, dentition, palate shape, position of foramen magnum and cranial ridges. Then the learners had to compare these skulls and sequence the skulls according to brain capacity. Pelvic bones of three species were

compared to decide which were bipedal, quadrupedal and a transitional species. They had to analyse DNA fragments of six different species and decide whom had the most in common. After this, they had to draw a phylogenetic tree using the information they generated during the workshop. So, learners had to gather evidence, compare variables to predict the place of the species on a phylogenetic tree.

Guidance and scaffolding were done before the activity, when the facilitator explained what was expected of the learners and how to measure the craniums of the skulls. During the activity, the learners were assisted by the facilitators, who assisted with well-placed questions which helped to guide the learners to the solution. Afterwards, some of the learners had to arrange the skulls in the correct evolutionary sequence, and all the learners could discuss the sequence during the process. They also had to state why they decided which pelvic bone suited the correct organism. The DNA sequencing was discussed and then the facilitator guided the learners through the position of the organisms on the phylogenetic tree. This was usually the pinnacle of the activity. It linked all the evidence together into a conclusion.

2.5.3 WORKSHEETS

The completion of worksheets by learners (Kisiel, 2006) was one of the strategies used by museum educators to facilitate learning. For the purposes of this research study, a worksheet is a booklet that learners must solve which contains problems or tasks that are related to a particular topic or activity (Mortensen & Smart, 2007). Nyamupangedengu and Lelliott (2012) found that many museums in South Africa were opposed to the use of worksheet, as it restricted learning in their view. They also found that field trips to museums in South Africa were mostly characterised by large numbers of learners, accompanied by chaperones (tour guides) who were not science teachers, with none or little facilitation, or little supervision by teachers. This necessitated the use of worksheets to ensure that learners were exposed to similar worthwhile learning experiences. The worksheet used in this study was compiled by the university lecturer using inquiry-based learning as a basis. The worksheet was aligned to the school curriculum with the assistance of the subject advisor in this study. The learners had to follow the instructions on the worksheet and investigate the artefacts. They also had to complete the worksheet by entering the data, drawing their observations and linking the data to draw a phylogenetic tree.

2.5.4 UNIVERSITY LABORATORY AND ARTEFACTS

"*Museum experiences can help to develop students' scientific skills and understanding of science whilst also helping them to develop an enquiring and critical attitude towards science, to engage with it and to consider the possibility of a career in it"* (Mutjaba *et al.,* 2018:4).

School visits to informal science learning institutions (ISL) such as sciences museums have shown to improve learners' conceptual knowledge and their attitude towards science in European countries (Filippoupoliti & Koliopoulos, 2014). A study conducted by Whitesell (2016) in America suggested that field trips might be an effective tool for reducing achievement-gaps between diverse groups of learners. Data from international tests such as the Programme for International Student Assessment (PISA) show that informal learning experiences (such as visit to a science museum) could enhance and enrich student learning and positively influence interest and achievement in science (Hlengwa & Koleka, 2018; Woods-McConney *et al.,* 2014). In South Africa, science museums could play an integral part in increasing an understanding of evolution for learners.

Mutjuba *et al.* (2018) indicated that learning rarely if ever occurred from a single experience. Science learning takes place over a long time through a myriad of experiences. Hence, informal science learning spaces could assist children's learning process. Science museums should no longer be places with static scientific exhibits, but places where interactive learning takes place. Furthermore, informal science learning cannot be measured the same way that formal school learning is measured. Concepts such as excitement, the understanding of scientific facts and participate in scientific activities could be used as measurements of effectiveness of a visit to a museum (Bell *et al.,* 2009; Hlengwa & Koleka, 2018). Internationally, it was found that there are several deterrents for teachers to make use of ISL, namely, a perceived mismatch between curriculum and the ISL resources, pressure from administrators to focus on tested subjects and inexperience on how to incorporate these resources into their classrooms (Anderson *et al.,* 2006; Kisiel 2014). Other

issues raised by teachers were the logistical challenges of a field trip, as well as bad behaviour of learners during these field trips (Kenna, 2019).

In this research, I attempted to address some of these challenges. The workshop content was designed to address the grade 12 syllabus, as well as the yearly diagnostic reports released by the DBE to address the misconceptions of learners in the final examination papers. The workshop included all the content that learners needed to know about this specific topic. This meant teachers brought their learners, and after two and a half hours, the learners knew everything they needed to know about human evolution. The discipline of learners and logistics surrounding such a workshop were addressed during the second year when the workshop was done at schools. In this manner, the learners did not have to travel by bus, which also made it more affordable. It also removed the burden of learners misbehaving on the bus. The “fossils” used in the workshop were casts (Figure 2.7). The learners were allowed to handle them and observe the differences and similarities. The learners also had a piece of string which were used to measure the approximate size of the cranium.



Figure 2.8: The different skulls that learners had to identify and do a comparison on identified features

The pelvic bones (Figure 2.8) were also reproductions. Learners had to observe the differences and then decide which one was narrower indicating quadrupedal locomotion and which one was broader, indicating bipedalism. They also had to choose the pelvic bone that fit the description of being a transitional fossil.



Figure 2.9: The three different types of pelvic bones that learners had to observe, draw and sort

The three types of stone tools (Figure 2.9) were real artefacts that the learners had to study. The university lecturer discussed each one at the beginning of the workshop, indicating how sophisticated they are. He linked the sophistication of the tools with brain size and cognitive development. Learners then had to decide which species of hominin was most likely to produce each stone tool.



Figure 2.10: The three different stone tools that learners had to draw and sort from least sophisticated to most sophisticated

Furthermore, the university lecturer made use of teaching tools and it changed as the project progressed. At first, the artefacts were discussed, and after the workshop, there was a feedback session. Sometimes a data projector was used to summarise the data. The university lecturer mostly made use of the white board in the laboratory to write the averages of the skull measurements that the learners obtained. This was also used to draw a phylogenetic tree where all the data from the workshop were linked. During the session at the schools, the white board was not an option in the school halls and the presentation needed to be prepared beforehand and used with a data projector. In the case of classrooms being used, the chalk board was used.

2.5.5 NATURAL HISTORY MUSEUM

Learning in museums and other non-school-based (informal) environments is qualitatively different learning from that in schools (Falk & Dierking, 2000). Natural History Museums (NHM) are ideal in assisting learners to learn about science (Mutjuba *et al*., 2018; Shaby *et al*., 2019). One of the reasons why NHM, or science museums are successful, is that they facilitate social interaction between people and create enthusiasm for science (Mutjuba, 2018; Salmi, 2003; Tal *et al*., 2014)). NHM have several advantages over conventional schooling. One such advantage is that learners are more motivated in informal settings then they are in school. Furthermore, NHM, or informal settings, often provide rare material such as real fossils, or life-size models of extinct creatures, which are not available in schools. The staff in NHM responsible for the provision of teaching and information, generally often make a commitment of time to the preparation of these that is beyond what a schoolteacher can manage (Connealy, 2018).

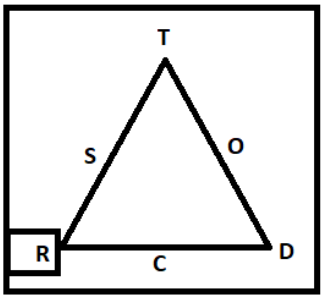
In South Africa research on the engagement between schools and ISL are limited (Lelliott, 2017). Lelliott (2009) found that school field trips to museums were often not conducted in a way to optimise learning.. Effective instructional activities during these field trips should address this challenge efficiently. Interactivity is increasingly seen as essential in children's learning experiences in a museum context (Cheng *et al.,* 2011; Falk & Storksdieck, 2005; Tal *et al*., 2014). Learning is embedded in the interactive process between learners and knowledgeable ones, as well as the media

at hand, which makes museum learning both dialogical and hands-on (Braund & Lelliot, 2017; Henderson & Atencio, 2007, Shaby *et al*., 2019; Tal *et al*., 2014). Fish *et al*. (2016) found that even though township, rural and urban school learners enjoyed a science show equally, the urban school learners gained the most cognitively. This was because township and rural learners were behind urban learners as far as scientific knowledge was concerned. They recommended that science centres or museums should adapt their programmes to suit the learners coming from these types of schools.

The palaeontology museum at Wits was a museum that exhibited extinct animals and plants from South Africa. The learners could observe the different fossils and some life size models of extinct animals. There was also a human evolution exhibition in the museum, which included all the South African fossils. The museum part of the field trip included a worksheet that had instructions for a treasure hunt. Learners were briefed before they started and were then given an hour and a half to search for the different clues in the museum. Afterwards, a feedback session was held with the learners. This part of the field trip included all kinds of animals and plants and were not bound to the curriculum. It gave the learners a contextual view of South Africa's rich fossil heritage and how different the landscape was millions of years ago. Learners had time to read some of the information vignettes at each exhibition (Figure 2.10) and learn interesting facts about the ancestors of today's animals and plants. This is the part that learners missed out on if the workshop was conducted at their schools.



Figure 2.11: Exhibit of pelvic bones in university museum (James Kitching Museum)



2.6 RULES

Rules are the explicit and implicit norms, conventions, regulations and standards that governs actions within a activity system (Sannino & Engeström, 2016). The rules that governed this activity system were the policies from the DBE in South Africa, as well as the rules that governed field trips to the university.

2.6.1 THE NATIONAL CURRICULUM STATEMENTS AND EXAMINATION GUIDELINES FOR LIFE SCIENCES

In South Africa, the National Curriculum Statements (NCS) for the grades 10 to 12 band, also known as the Further Education and Training (FET) band, were introduced in 2006. This was a new curriculum that was developed after Apartheid, and it included the topic evolution for the first time in fifty years (Sanders, 2018). The curriculum was revised in 2009, and the new CAPS (DBE, 2011) were implemented in grade 10 during 2012.

Some of the seven principles on which CAPS was based were used in this study. The principle of critical and learning was one of the cornerstones of this research. The second principle that was incorporated in this workshop was high skills and knowledge. The next principle namely social transformation addressed the redress of the inequalities created by Apartheid, which could also be linked to another principle namely human rights, inclusivity, environmental as well as social justice. These two principles were addressed through the involvement of all schools, including schools from disadvantaged communities. Hence, learners were representative of all racial groups. The principle of credibility, quality and efficiency was addressed by the practical activities that the learners performed. The principles not addressed by this study was valuing of indigenous knowledge and progression.

The Life Sciences curriculum is organised into four knowledge strands, namely, life at molecular, cellular and tissue level, life processes in plants and animals, environmental studies and diversity and the fourth strand namely diversity, change and continuity. The fourth strand was chosen for this research. In section three of the CAPS document, the content is outlined in detail per grade. The content is outlined in a table as a work schedule where each content topic is delineated into sub-topics alongside the linked practical investigations and resources needed. A timeframe is also given to assist the teacher with pacing the content. Other features of this table are that it indicates the formal assessment activities that should take place during each term. The topic Human Evolution is outlined as followed:

Topic: Human Evolution		
Content	**Investigations**	**Resources**
• Evidence of common ancestors for living hominids including humans: Anatomical differences and similarities between African apes and humans: - Fossil evidence: key features: bipedalism (spine and pelvic girdle), brain size, teeth (dentition), prognathism and palate shape, cranial and brow ridges. The number of fossils that have been found (it is important to know that thousands of fossil fragments have been found) - Genetic evidence: mitochondrial DNA - Cultural evidence toolmaking • Out of Africa hypothesis Evidence African origins for all modern humans: genetic links, mitochondrial DNA: - Rift valley fossil sites in East Africa (Kenya and Tanzania) and in Ethiopia. Scientists e.g., Johansen and White, the Leaky family - Fossils discovered at these sites: *Ardipithecus, Australopithecus, Homo* - Fossils sites in South Africa: Fossils discovered at these sites: *Australopithecus* and *Homo*	• Poster presentation Map out the three major phases in hominid evolution from 6 mya up to the present: - A*rdipithecus* (Ethiopia) - *Australopithecus* (East and South Africa) - *Homo* (various sites) The map/timeline should show the diagnostic features and the approximate times that examples of the three major genera existed. It is not necessary to show the relationships between genera. (Scientists may interpret relationships differently as new evidence is found)	• Textbooks • Newspaper articles (e.g., the discovery of Sediba) • DVDs if possible • Maps, pictures and photographs

Table 2.4: CAPS (DBE, 2011:63) the outline of the topic human evolution

The Caps gives a very broad outline of the topics. Clarity on the depth of the topics to be assessed in the grade 12 National Senior Certificate (NSC) examination is given in the DBE examination guidelines. The purpose of these examination guidelines is to assist teachers to adequately prepare learners for the examinations. These guidelines were used as a framework for the workshop. The examination guidelines for evidence of common ancestors for living hominids, including humans are as follow;

Examination guidelines: Topic: Evidence of common ancestors for living hominids, including humans	
Examination guideline	**How it was covered in this workshop:**
Interpretation of a phylogenetic tree to show the place of the family Hominidae in the animal kingdom	The phylogenetic tree was covered in detail, from explaining a common ancestor, transitional species to extinction and speciation. The learners used all the evidence they gathered and decided where the organisms fit on the tree
Characteristics that humans share with African apes	The characteristics that are similar and different between African apes and humans were done in detail when they worked with the skulls and pelvic bones and compared features. They had to sequence them in evolutionary order
Anatomical differences between African apes and humans, with the aid of diagrams, as it applies to the following characteristics: •Bipedalism (foramen magnum, spine and pelvic girdle) •Brain size •Teeth (dentition) •Prognathism •Palate shape •Cranial ridges •Brow ridges	This was done during the feedback session when all the data was linked together to show how organisms changed gradually over time. Also, they saw the differences in the different genera
Lines of evidence that support the idea of common ancestors for living hominids including humans: • **Fossil evidence**: Evidence from fossils of different ages show that the anatomical characteristics of organisms changed gradually over time • **Emphasis on evolutionary trends** provided by the anatomical features of fossils of the following three genera: - *Ardipithecus*	• Emphasis on evolutionary trends were also done while the learners were busy with the different skulls, pelvic bones, DNA sequencing as well as the phylogenetic tree • Fossil sites were discussed in the introduction part of the workshop, where learners were introduced to the different skulls

- *Australopithecus* - *Homo* as well as: - The age of each fossil found/timeline for the existence of the three genera - The fossil sites where they were found: emphasis on the fossil sites that form a part of the Cradle of Humankind - The scientists who discovered them	
• **Genetic evidence**: mitochondrial DNA	• **Genetic evidence** was done during the workshop when the DNA sequences were analysed, and the mutations (differences) were counted and compared between the different organisms. The organisms closer to each other had fewer mutations (differences)
• **Cultural evidence**: toolmaking	• **Cultural evidence** was addressed with stone tools. The learners were introduced to the tools at the beginning, and they were told that with more thought the tools become more sophisticated. During the workshop they had to distinguish between three different tools and decide which were the oldest, middle one and the youngest

Table 2.5: Exam guidelines (DBE, 2017:15), human evolution and how it relates to this research

Lastly, CAPS requires that three Specific Aims should be assessed throughout the year. They are as follows:

1. **Specific Aim 1: Knowing Life Sciences**

This aim relates to the knowing and understanding of concepts so that learners can make links between different concepts. The learners should acquire knowledge, understand ideas and concepts. They should be able to link the concepts and ideas

to help them understand Life Sciences. Another skill under this aim is to apply their newfound knowledge to new and unfamiliar scenarios in Life Sciences. They should also be able to analyse and evaluate scientific knowledge as well as synthesising new concepts and ideas. This specific aim was infused in the workshop as learners had to obtain knowledge and make links between the ideas and new concepts. They also had to analyse and evaluate the evidence they were working with and come up with a conclusion.

2. **Specific Aim 2: Investigating phenomena in Life Sciences**

This aim relates to scientific investigations as well as using practical skills to solve problems. There are seven skills linked to this aim. Learners should be able to follow instructions and handle apparatus or equipment during an investigation. They should make observations and do measurements. These observations and measurements should be recorded as data in tables and/or graphical form or scientific drawings. They must be able to interpret their data and come to conclusions. Lastly, they should be able to plan or design scientific experiments or investigations. During this workshop the learners had to follow instructions and handle the different artefacts as well as measure and draw some of them. They had to make observations and record this information as data as well as interpret their data.

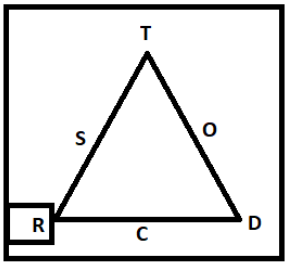
3. **Specific Aim 3: Appreciating and understanding the history, importance and applications of Life Sciences in society**

This aim relates to the context of Life Sciences. Leaners need to know about how certain scientific discoveries came about and why it is relevant. They also have to learn about the links between Life Sciences and indigenous knowledge systems. Lastly, they need to know where Life Sciences is applied in real life, how it is applied in industry and what careers are available in this field. The learners were given some background on the fossil discoveries and how it changed the way the world is viewed. If the learners were fortunate enough to go to Wits, they were taken on a tour of the fossil preparation laboratory where they could see how the fossils are extracted from the rock. They had opportunities to speak to the staff working in the laboratory. Furthermore, the learners were exposed to a university and a science faculty. They

could see real scientists at work and speak to post-graduate students about possible career paths.

2.6.2 THE UNIVERSITY AND SCHOOLS

The university's code of conduct had to be followed when learners arrived at the university. The learners had to behave in a disciplined manner. The teachers were expected to be with the learners at all times, ensuring that they behave themselves. Learners were also not allowed to be unaccompanied on campus during their lunch break. While they were busy with the museum visit, they were expected to cooperate with the university staff members and not to damage the exhibitions. At school school-based workshops learners had to adhere to the requirements of their schools.



2.7. COMMUNITY

Lave and Wenger (1991:98) described a community of practice as a "set of relations among persons, activity and world, over time and in relations with other tangential and overlapping communities of practice". Members of a community of practice negotiate the sharing of learning and knowing within a social activity. Participants within this community of practice had a shared knowledge of how things work within their community, and they had a common language and symbols of discourse as well as a common identity (Lave & Wenger, 1991). A social group's culture defines the rules and how members of the group socialise. Culture is defined by Stetsenko (2010:10) as people "collaboratively engaging with their world through collective efforts to make things happen".

Communities of practices are not isolated entities, but they may form a boundary practice, where mutual engagement occurs (Wenger, 1998). Interactions between the members of different communities may lead to a new hybrid community. (Lave & Wenger, 1991). Wenger (1998) proposed three dimensions to the coherence of a community of practice, namely mutual engagement, joint enterprise and shared repertoire. Mutual engagement referred to all the activities and interactions that the community share. In this research's activity system, there were three communities working together. The members of this blended or hybrid community consisted of the university lecturer and his support staff, the district subject advisor for Life Sciences, and the schoolteachers and principals. The university lecturer and his support staff participated in similar activities and interacted with similar visitors. The district subject advisor was the link between the schools and the university museum, as well as the administrator of the activities. Each school was a community of practice on their own with their principal authorising the field trip and the teachers communicating with the learners and parents. Joint enterprises were the set of goals or requirements for the practice negotiated by the members of a community. The joint enterprise of this activity systems' community was the presentation of the workshop and the learners' visit to the museum. Furthermore, the shared repertoire of this community were the resources used, which were the university laboratory, the artefacts, the worksheets and the museum. In the last year of the study, the university laboratory and museum were not part of the shared repertoire. The same schools were participating in the workshops throughout as they formed part of this community of practice.

Research in the United States of America indicated that formal partnerships between schools and informal settings was an effective way to assist learners with their science education (Bobick & Hornby, 2013; Whitesell, 2016). Falk *et al.,* (2014) conducted research on how connected science education community is in the United Kingdom. They found that schools and universities were not as interconnected as informal sciences communities. Whilst schools benefited from ISL, schools themselves did not take the initiative to visit the ISL. Institutions such as museums were well connected and worked collaboratively. Falk *et al.,* (2014) concluded that, to maximise the effectiveness of science education, the various communities had to build collaborative relationships. Programmes with the active support of the principal

of a school were those most likely to succeed (Fullen, 2016; Murphy, 2016). Good communication was essential for the establishment of effective partnerships and requires changes in the organisational practices, where differences in institutional practice could be obstacles to more effective relationships (Kisiel, 2010). Teachers and museum educators worked in very different contexts, which caused these differences in institutional practices.

DeWitt and Osborne (2007) suggested the need for the resources in museums to be aligned with the requirements of teachers and their curriculum needs., Moreover, as well as clarifying the purpose of a visit to an NHM, the museums should maximise the use of museum resources, such as the exhibitions, to support learning. (Anderson *et al.,* 2006; Braund & Lelliot, 2017; DeWitt & Osborne, 2007; Tal & Morag, 2007). For partnerships between schools and informal sciences learning organisations to be successful, teachers needed to 'cross boundaries' (Aikenhead, 2006) into multiple communities and incorporate resources from ISL organisations into their practice. ISL educators had to look at school communities, as well as their own organisation, to foster effective connections with schools and/or teachers. Wenger (1998) indicated that for one community (e.g., museums) to interact successfully with another community, both communities should clarify boundaries, and define strategies for encounters or crossing those boundaries. The hope was that at the end of this research, the teachers in this community would keep on using the university when they taught human evolution.

2.7.1 UNIVERSITY LECTURER AND STAFF

The success of productive collaboration between teachers and museum educators largely rests on the shoulders of the museum educators (Dewitt & Osborne,2007). Research on the interactions between museum educators, learners and teachers in America shows that a school group was often led by a museum educator, who in turn provided content, but encouraged little social interaction between the various members of the group (Cox-Petersen *et al.,* 2003). Even when a teacher was leading the visit by using worksheet, social interactions between teachers and learners were not common (Kisiel, 2003). A study conducted by Tran (2007) in the United Kingdom

found that the two key aims of the museum educators' efforts were to encourage learners to return to the museum whilst also helping to foster and develop learners' interest in science. For them, it was more important to provide a meaningful and memorable experience than developing students' science content knowledge. There were differentiated roles for the museum educators and teachers, with museum educators expected to take the lead in educating learners. The vast majority of teachers, who use museum resources, did not attend professional development opportunities offered by museums in the United Kingdom (Dewitt & Osborne, 2007). The museum educators were thus responsible to develop and provide good quality museum experiences for the learners. Teachers did not have the experience, skills or time to design learning activities needed for a museum visit (Connealy, 2018; Cox-Petersen & Pfaffinger, 1998; Griffin & Symington, 1997).

In this activity system, the university lecturer had a PhD in geology and was the main driver of the programme. He was teaching geology to pre-and post-graduate university students. The university started the outreach programme to educate the public on the richness of South Africa's palaeontological finds. This was in adherence with one of the aims of the South African Palaeontology Strategy (Department of Science and Technology, 2011), namely, to educate the public on South Africa's rich fossil heritage and instil a sense of pride. This outreach programme has been active for over ten years in different formats. This research was covering the collaboration between the university and one specific school district.

2.7.2 DISTRICT SUBJECT ADVISOR

The duties of a district subject advisor dictates that they must monitor the implementation of policies, as well as render support and development for educators that they are responsible for (ELRC, 2017). Part of their responsibilities is to facilitate workshops and training sessions and support teachers in their content knowledge. They also have to organise relevant co-curricular activities such as content or pedagogy workshops. Mthembu (2015) argued that district subject advisors should act as instructional leaders, because their core function was the management of teaching and learning. Instructional leadership was the management of education,

including managing an educational programme and promoting a positive learning environment (Hallinger, 2009). Instructional leadership was concerned with teaching and learning, including the professional learning of teachers, as well as the growth of learners (Bhengu & Mthembu, 2013). Further, instructional leadership helped to create and support an environment which makes both high-quality teaching and learning possible (Bush, 2013). Subject advisors had to put teaching and learning at the centre of their daily focus and make use of innovative strategies (Naicker *et al.,* 2013). The results of research done in Botswana indicated that instructional leaders needed to accept that educators' curricular needs were dynamic and did not remain unchanged (Moswela, 2010). Hence, subject advisors were required to support educators in terms of pedagogy so that they could be in line with CAPS (DBE, 2011). In accordance with this, the continuous professional development of educators was essential to build capacity for effective management of curriculum (Sharma, 2012). Subject advisors were catalysts to enhance teaching and learning in term of planning, controlling standards of work and professionally developing educators to teach effectively and efficiently. Research data from a school district in the United States of America, found that where the district leadership was positive towards the collaboration, it was easier to get access to schoolteachers and students (Connealy, 2018).

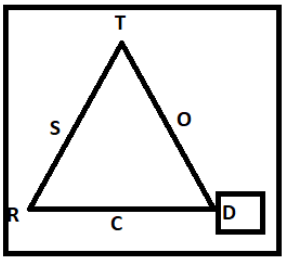
The subject advisor in this research study was also the researcher. The subject advisor was responsible for Life Sciences in her district. She met with the university lecturer through workshops he conducted with all the Life Sciences subject advisors in the province of Gauteng. These workshops were held as part of a collaboration between the GDE and the university. This approach had a greater reach as all the districts were introduced to the programmes at the university. A collaboration between the university and this district was initiated. The subject advisor found that the teachers in her district struggled with the teaching of human evolution and thought that it would be a good opportunity to not only empower the learners, but the teachers as well. Several meetings were held, and the format of the workshop was discussed. The subject advisor advised the university lecturer on what the DBE required from such a programme and the workshop was changed to incorporate the demands of the CAPS curriculum (DBE, 2011) and examination guidelines (DBE, 2017).

2.7.3 SCHOOLS

Connealy (2018) found in the United States of America that engaging school leaders in collaboration efforts with informal ISL proved to be challenging. The study found that all the principals of schools involved were supportive of the collaboration but did not initiate the collaboration. The research done by Tal *et al.,* (2005) showed that in 40 class visits to four NHMs in Israel, most teachers were unable to indicate why they had chosen to take students on a field trip to the museum. They had neither planned the trip nor chosen the learning activities and viewed the field trips as a fun event, and not as a well-planned educational experience. Teachers also indicated that the learning goals that would be useful for their learners are often not fully realised during field trips to informal institutions due to a misalignment in the expectations of schoolteachers and museum staff.

Teachers in the United States of America, Germany and Canada indicated that they thought a field trip served an educational purpose but they rarely enacted best practices for preparing learners for a field trip (Anderson *et al*. 2006). The teachers cited curriculum fit as highest importance when planning and seeking approval for the field trip, but in contrast to this, they rated the success of the field trips based on affective criteria rather than curricular or academic criteria. Kisiel (2005) found that 90% of teachers who took their learner on a field trip in the United States of America to an informal education institution, reported that they had hoped the trip would complement the school's syllabus/curriculum goals, but only 23% of them found that this was the case. In South Africa, a study found that teachers cited learning, classroom curriculum, exposure to new experiences and the visualisation of phenomena as reasons for taking learners on a field trip (Leliot, 2009).

The aim of this research's workshop was to address the teachers and principal's concerns with field trips. The workshop was aligned with the curriculum, but there was also exposure to new experiences and visualisation of the phenomena as the learners were taken to the museum and the fossil.



2.8 DIVISION OF LABOUR

The university staff

The university lecturer was responsible for the preparation of the artefacts used in the workshop. He had to organise with his staff to facilitate the museum tour. Some of the post-graduates also assisted with mentoring the groups while they were busy with the inquiry-based learning. During the first phase of the research, a university staff member was responsible for organising the transport from the schools to the university, as they managed to obtain funding for the project. She arranged the dates and times with the schools and bus companies. She also had to adhere to Wits policies on the hiring of bus companies. During the last phase of the research, the lecturer travelled with support staff to the schools and conducted the workshop at the schools. They had to organise enough artefacts for the workshop and the logistics of transporting all the equipment, data projector and worksheets to a school.

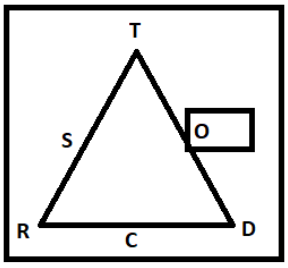
The subject advisor

The subject advisor had to ask permission from the district director to involve grade 12 learners in this project. Usually, schools prefer not to take grade 12 learners on field trips, because of the loss of teaching time. After receiving the permission from the district director, schools had to be contacted to attend an introductory meeting. Memorandums had to be sent out to school principals to inform them of the dates. The university staff and the subject advisor had to plot dates on when the schools will be visiting the university. These dates had to be communicated with each principal and teacher, as well as the district management team, so that everyone was aware of the project and the dates. The subject advisor also accompanied the schools to the university to ensure that learners were disciplined and that teachers were in control of the learners. During the last phase of the research, the subject advisor had

to organise dates that would suit the schools and the university lecturer and attended the workshops at the schools.

The schools

The schoolteachers had to inform the learners and send out the information pamphlets and letters of consent and assent to the learners and their parents. They had to manage the learners on the day of the field trip. This was done through a process of keeping a class list and ticking of their names after they arrived, after lunch and before they left. They were also responsible for the discipline of the schools' learners during the fieldtrip. The principal had to manage the system at school because two or more teachers were not at the school that day, and they do not only teach the specific group of learners. Plans had to be made for substitution teachers. The learners were supposed to behave in a disciplined manner and to participate in the activities.



2.9 OBJECT

The teaching of human evolution to grade 12 learners in an effective way in order to improve their performance in the topic was the objective of this system. The learners had to leave the workshop understanding the concept evolution, how human evolution work and what evidence it is based on. Following, is some background on learners' performance in the topic.

2.9.1 LEARNERS' DIFFICULTY WITH THE CONCEPT OF HUMAN EVOLUTION

In a study done at the Cradle of Humankind in Gauteng by Leliot (2016), it was found that South Africans had the lowest percentage acceptance of human evolution. Out

of five nationalities (American, European, Oceania and Asia), only 58.6% of South Africans accepted human evolution. The same study found that Black South Africans were less accepting of human evolution compared to other population groups. Furthermore, Kyriacou *et al.,* (2015) found that South African Life Sciences teachers still exhibited poor content knowledge and affective barriers to the teaching of evolution, which was supported by research done by Sanders and Ngxola (2009). Sutherland and L'Abbè (2019) stated that religion, specifically Christianity, was a stumbling block which hindered the understanding of evolution by South African teachers. They went further to argue that many South African teachers were unequipped and afraid to teach human evolution. Many had their own reservations about the teaching of this controversial topic. Pillay's (2011) indicated that although the evolution theory was rejected due to the lack of content knowledge, many Christian and Muslim teachers indicated that it goes against their religion, which had a negative impact on their understanding of the topic (Abrie,2010; Coleman *et al.*,2016; Naude & De Beer,2014). Another study (Tshuma & Sanders, 2015) found that there are many mistakes in the Life Sciences textbooks, which perpetuated misconceptions in teachers. It therefore follows that this was transferred into the classroom and contributed to learners' lack of understanding of the concept. This concurred with international research, pointing to the fact that learners and teachers had many misconceptions regarding the basic principles of biological evolution (Glaze & Goldston, 2015; Sickel & Friedrichsen, 2013; Yates & Marek, 2014). Dunk *et al.* (2017) found that the knowledge of evolution and evolutionary terms did not have a significant impact on the acceptance of evolution.

Furthermore, evolution is a concept that is difficult to understand due to cognitive bias (Evans & Lane, 2011; Legare *et al.,* 2013). Firstly, there is the essentialist tendency to view species as unchanging (Emmons & Kelemen, 2015; Herrmann *et al.,* 2013). The belief that members of a category are united by a common essence, which determines the members' outwardly observable properties, is called psychological essentialism (Gelman, 2003). Essentialist reasoning assumes that categories are stable and cannot mutate into something else (Gelman & Rhodes, 2012). This reasoning is incompatible with evolutionary theory.

A second way of thinking that makes it difficult to understand evolution is teleological reasoning. Teleological thinking reasons that a designer was motivated to design a

species to meet certain objectives. This is in contrast with evolution, which is caused by blind variation and selective retention (Legare *et al.,* 2018). Evolution is driven by two components. The first component is blind chance, which contradicts the view that everything exists for a reason or that interdependent relationships exist between species on purpose (Legare *et al.,* 2018; Shtulman & Calabi, 2013). Species do not evolve with a specific foresight in mind, but through natural selection, which favours variants that overcame adaptive challenges better than other variants.

The third reasoning that makes the understanding of evolution difficult, is existential anxiety (Legare *et al.,* 2018). The possible extinction of the human species causes anxiety, which impacts on the understanding of evolution (Legare & Visala, 2011). The discussion of our mortality is shown to be a deterrent in the understanding of evolution and the endorsement of intelligent design (Legare & Visala, 2011).

Shtulman and Calabi's (2013) researched the effects of instruction in general on the understanding of evolution and natural selection in the United States of America and found that standard instruction was not effective. One reason that standard instruction was not effective, is that complex concepts like natural selection and common ancestry were typically introduced in a single lecture using definitions, rather than using more interactive methods (Chi, 2009) such as inquiry-based methods, application or analysis (Legare *et al*., 2018). Teachers should utilise collaborative and interactive activities that necessitate students working together to analyse data and generate their own evolutionary explanations (Legare *et al.,* 2018, Shtulman & Checa, 2012).

2.9.2 CHALLENGES WITH PHYLOGENETIC TREES/CLADOGRAMS

Phylogenetic trees are interpreted by evolutionary biologists according to how they illustrate evolutionary relationships amongst a set of taxa (Baum & Offner, 2008). Phylogenetic representations are compared in order to find similar patterns to find support for hypothesised relationships amongst taxa. Similarities are found by comparing monophyletic groups across representations. According to Halverson (2011), scientifically accurate phylogenetic trees had the following features:

- the relationships are grouped based on evolutionary history and ancestry,

- all related organisms linked with a single representation,
- taxa are place at the terminal tips, and
- hypothetical ancestors are placed at nodes.

Biology learners in the United States of America struggled with the interpretation of phylogenetic trees (Dees *et al.,* 2014), and this was an obstacle to understanding evolution (Meir *et al.,* 2007). It was notoriously difficult to interpret, partly because they contain unfamiliar notational conventions (Novick & Catley, 2007) and because they were prone to inaccurate, essentialist interpretations of evolutionary change (Shtulman, 2006). Gregory (2008) found that some of the misconceptions about cladograms that people had, which also relates to grade 12 Life Sciences learners, were

- they think that taxa on one side is “higher” or “lower” than those on the other side,
- they see the longest line as the “main line” from which other taxa have deviated or side-tracked,
- they find information about relatedness from the ordering of cladogram’s terminal nodes rather than from its branches,
- it is regarded as representations of morphological similarity, rather than common ancestry,
- some taxa is regarded as the ancestors of other taxa, rather than interpreting all taxa as “siblings” or “cousins,
- the length of the branches is seen as measures of evolutionary change (or lack thereof), and
- the taxa on one side of a cladogram appeared, in their current form, earlier than those on the other side of the cladogram.

Shtulman and Checa (2012) identified the following misconceptions that people visiting museums in the United States of America had with phylogenetic trees depicting human evolution (Figure 2.11);

- humans are the most evolved of all primates,
- human evolution represents the “main line” of evolution, while the side-tracks from the main line represents the evolution of other primates,

- humans are less closely related to gorillas than chimpanzees are related to gorillas (because the nodes of the former pair are adjacent, but the nodes of the latter pair are not),
- humans are more like chimpanzees (the closest node to humans) and the least like new world monkeys (the farthest node from humans),
- each primate is the descendent of the primate on its left and the ancestor of the primate on its right,
- humans have undergone more evolutionary change than other primates (because their connection to the root node is longest),
- each primate appeared, in its current form, earlier than the primate to its right and is older than the primate to its right,
- humans are less related to orang-utans than chimpanzees are related to orang-utans (because of differences in the number of intervening nodes), and
- chimpanzees came into being instantaneously at the point illustrated by the rightmost node.

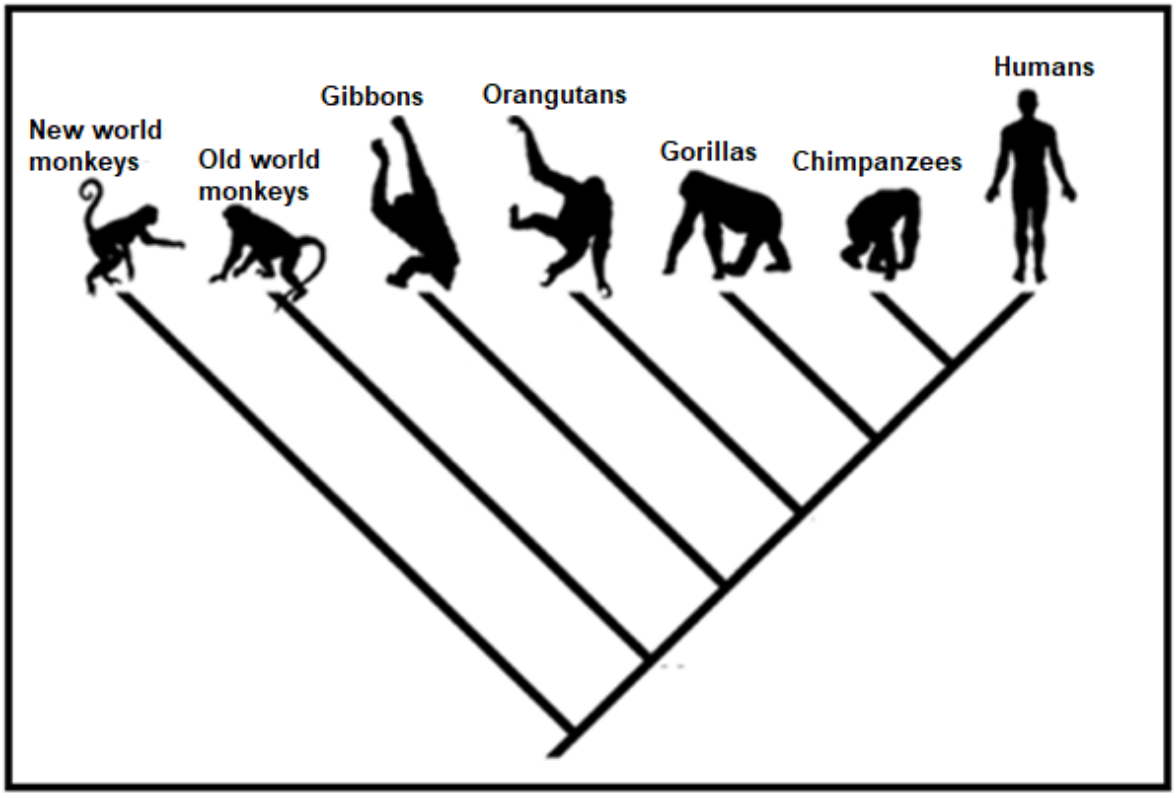


Figure 2.12: A cladogram depicting the phylogenetic relations amongst seven primates adapted from Gregory (2008) (Shtulman & Checa, 2012:30).

In this study, the university lecturer tried to address these misconceptions through inquiry-based learning. Learners had to observe the morphological differences, stone tools, genetic differences and used this to complete a phylogenetic tree. This tree was already drawn, and they had to place the different organisms in the relevant places. A lot of discussions were taking place during this part of the workshop. Every organism's place on the tree had to be discussed and this was done on a question-and-answer basis during the feedback session.

2.9.3 IMPROVEMENT IN GRADE 12 LEARNERS' PERFORMANCE

The DBE releases a National Diagnostic Report (NDR) on learner performance every year after the National Senior Certificate (NSC) examinations. It illuminates key observations in learner performance. Chief markers, internal moderators and subject specialists of all eleven provinces compile subject reports after the marking process had been completed, that outline qualitative data. All the questions per paper are analysed and common errors and misconceptions of learners are identified. This is done to assist teachers to correct these errors when they are teaching. Only the findings that are addressed by the workshop are stated in Table 2.6. The other findings are mainly addressing the fact that learners misinterpret or misread questions. They also have problems interpreting information from tables and graphs, which is a challenge identified in other topics as well.

Diagnostic report findings on common misconceptions regarding human evolution question in Life Sciences paper 2	**How it was addressed in the workshop**
The diagnostic report of the NSC 2017 outlined the following: • Most candidates knew the types of evidence used to support human evolution. However, some gave examples of cultural evidence, such as tools and this was not credited as the question asked for types of evidence and not examples	• The three types of evidence are clearly outlined on the worksheet. They are fossil evidence, genetic evidence and cultural evidence. This

• Candidates had difficulty in giving the correct response on how the brain volume of a fossil could be estimated. They could not distinguish between the skull and the cranium. Instead of measuring the volume of the cranium, they referred to size of the skull	was emphasised throughout the workshop • The first question in the workshop required learners to measure the craniums of each skull
The diagnostic report of NSC 2018 stated the following: • Many candidates failed to provide a definition for transitional species and they did not include intermediate characteristics in their explanation. Thus, they struggled to provide the structural features to support *Australopithecus* as a transitional species between the chimpanzee and *Homo sapiens* • They also compared different features, for example, teeth in one species and jaw shape in the other species as opposed to looking at a common feature in all three species e.g., considering the shape of the palate in *Australopithecus* and comparing it to that of the chimpanzee and *Homo sapiens*	One question requires learners to choose the intermediate species. They had to choose the pelvic bone that represents the transitional species They had to compare the different species' skulls and record the observable features in a table
The diagnostic report of NSC 2019 stated the following: • Many candidates received credit for 'increased brain size' but could not explain how this is related to intelligence. Instead, they gave examples of intelligence such as creative thinking and language development	Cranium size were related to intelligence and the sophistication of the stone tools. This was discussed during the feedback session

• Teachers must ensure that learners know the changes in the position of the foramen magnum as being 'more forward' in humans and 'more backward' in the African apes. No other description like central, bottom, middle or base of the cranium is acceptable as these descriptions are relative and have different interpretations • Teachers should emphasise the use of the phrase 'to allow the spinal cord to enter vertically' when explaining the significance of the more forward position of the foramen magnum in bipedalism • Learners must also know how the pelvis and the spine of humans and other primates contribute to bipedalism	The position of the foramen magnum was emphasised during the workshop as learners had to find each skull's foramen magnum and then describe the position in a table The position of the spine when entering the foramen magnum was explained before the workshop started to help learner identify which skulls represented bipedalism or quadrupedalism The learners had to compare three pelvic bones and choose whether they represented bipedalism or quadrupedalism

Table 2.6: How the workshop addressed the problematic topics identified in the national diagnostic report (DBE, 2018; DBE, 2019; DBE, 2020)

Obviously, we could not change these misconceptions on a national level, but we could address all these concepts in our workshop within the specific district..

CHAPTER 3
RESEARCH DESIGN

3.1 INTRODUCTION

This chapter addresses the methodology used in this study. Below follows (Figure 3.1) a flow chart outlining the chapter.

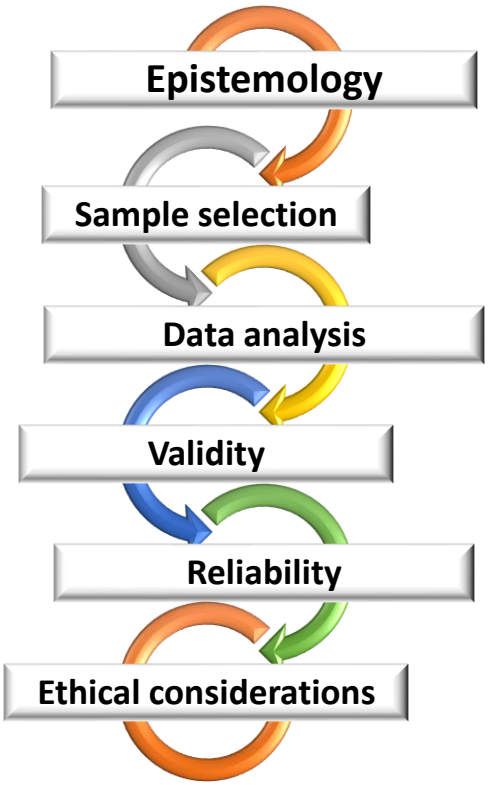


Figure 3.1: Flow chart outlining chapter 3

3.2 EPISTEMOLOGY

Epistemology deals with knowledge (Henning et al., 2004) and the way in which knowledge can be known. The framework or view that knowledge is seated in, is called a paradigm. This study was rooted in two paradigms, namely an interpretivist paradigm, as well as positivism. In interpretivist studies, the process is a lived experience and multiple realities are constructed socially by individuals (Merriam,

1998). Researchers are interested in understanding the experience of the participants, each having their own intentions beliefs, values and reasons (Henning et al., 2004). This type of approach to research is usually called qualitative research.

There was also an element of the positivist paradigm in this study, which is when knowledge stem from observation and measurement. A quantitative research approach is rooted in positivism. These are two opposing paradigms, but they were used together in this research study. Therefore, the mixed method was chosen as the design approach. Johnson & Onwuegbuzie (2004) stated that pragmatism could be used as a paradigm for mixed method research to help build a bridge across conflict between qualitative and quantitative research approaches. Pragmatism has the following characteristics:

- rejects traditional dualism such as facts vs. values,
- prefers moderate versions of philosophical dualisms based on how well they solve problems,
- recognises the importance of the social and physical world as well as the psychological world,
- place emphasis on the influence of the inner world of human experience,
- knowledge is viewed as being based on construction of the reality of the world we live in,
- supports the view that research conclusions are rarely viewed as perfect, certain or absolute,
- endorses different and conflicting theories and perspectives, and
- and human inquiry is viewed as being analogous to scientific inquiry (Johnson & Onwuegbuzie, 2004).

Mixed method research combines qualitative and quantitative research techniques, approaches and methods in a single research study (Creswell & Hirose, 2019; Johnson & Onwuegbuzie, 2004). Creswell (2009) stated that mixed methods was a good design to use, in order to build on the strengths of quantitative and qualitative data. Johnson and Turner (2003) proposed the fundamental principal of mixed method research as being the collection of multiple data using different strategies, approaches and methods to result in a comprehensive study with non-overlapping

weaknesses and complementary strengths. According to Johnson and Onwuegbuzie (2004), the strengths and weaknesses of a mixed method design were as follow:

Strengths:

- pictures, words and narrative can add meaning to numbers,
- numbers can add precision to words, narrative and pictures,
- provide both quantitative and qualitative research strengths,
- answer a more comprehensive range of questions,
- provide better evidence for a conclusion through the merging of findings, and
- the strengths of one method can overcome the weaknesses of the other method.

Weaknesses:

- could be difficult to carry out both qualitative and quantitative research concurrently,
- researcher has to know about multiple methods and approaches and be able to mix them appropriately,
- more expensive, and
- more time consuming.

In addition, Johnson and Onwuegbuzie (2004) put forward a mixed methods research process model. This process model was composed of eight steps, namely:

1. research questions are stated,
2. determine if mixed method is appropriate for the study,
3. select a specific mixed method research design,
4. data collection using the different methodologies,
5. data analysing using the different methodologies of data reduction, data correlation, consolidation and comparison,
6. interpreting data by integrating the different data sources to form a coherent whole,
7. legitimate data by ensuring trustworthiness and validity, and
8. draw a conclusion upon the data findings.

There are two kinds of mixed method research (Johnson & Onwuegbuzie, 2004). The first was mixed models research where quantitative and qualitative approaches were

mixed throughout the research. The second was mixed method where the research were divided into stages, namely a quantitative and qualitative stage. Creswell (2005) proposed a mixed model, named triangulation and later on Creswell & Plano Clark (2018) proposed two mixed methods called explanatory sequential design and exploratory sequential designs. Accordingly, there are three types of mixed method designs:

- triangulation mixed method design,
- explanatory sequential mixed methods design
- exploratory sequential mixed methods design and
- embedded mixed method design.

In the triangulation design (Creswell, 2005), the researcher collects both quantitative and qualitative data simultaneously, then the data from the two research approaches are cross-checked against each other and merged.. Equal priority is given to both quantitative and qualitative data... The fact that it merges the strengths of both qualitative and quantitative research designs is seen as a benefit of this design type. A weakness of this design is that it is difficult to translate one form of data into another to integrate and compare the databases. Inconsistent results may emerge which could result in additional data that has to be collected.

The explanatory sequential design (Creswell & Hirose, 2019, Creswell & Plano Clark, 2018) consists of two phases, where the quantitative data is collected first, followed by the collection of the qualitative data. The qualitative data is used to explain the quantitative results. Priority is placed on the quantitative data collection, and it is a major part of the data collection process. Researchers often present two phases in their study reports with clearly defined quantitative and qualitative parts. Qualitative data are used to refine the quantitative results.. This approach captures the best of qualitative and quantitative approaches. The exploratory sequential design (Creswell & Plano Clark, 2018) is when the researcher firstly gathers qualitative data and then quantitative to explain the trends that are present in the qualitative data. The qualitative data is emphasised in this design. The researcher presents the research in two separate phases. The qualitative exploration leads to detailed, generalisable findings through the second quantitative phase. The disadvantage of this approach is that extensive data collection is required (Creswell, 2005).

The mixed method design type chosen for this research study, was the embedded design (Creswell 2014,) and the quantitative and qualitative research designs were utilised concurrently (same as in the triangulation design). There was a quantitative aspect, such as a pre-test at the beginning of the research, followed by an intervention. During the intervention phase, qualitative data such as interviews and observations were gathered. This was followed by a post-test.. In this design type, either one of the qualitative or quantitative designs could be emphasised. The methodological approach fit this research well, as the aim of this research was to determine if and how this programme (intervention) had an influence on the learners attending the intervention. A diagrammatic depiction of the process followed for this particular research design is depicted in Figure 3.2. below:

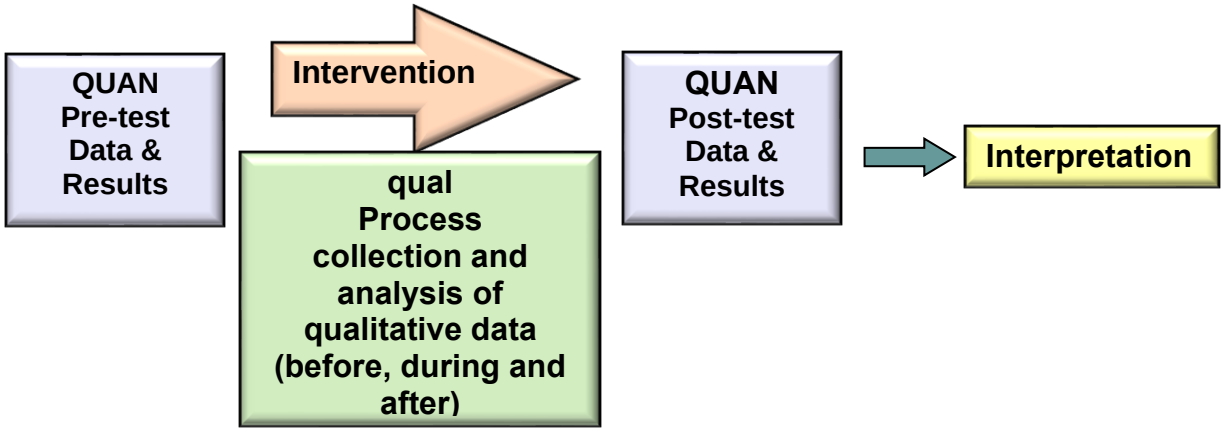


Figure 3.2: The Mixed Method Concurrent Embedded design for this research study.

The plan of this research

During this research, an intervention programme was done at a university palaeontology museum. The grade 12 learners attended the programme (workshop) and before the learners started with the workshop, they had to write a pre-test to determine their baseline knowledge about the topic. They then participated in a workshop, where they discovered the content through interactive inquiry-based learning. During and after the workshop, some learners and teachers were interviewed to ascertain their views on the workshop and the content, and to get a deeper understanding of their views. Observational data were obtained through field notes, video recordings and photos. After the intervention (workshop) finished, the learners wrote a post-test, and the results of these tests were used to determine if there was an improvement in the learners' scores, thus indicating that they had a

better understanding of the topic. Teachers and principals of the schools attending the programme, were interviewed afterwards to ascertain their overall views of the programme. The data from all the resources were triangulated and merged to establish the research findings.

3.5 SAMPLE SELECTION

Creswell (2009,2014) stated that a researcher had to decide at which level data will be collected. This level was referred to as the unit of analysis. In this study, learners, teachers and principals in one educational district were interviewed. Hence, the school district was the unit of analysis..

In this study, purposeful stratified sampling (Leavy, 2017) was chosen. In this type of sampling, the researcher divides the population based on specific characteristics and then use simple random sampling to get a sample from each subgroup (Creswell, 2005). In this research, the sample groups chosen were the different schools in the educational district. There were different types of schools in the district and schools were chosen to be representative of these various schools. Within each school, data was obtained from learners, teachers and principals.

3.5.1 PARTICIPANTS

The learners came from the same educational district. Learners from different types of schools were purposefully selected to determine how the workshop would impact on different types of learners. As previously stated, South Africa has different types of schools. Well-performing independent schools were not part of this study because there were none of these schools in the district used in this study . Two sets of public schools, namely ex-model C schools, which were privileged during apartheid; and township/rural schools that were previously disadvantaged were considered in this study. The ex-model C schools were usually well resourced and well-performing (De Beer & Ramnarain, 2012), while township schools still carried the burden of Apartheid (van der Berg, 2008). The township/rural schools were situated in poor communities,

and they usually did not have sufficient teaching resources and were often underperforming (Taylor, 2008).

The four ex-model C schools that were chosen for this study, were also different in cultural composition. Two of these schools used Afrikaans as the medium of instruction while the other two schools used English.. In the two English medium schools, most of the learners did not speak the English language at home; rather, English was a second or third language for them. All four of these schools were classified as well-performing schools and represented Black, Indian, Coloured, and White learners. Two of the schools had a majority of White learners with some Coloured and Indian learners. Two of the schools were mostly composed of Black learners, but also had a cohort of Coloured and Indian learners. The seven remaining schools were all from previously disadvantaged communities with a poor socioeconomic background and were composed of only Black learners. Learners from these schools were taught in English, which was often their second or third language. Only one school had English first language learners.

3.5.2 SITE SELECTION

The research took place at ESI WITS. The ESI housed a laboratory (Cate Druce lecture hall) where post-graduate students did their practicals. There was also a large underground storage facility in the same building, where the different type of animal and plant fossils were stored (Figure 3.3). The fossil preparation laboratory was also situated underground, and it was here where the technicians extracted fossils from the breccia. There was another laboratory, where local and international scientist worked on hominins found in South Africa.



Figure 3.3: A fossil collection in the fossil storage facility in the ESI.

Adjacent to the ESI building, was a museum (the Kitching Gallery) of South African fossils (Figure 3.4). This museum was developed by Dr Ian Mckay, who was also the lecturer involved in this study. There were many animals as well as plant fossils found in the museum, with descriptions of where they were found, and what their significance in evolution was. There were life-sized dinosaurs, such as the Afrovenator and the Tapinocaninus in the entrance hall (Figure 3.4. a-b). There were also life size models of a Gorgonopsian*, Aulacephalodon* and other extinct animals. The fossils that supported human evolution found in South Africa were also on display. For the purpose of this study, the learners were divided into two groups of sixty each. The first group would go to the museum, where they would take part in a 'treasure hunt' activity, while the other group would go to the laboratory (Cate Druce lecture hall).



Figure 3.4 a) The Afrovenator in entrance hall

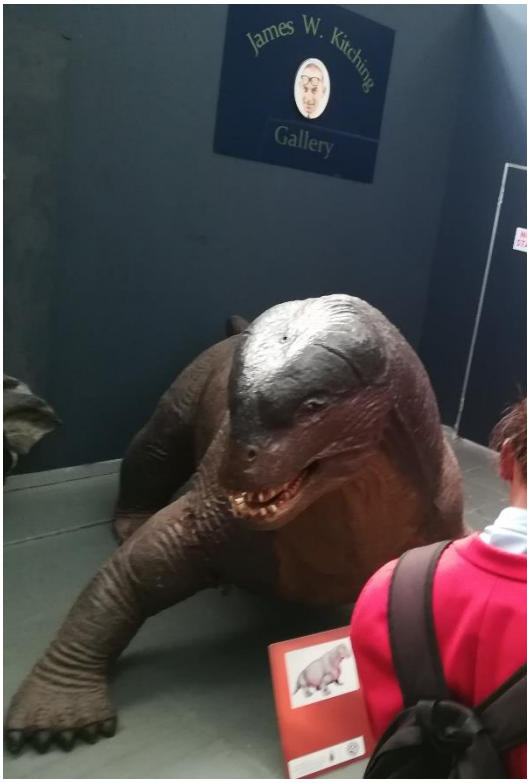


Figure 3.4 b) The Tapinocaninus in entrance hall



Figure 3.4 c) “George and Albert” second floor of museum



Figure 3.4. d)The *Dinocynodon* exhibition at second floor of museum.

The Cate Druce lecture hall was used for the workshop as the artefacts were also stored here. At the front of the laboratory, there was a white board, as well as a data projector that was used. The laboratory had long benches where the learners could work in groups (Figure 3.5). The learners were also taken to the fossil preparation laboratory where they could speak to the technicians and ask question about the extraction process. They were also able to see how the extraction is done.



Figure 3.5 a) Front view of Cate Druce lecture hall



Figure 3.5: b) View towards back of Cate Druce lecture hall.

During the second phase of the programme, it was decided that a different approach to the programme should be investigated. This decision was made after reflection on the interview data. The lecturer with some ESI staff went to schools and conducted the workshop at the schools. This was mostly done in large school halls and enough artefacts were brought along to conduct the workshop for a large group (Figure 3.6).



Figure 3.6 View from above of a typical school hall set-up, skulls in front

3.6 DATA COLLECTION

As previously stated, an embedded, mixed methods design was used in this study.. The data were cross checked, to reach more comprehensive findings. For example, in this project, quantitative data such as correct answers to content questions in pre- and post-tests were used to test the hypothesis that a PUMP will increase the learners' knowledge about the palaeosciences. Concurrent with this data, qualitative data such as semi-structured interviews, observation and open questions in the post-tests were used to explore the benefits of this PUMP to stimulate enthusiasm of learners and teachers for the programme, as well as investigate factors that impact on the schools' willingness to participate in field trips. It should also be noted that the

data was represented as a) data obtained: at museum-based workshops; b) from school-based workshops and c) a combination of these.

This investigation was seated in a sociocultural framework, hence particular attention was paid to how learners interact with one another, facilitators and objects. The cognitive and affective benefits of the programme were studied through observations, interviews and open-ended questions on the post-test. The influence of contextual factors such as the learner's sociocultural background, including the socioeconomic background of the school they came from, their mother tongue, and culture of the school with regards to field trips, was also investigated. Both quantitative and qualitative data were used in this research. Quantitative data is used for generalisation and qualitative data offers more in-depth information about the context and setting. The following methods were used to answer my research questions.

1. To ascertain factors that influence a school's willingness to send learners on a field trip, interviews were conducted with the principals in the educational district. They were asked what field trips the learners in their school have been on during the year, why those field trips were chosen, and what factors influenced those decisions. Teachers from each school participating in the PUMP field trips were interviewed on the same topic.
2. To establish whether the PUMP increases learners' content knowledge both quantitative and qualitative data sources were used. The data form the pre- and post-tests were used to determine if there was a difference in their performance. The essay question in a common examination was used to compare the scores between schools that attended the workshop and schools that did not attend the workshop. Semi-structured interviews with learners and teachers, and actual observation of the learners at work, were used as qualitative data sources. According to Creswell (2005), a pre-test measured characteristics of participants before an intervention; in this study, it measured the learners' content knowledge before the hands-on workshop. The post-test measured the same characteristic after the intervention; in this study, the learners' content knowledge after the hands-on workshop were measured. The pre- and post-tests had the same questions to measure whether there is an improvement in the learners' knowledge and understanding of the content. The post-test contained some questions addressing the affective domain, such as, what they enjoyed and how the

experience could be improved. The questions in the tests were based on terms used in the syllabus (CAPS document).

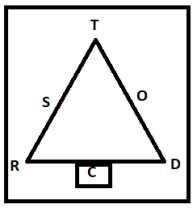
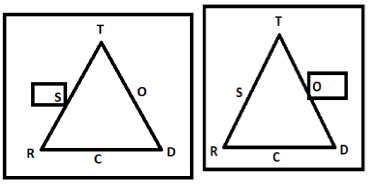
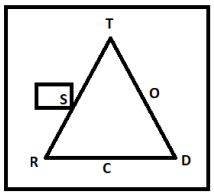
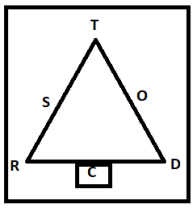
3. To establish whether the learners' enjoyment of the topic increased, qualitative data sources was used. A focus interview was held with some learners after the workshop, to obtain their views on the programme. The questions regarding enjoyment of the workshop in the post-test were analysed. The semi-structured interviews with the teachers were used to answer this question.

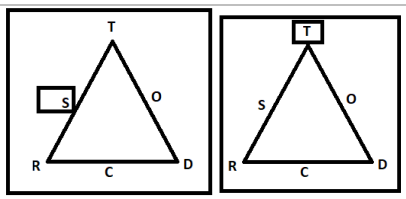
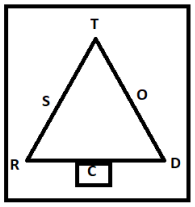
4. To evaluate the relative impact of the various sociocultural factors taking place during the activities at the PUMP, observations were done. Video clips of the feedback sessions and photos of the learners doing the activities were used as an observational tool. According to Borko *et al*. (2008), videos provide a viable and, in some ways, superior alternative to actually observing within a classroom setting. It could be paused, replayed and the researcher could focus attention on the specific aspects of importance. It allows the researcher the opportunity to reflect on certain scenarios without the real-time classroom interruptions.

5. Teacher's response to the programme were answered by conducting semi-structured interviews with teachers in attendance, to ascertain their view on the PUMP. They were asked about their preparation of the learners before the visit. Observations on their participation during the visit was analysed. Interviews were held with the museum educators to obtain their view on the effectiveness of programme. Some teachers were approached after time have lapsed to determine how the results of the learners compared to previous years. They were also asked what influence the programme had on the teaching of the topic compared to previous years.

6. The researcher and outreach staff reflected on the how PUMP changed over time as a result of feedback from learners, teachers and subject advisors *via* feedback from the pre- and post-tests, interviews and observation, and whether the changes have had a positive impact learner cognitive, affective and formal academic performance, as well as the participation of the teachers.

A summary of the research questions, tools, participants and which part of the CHAT system it addresses is found in Table 3.1 below:

Research questions	Data sources and participants
1. *How does planning of a fieldtrip, funding, logistics and syllabus coverage influence a school's willingness to send learners on fieldtrips?*	Semi-structured interviews with teachers and principals 
2. *Does the Palaeosciences University Museum Programme (PUMP) increase the learners' understanding of the knowledge strand; "Change, Diversity and Continuity" in Life Sciences?*	Pre-and post-tests Results of essay question in common examination in district. 
3. *Does the PUMP increase the enjoyment of learners for the Life Sciences' topics contained in the knowledge strand "Change, Diversity and Continuity" and Life Sciences in general?*	Focus interviews with learners Open-ended questions on post test 
4. How do teachers perceive the PUMP and how do they integrate it into their teaching programme?	Semi structured interviews with teachers 
5. *How is socio-cultural theory implemented in the PUMP?*	Observations of learners while they are doing the activities and during feedback

Research questions	Data sources and participants
	
6. Will a process of continuous reflective practice improve an education programme at a university-based museum?	Reflection sessions between lecturer and researcher. 

Tabel 3.1: Research questions linked with data sources and CHAT framework.

3.6.1 PRE- AND POST-TESTS

). Creswell (2014) stated that a pre-test measured a characteristic before a treatment, or in this case, an intervention. The post-test measured the same characteristic after the intervention. In this research, the instruments were achievement pre- and post-tests that were used to measure learners' achievements before and after an intervention. This intervention or workshop was unique in the sense that it was adapted to suit the grade 12 curricula in South Africa. There were no standardised instruments available to use to determine what learners understood and what they did not understand. The instrument was designed with time allocation in mind. The learners were given questions with multiple possible answers, and they had to choose the correct ones. The questions were based on the content covered in the workshop. The pre-and post-test were the same. Multiple choice made it easier for learners as the terminology was still new to them. The following questions were asked in the tests to determine learners' knowledge about the topic prior to the workshop:

1. Circle **two** characteristics that all hominins have in common (circle the correct answers)
   a) Naked skin
   b) large brains
   c) walked upright
   d) walked on all fours
   e) large canines
   f) small canines

2. Which of the following are not hominin? (Could be more than one)
   a) *Homo sapiens*
   b) *Pan troglodytes*
   c) *Australopithecus africanus*
   d) *Australopithecus sediba*
   e) *Gorilla gorilla*
3. The evidence used by scientists to study evolution of hominins
   a) cave paintings and comparative cultural evidence like tools
   b) fossils, genetics, and comparative cultural evidence like tools
   c) graves, genetics and cave paintings
   d) fossils, graves, and genetics
   e) genetics, cave painting, and fossils

4. The foramen magnum of a habitually upright walking hominin is:
   a) at the back of the spine
   b) more towards the front of the base of the skull
   c) more towards the back of the base of the skull
   d) on top of the skull
   e) at the base of the spine

5. The hominin with very small eye-brow ridges:
   a) *Australopithecus africanus*
   b) *Homo erectus*
   c) *Homo sapiens*
   d) *Australopithecus sediba*
   e) Pan troglodytes

6. In your opinion, did humans evolve from other species of animals?
   a) Strongly disagree
   b) Disagree
   c) Neither agree or disagree
   d) Agree
   e) Strongly agree

The first two questions dealt with the first part of the workshop where the difference between hominin and hominid was discussed. The third question dealt with the main topics of the workshop, namely the three types of evidence scientists use as evidence for human evolution. Questions four and five dealt with the evidence the learners had to measure and observe. Question six was concerned with learners' view on human evolution before and after the workshop. The purpose was to determine whether there was a change in learners' opinions after they have seen the evidence supporting human evolutions.

The second part of the quantitative data that were used, was the essay question that was asked on human evolution in the preliminary examination during the first year of the study. The question expected learners to describe the characteristics of the skull of *Homo sapiens* that differentiates them from African apes. They had to explain how the differences in the human skeleton and that of the African apes results in different modes of locomotion

3.6.2 INTERVIEWS

The interviews used in this research were less structured.. Open-ended questions (which were used in this research) allow participants to create more options for responding (Creswell, 2009). The interviews for this study took a conversational tone and questions that were linked to the research questions were used. Some of the advantages were that the researcher obtained useful information and allowed the participants to describe detailed personal information. The interviewer had more control over the information because the interviewer decided on the types of questions to ask. Some disadvantages were that the information was 'filtered' through the views of the researcher and the data may reflect the perspective that the participant wanted the interviewer to hear.

Focus group interviews were conducted with groups of up to six learners. One of the main features of this type of interview is social interactions within the group of interviewees and the type and range of data generated as a result.. Creswell,(2005) stated that they were useful when time was limited, and participants were hesitant to provide information)., Taylor *et al*. (2016) suggested between 5 and 10 participants, while Creswell (2005) argued for four to six participants.. In this study, the average group size was four to six learners.

Semi- structured interviews usually contain a mix of structured and less structured questions. The researcher has a list of question that can be explored, but it allows the interviewer to adapt to the unfolding situation. The interviewer can probe deeper with follow up questions. Care was taken not to ask leading questions. Semi-structured interviews were conducted with the teachers and principals of the schools attending the workshop.

The focus group interviews were held in an informal setting and the learners were asked to volunteer. Only learners who volunteered were interviewed. The main questions were as follow:

- What did you expect would happen today (what did your teacher tell you about today)?
- What did you enjoy about today?
- What didn't you enjoy about today?
- Are there any improvements that you would suggest for this workshop?
- Would you ever bring your own children to a science museum like this one?
- Do you think that humans evolved from animals?

.

Semi-structured interviews with the principals were more concerned with the first research question, namely, the reasons whether or not to send learners on field trips. The list of questions asked during these interviews were as follow:

- Do you allow the learners at your school to go on educational field trips?
- What type of field trips did your learners attend this year?
- What are the challenges with sending learners on an educational field trip?

The semi-structured interviews with the teachers were conducted during the workshop in the museum or long afterwards, to determine what the long-term effect was. They were asked whether they thought the programme was beneficial for their learners and to give reasons for their answer. The interviews were the main source of qualitative data for this research. The follow up interview questions were as follow:

- Did you see a difference when teaching this topic between the learners attending the workshop this year and learners' previous years who didn't attend the workshop?
- What are the differences if there are any?

3.6.3 OBSERVATIONS

Creswell (2014) noted that qualitative observation was when a researcher took field notes of a specific phenomenon and that it was usually done in an open-ended manner. According to Creswell (2005:211), there were three observation roles, namely:

- participant observer – the observer is part of the activities during the research and write down notes after the intervention. The observer becomes an insider,
- nonparticipant observer – the observer does not participate in the activities. The activities are observed, and notes are recorded. The observer is an outsider who remains on the periphery,
- changing observational roles – researcher changes roles between strictly participatory or nonparticipator. Engaging in both roles permits the researcher to be subjectively involved in the setting, but also viewing the setting more objectively.

The changing observational roles were chosen for this research No formal observation protocol was followed. During the workshop observations were made concerning:

- learners' involvement/interest in the activity,
- whether they asked for assistance from the lecturer or university assistants and what kind of questions they asked,
- whether they participated in the discussion during the feedback session, and
- if they took notes during feedback session.

. Handwritten observation notes were made by the researcher as well as

photos of the activity and video recordings of the feedback session.. Taylor *et al*. (2016) stated that photos and videotape equipment could capture details that would otherwise be forgotten or go unnoticed. Pirie (1996) stated that audio visual recordings were a way of capturing everything that was taking place and allowed the researcher to postpone the moment of focusing and decision-making. It gave researchers the opportunity to revisit the aspect of the classroom that were recorded, allowing more time to reflect on the events. Video clips allowed the researcher to look for anything that could influence the intervention.. .

. The recordings of the feedback sessions were viewed afterwards, and observations notes were made.

3.7 DATA ANALYSIS

Creswell (2014) stated that in using mixed methods, a researcher could choose to integrate the data from quantitative and qualitative methods at analysis-level or not. A concurrent embedded mixed method design was chosen for this study. The mixing of data from the two data sources usually take place in the interpretation section. A popular way is to state the outcomes of the quantitative data, and then follow it up with the qualitative data that support or disproof the quantitative results.

The data from the quantitative sources and qualitative sources in this study were not integrated at the analysis level, but only at the interpretation level where the qualitative data was used to provide supportive information for the quantitative data. Hence, the secondary data, which were different from the primary data, were embedded in the larger study (Creswell, 2009). Embedding also meant that the secondary method addressed a different research question than the primary method, the quantitative data addressed the outcomes of the research, while the qualitative explored the process experienced by the participants.

The quantitative data were analysed to answer the question two on whether the PUMP intervention improved learner's understanding in the topic human evolution. The qualitative data were used to answer the remaining questions. The role of the data in the activity system can be viewed in Figure 3.7 below. The analysis of the qualitative data will be discussed afterwards.

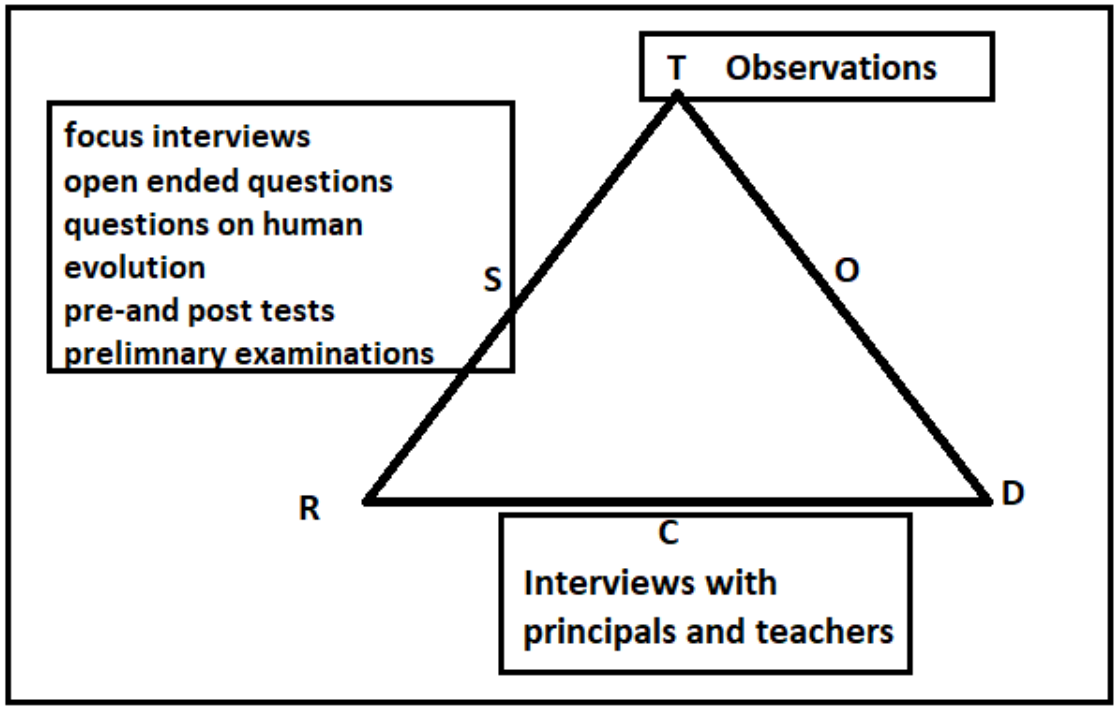


Figure 3.7: Data analysis placement in CHAT framework

3.7.1 QUALITATIVE DATA

The interviews and observation notes were transcribed and coded inductively. Codes are the use of words, codes or labels to assign meaning to descriptive information (Creswell, 2014; Miles *et al*. 2014;, Taylor *et al*., 2016). Coding is an exploratory problem-solving technique and it's only the first step towards an analysis and interpretation of data to write a report (Miles *et al*., 2014; Saldana, 2009). It is not just labelling; it is the linking of concepts. It is also a cyclic act; the first cycle of coding data is rarely perfect, and it should be followed by a second and possibly a third phase, which further narrows down and focuses salient features.

In this study, two types of coding were used during the first phase of coding, namely in vivo coding and evaluation. Saldana (2009,2013) contended that in vivo coding was appropriate for all qualitative studies and that it honoured the participant's voice. It could be used alongside other methods of coding. In vivo coding was useful with educational studies to understand the view of learners, because coding used their actual words deepening the understanding of their cultures and worldviews. In vivo codes may help to "crystallise and condense meanings" (Charmaz, 2006:57), as well

as to “preserve participants’ meanings of their views” (Charmaz, 2006:55). It could provide imagery and metaphors for rich category, theme and concept development (Saldana, 2009).

Another type of coding used was evaluation coding. This was the application of non-quantitative codes to assign judgments about the merit and worth of programs (Rallis & Rossman, 2003:492). Patton (2002:492) contended that programme evaluation was to make judgements about the programme, improve the programme effectiveness or to inform decisions concerning the future of the programme. Evaluation codes were appropriate for evaluation studies, particularly across multiples sites and extended periods of time (Saldana, 2009). It could emerge from the commentary provided by the participants and this coding could be supplemented by other coding methods. Evaluation data could be obtained from participant observation, focus interviews and individual interviews. Individuals had their opinions, which would result in a wide range of responses.

Second phase coding followed initial coding, and the purpose was to develop a conceptual and thematic organisation of the first phase of codes. The codes were reorganised to eventually develop smaller and a more select group of broader categories and themes (Saldana, 2009:149). Focused coding was used in the second phase of this research, and its purpose was to search for the most frequent or notable codes to develop “the most salient categories" in the data corpus and "requires decisions about initial codes make the most analytic sense" (Charmaz, 2006:46).

Focused coding per Saldana (2009), was when similar data codes were clustered together and reviewed to create category names. Furthermore, it enables the researcher to compare newly constructed codes across other participants’ data to assess how they compared and whether they were transferable. The individual interviews, focus interviews and observations notes were transcribed and coded. From the codes, categories were developed, and the similar categories were grouped together into themes. Methodological triangulation (Denzin & Lincoln, 2018) was used, and the main sources of qualitative data were compared to determine if there were similar results and from these sources the main themes were developed. These themes were used to answer the research questions one, three and four.

3.7.2 QUANTITATIVE DATA

There are two datasets in this research, namely the data from pre- and post-tests taken from the same group of learners. The data were statistically analysed to describe trends in data. A paired two tailed t-test was used to determine whether the results are statistically significant. The means of both tests, as well as the standard deviation were calculated. The question in the preliminary examination was analysed using the unpaired two tailed t-test. These were two different groups, namely one that attended the workshop, and one that didn't attend the workshop.

3.8 VALIDITY

Creswell (2014) defined validity as the accuracy of the results according to the viewpoint of the researcher, participant and readers.. Babbie (2008:343) states that it is the extent to which the true meaning of a concept being research is being empirically measured. A qualitative researcher explores multiple realities and needs to represent these realities correctly. Eisenhart and Howe (1992) put forward standards that ensured validity in educational settings. Firstly, the data collection and analysis procedures should fit the research questions. In this study, the qualitative research questions were addressed by interviews and observations that were subsequently coded and reduced to themes. The quantitative question was addressed by using pre-and post-tests, as well as a standardised test. The results were compared statistically. Standard two is addressing whether the data collection and analysis methods are effectively applied. The qualitative data was analysed inductively to fit the interpretivist sociocultural theoretical framework. The quantitative data were used to analyse the effectiveness of the intervention. Standard three is about the coherence of prior knowledge and to eliminate researcher bias. As the district subject facilitator in this particular district, I was aware of my own bias towards the schools. I had to overcome my own bias and not allow it to interfere with the data analysis. This was done through continuous reflexivity and discussions with my former study leader. Standard four is about the discussions of the worth of the study. This study contributes to the development of workshops at ISE that would assist in teaching relevant content to learners, as well as contributing to the development of

South African teachers. It also highlights the logistical challenges that schools have with field trips, which could assist schools and ISE in future to understand the challenges and find solutions. The last standard addresses the comprehensiveness, as well as the technical and theoretical quality of the research. Outside knowledge and perspectives should be incorporated in a research study. The theoretical framework used in this study, provide the different perspectives. Merriam (2002) differentiate between external and internal validity. Internal validity asks if the results are in line with reality. The strategies used to ensure internal validity are peer-review, member checks and data obtained over a long enough period and triangulation. In this study, the observations were discussed with my former study leader. I was not able to do member checks with the learners and teachers regarding the transcripts of the interviews. Peer-review was done by sending some of the transcripts with it codes to my former study leader, who gave me feedback on the validity of my themes. The themes from the observations and interviews were triangulated to determine whether they compare, and main themes were developed to describe the data. External validity or generalisability was ensured by making a rich, thick description (Creswell, 2014) of the context of the study. This made it clear for other researchers whether they could duplicate the findings in their own research settings. In this research, the participants and the site of research were discussed in detail. Photos were included to assist readers visualise the context of the study.

The quantitative part of the study made use of a pre-and post-test. Content validity (Creswell, 2005) was the degree to which questions were representative of all the possible questions that could be asked. In this research study, I included a question from all the topics that were covered. I used the pre-and post-test as a pilot on two groups of learners. I checked whether there were questions that all learners generally left out in post-test, or if learners couldn't answer all the questions due to fatigue. I found that the tests were adequately timed, and it did not take too long to answer. There was no question in the post tests that the majority of the learners could not answer. The pre-tests were also checked for questions that were too easy, and there were no questions that were correctly answered by all the learners.

3.9 RELIABILITY

Reliability refers to research being sound in relation to the appropriate methods chosen, and how those methods were applied and implemented in qualitative research. (Rose & Johnson, 2020). The processes within the study should be addressed in detail for other researchers to obtain the same results in future Shenton (2004). Hence, the research design and its implementations should be outlined and discussed in detail. The researcher should provide a comprehensive description of how data were collected. Documenting the different steps during the research and checking of transcripts for mistakes as well as checking the code's meanings stay consistent is part of ensuring reliability (Creswell, 2009,2014).

In this research study, the correctness of the transcript was done using a digital recorder during the interviews. Similar questions were asked during the different types of interviews. Some parts of the workshops were also recorded which ensured that the observations could be double-checked for correctness. Reflective appraisal of the research helps to evaluate the reliability of the process. I made reflective notes throughout the process, as well as some reflective audio recordings. Part of reliability is the description of the data collection and what happened in the field. The photos included in the chapter helps the reader to visualise the sites and artefacts. This rich description contributed to the reliability and generalisability of this study.

With the quantitative data, the test-retest reliability (Creswell & Creswell, 2018) was used. According to the authors, reliable instruments deliver scores that are stable and consistent. It should be nearly the same when administrated at different times. This study ran over a two-year span and multiple groups of learners were tested. The values stayed consistent.

The statistical significance of the data was obtained by calculating the p-value using the two-tailed t-test. The p-value indicates that probability that the data was obtained randomly (McLeod, 2019). A critical value (α) of 0.05, usually chosen by statisticians (Bhatti & Kim, 2020), was chosen and a p-value smaller than this indicates greater statistical significance as there is only a 5% chance of the null hypothesis being accepted. The reason for using a two-tailed t-test was that the difference between the scores of one group of people were taken at different times and the sample group

was greater than 30 (Creswell & Creswell, 2018). The null hypothesis was that there would be no difference between the means (μ) of the two scores.

H_0: $\mu_1 = \mu_2$

The alternative hypothesis was that there would be a difference between the means of the two scores, namely, the post-test scores' mean would be greater than the pre-test scores.

H_1: $\mu_1 < \mu_2$

The confidence interval was also calculated, and it indicates the range of values that indicate 95% confidence that it contains the true mean of the populations (McLeod, 2021).

3.10 ETHICAL CONSIDERATIONS

Permission to conduct this research study was obtained from the Gauteng Department of Education. Permission was also obtained from Wits, Reference number: HRECN18-04-017 and the ESI to conduct the research. Informed consent is an integral part of a study (Creswell, 2014), and the institution/university where the study takes place has an ethics revision board that reviews each research study's ethical background (Pillay, 2011). Ethics review boards play an important role in the entire research process (Connelly, 2014, Lautenbach & Batchelor, 2013).

Orb and colleagues (2000) stated that participants' autonomy should be respected, and that they should be able to exercise their rights to voluntary participate or refuse to be part of a in a research study. The participants should receive information about the research, understand what is expected of them and understand what it is that they are giving consent to (Creswell, 2014; Pillay, 2011;; Orb *et al*., 2000).

Each learner had to complete a learner's assent form composed of two parts. Firstly, the project was explained. Secondly, their permission to; write a pre-and post-test, be part of a voluntary focus interview, be photographed and videotaped were asked. They had to tick separate boxes (yes or no) for each part of the research. Some of the learners were not eighteen years old yet, so the parents of every learner also had

to sign a consent form where the project was explained, and permission was asked for their child to write a pre-and post-test, take part in a focus group interview and be photographed and videotaped for research purposes. The parents also had to tick the appropriate boxes indicating what parts of the research they approved of and which parts they did not.

Every principal received an information pamphlet on the research and workshop and had to sign a permission form giving me permission to conduct research with his/her school learners. Interviews were also held with some of the principals, and they were asked to give verbal consent at the beginning of the interview. Each teacher that was interviewed had to sign a consent form to be interviewed, but they were also asked to give verbal consent when the interview started. The principals were also asked permission to use their school's previous years' grade 12 learners' preliminary examinations scripts for research purposes.

Before I started with the focus interview, I would ask the group of learners for volunteers to be part of the focus group interview. I would explain briefly what the purpose of the interview was and what type of questions I would ask. The volunteers would then accompany me to a quiet place where I could record the interview. I explained to them that they did not have to answer a question if they didn't feel comfortable and was permitted to leave whenever they felt like it.

During the workshop and museum sessions, I would approach a group of learners and ask them if I could take a photograph of them. If they did not want to be photographed, I did not take a photo of that group. The same applied to the video recordings of the feedback sessions. I made sure that no learner was videotaped that did not give permission to be videotaped. All the photos placed in this thesis were taken with the consent from the learners and their parents.

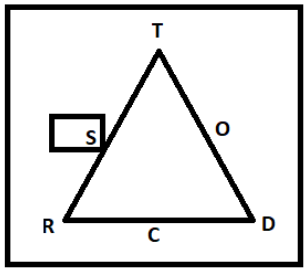
Another part of ethical consideration is anonymity (Orb *et al*. 2000). The privacy and confidentiality of individuals in study should be protected (; Babbie, 2008; Creswell, 2014). The learners' names were not used on the pre-and post-tests, and they were given random chosen numbers. The learners that were part of the focus interview were not asked their names. The teachers and principals' names, the names of their schools and the district were not used in this thesis. Hence, total anonymity was guaranteed. The photos placed were done with the permission of the learners and

nowhere are their names or the names of their schools used to identify them. As part of the information in the consent/assent forms, they were told that the photos could be used for research purposes and placed in academic research papers. No harm should be done to any participant during a research study (Creswell, 2014; Babbie, 2008; Pillay, 2011;). No participants were forced to participate in this research, no harm was done to any participant and as previously stated, if they did not want to answer questions they were not forced to do so.

CHAPTER 4
DATA ANALYSIS

4.1 INTRODUCTION

In this chapter, the results of my study will be discussed. I will be guided by the CHAT framework (Chapter 2) to present my results, while ensuring that both activity centres' data are woven in throughout.



4.2 SUBJECT

In this section, I will present the impressions of the learners and their views on the workshop. The data obtained through interviews with learners and the multiple-choice question as well as the open-ended questions on the post-test will be used in this section.

4.2.1. ENJOYMENT OF THE WORKSHOP

The post-test contained a multiple-choice question, which asked the learners if they enjoyed the activity. They were given the following options:

a) Very enjoyable
b) Enjoyable
c) It was ok
d) I did not enjoy it
e) Hated it

The data (Table 4.1) show that, overall, 32% of 596 learners found the workshop very enjoyable, and 41% found it enjoyable (a total of 73%). There was a difference

between the enjoyment of the workshop at school-based or university-based workshops. More learners found the workshop very enjoyable or enjoyable at the university (79%) compared to the school-based workshops (66%). More learners were indifferent about the school-based workshops (30%) than the university-based workshops (18%). This could possibly be explained by the fact that there are many factors impacting on a workshop. When the learners attended the workshop at the university, they had social interaction with their friends on the bus while they were travelling to the university. The learners were also excited because it is a university environment, and not the usual school environment. The learners experienced the museum and fossil extraction laboratory at the university. In contrast, at school-based workshops, the learners had to attend a full day of school, followed by the workshop in the afternoon at school. There was no time for social interaction or experiencing a museum, seeing all the fascinating exhibits. Many learners appeared tired, and some were complaining that they were hungry. We had to stop one workshop to allow learners to buy food. The reason for conducting the workshop after school was that principals indicated that they did not want learners to lose teaching time.

Venue of workshop	Very enjoyable	Enjoyable	Was ok	Not enjoyable	Hated it
Workshop at school (n=297)	**82** (27.6%)	**115** (38.7%)	**90** (30.0%)	**8** (2.75%)	**2** (0.7%)
Workshop at museum (n=299)	**106** (35.5%)	**131** (43.8%)	**54** (18%)	**6** (2%)	**2** (0.7%)
Total (n= 596)	**188 (31.5%)**	**246 (41.3%)**	**144 (24.2%)**	**14 (2.3%)**	**4 (0.7%)**

Table 4.1: Summary of results obtained from the post-test multiple-choice question on enjoyment of the workshop

4.2.2. INTERVIEWS WITH LEARNERS

I will present the interview data in three sections, namely interviews at Wits, school-based workshop interviews, and combined. The interview process was as follow: at first, the learners were put at ease and the aim of the interview was explained to them. They were also asked if they had a problem if the interview was audio recorded, and that they could leave at any time. Usually, I would start with the first question and

ask the learner on one end to start. If they did not feel comfortable in answering, I would move to the next learner. Sometimes I would ask the question and then ask who wanted to answer. It depended on the group of learners, as some of them were shy and often it was challenging to get them talking. Other times it was easy, and they couldn't wait their turn.

Table 4.2 contains the codes that were obtained inductively whilst analysing the interview data and answers on the post-tests.

Code	Code description
W1	Enjoyed it because it was hands-on/interactive
W2	Better than textbook/teacher/lecture
W3	Enjoyed comparing the different skulls/pelvises
W4	Better/deeper understanding
W5	Interesting/exciting
W6	Enjoyable/fun
W7	Learnt something new/learnt about evolution/learnt a lot
W8	Beneficial/helpful/educational
W 10	Didn't enjoy workshop/explanation/it was boring
W 11	Good explanation by facilitator
W 12	Questions were answered
W 13	Presentation /explanation not good/change presentation style
W 14	Not my interest
W 15	Worksheet is good/questions on worksheet clear/simple
W 16	Will help with the exams
W 17	Enjoyed social interaction/group work
W 18	Add more fun activities
W 19	Want to learn more/motivated me
W 20	Should do content at school before the workshop
W 21	Need a better venue than the school

Table 4.2: The codes and code description

4.2.2.1. Interviews with learners at Wits

At Wits, learners were asked more questions about the excursion. They were asked the following questions:

1. What did you expect would happen today?
2. What did you enjoy most about today?
3. Would you change anything about the excursion and is so, what would you change?
4. How did you find the workshop?

5. Would you return to a science museum, and would you bring your own children here someday?
6. Do you believe humans evolved from animals/had a common ancestor with animals (this question will be dealt with under the section object below).

From the nine schools that visited Wits, 18 learners were interviewed. It should be noted that the university-based and school-based interviews were transcribed and inductively coded together. Hence, some of the codes did not appear in the answers received at Wits, compared to the once obtained at schools. Please note that graph (Figure 4.1) summarises the codes obtained at Wits university.

Learners' expectations

The learners were asked what their teachers told them to expect concerning the excursion. Of the 18 learners interviewed, 94% indicated that their expectations were met by the workshop. The following quote illustrate this view of learners:

> "Our teacher told us that we will be doing evolution today. I expected that we would interact with skulls and craniums and such things, and that is what we interacted with, and it was the nicest part of the day "

What learners enjoyed

All the learners interviewed felt that the excursion was beneficial. Fifty six percent of the learners indicated that they found the workshop the most interesting part of the day, as could be seen from the following quotes:

> "There was so much information which we could learn, it is extremely interesting. I also liked holding the fossils in my hands and looking at them"

> "Yes, and evolution, I didn't know how the different bone structures look and the pelvis, I didn't expect it. It was very nice"

> "I actually enjoyed the science lab, measuring skulls and learning more about the tools and evidence that the scientists use to explain evolution"

> "Also, the activities that we participated in, they taught us some things that we are going to do in the curriculum"

Some learners (22%) indicated that the fossil laboratory was the most interesting component, and 17% enjoyed the museum treasure hunt the most, as can be seen from the quotes:

> "The careful way the fossils are removed, without being damaged so that they can be studied in detail"

> "The way they cut and scrape the fossils from the stone. It was very interesting"

> "I would say it was the fossils that they were removing from the rock, but also the museum. We could look at the computer where they explained how they used the skeleton to construct Frieda"

> "I actually enjoyed the museum and the workshop; we got to learn about dinosaurs and mammals that look like dinosaurs. Then we learnt about human evolution. It was enjoyable the whole session was enjoyable

> "The museum was very nice…because it was colourful, we are bound to remember it"

> "I enjoyed the museum because I've got to learn about some of the stuff that I did not know about like the mammals. The museum guy told us that there are three types of mammals, but I only remember two. I enjoyed the museum we got to see the species that lived before like the dinosaurs. It was pretty cool"

Recommendations to improve the workshop

Learners were asked if there was anything that they would change about the workshop. Most learners (89%) indicated that the workshop should be left unchanged. Below follows one of the learners' comments:

> "I think it's a great programme, it should like stay this way, I don't feel like there is anything that needs to be changed, I enjoyed myself"

One learner indicated that the workshop should be allocated more time, while another learner said that it was too long. Seventeen percent indicated that the facilitator explained/discussed too much at the end, and that they would've liked more activities instead, as could be seen from the quote below:

> "You can keep it as is for the most part, just add more interactive stuff and don't explain as much"

Learners' views of the workshop

The learners' answers on their views of the workshop were analysed inductively and ten codes were obtained (Figure 4.1). It should be noted that no learners indicated that they didn't enjoy the workshop. The most frequent code (50%) was that the workshop was hands-on (W1). Learners felt that this was a beneficial trait, as could be seen from the following quotes:

> "I got to feel the shape of the skull of the Erectus and Mrs Ples, yah that was beneficial"

> "For me it was the hands-on experience with the skulls and the bones. I could put them next to each other and compare and understand how one differs from the other. For me this was wow"

The second most frequent code (33%) was that they felt they learnt something new or learnt something about evolution. Furthermore, two learners indicated that it gave them a deeper understanding of the topic. Two learners indicated that it was better than a textbook or a lecture, while two learners felt that it was interesting. This could be seen from the following quotes (the last quote also alluded to mediation during the activity):

> "I've learnt, I've learnt a lot. I feel like the information they gave were very beneficial, because the textbooks don't give you that. They just tell you what happened and why it happened and that's it. So, the actual information was very beneficial"

> "The information was very beneficial because if it was just words information like in my textbooks I wouldn't remember."

> "I also feel like you know it's not the same as when a teacher is standing in front in class and explaining all these things for us. This experience is better because you get to experience everything for yourself."

> “During the practical session someone explained parts of the evolution of the skulls and while we worked with the information, we gained a better understanding.”

Sixteen percent of learners indicated that the whole excursion was enjoyable and could not choose between the laboratory, museum or fossil extraction laboratory.

> “We enjoyed every moment because we came here to learn more about those things. So far everything went fine, and we enjoyed it. We learnt more about evolution”

One learner indicated that he/she got confused with the brain volume measurements. He/she did not understand why we used the string and what the 32/34 cm^3 meant. I quickly explained that it was an easy method used to compare the brain sizes, and that the measurements were not very accurate. Brain volume is usually measured in cubic volume (cm^3), but that this will not be possible in a workshop scenario. The other learners also chimed in and said that the volume in cm^3 concept was discussed in the workshop. The learner then indicated that this is what caused the confusion because he/she didn’t understand how cm^3 and cm relate to each other.

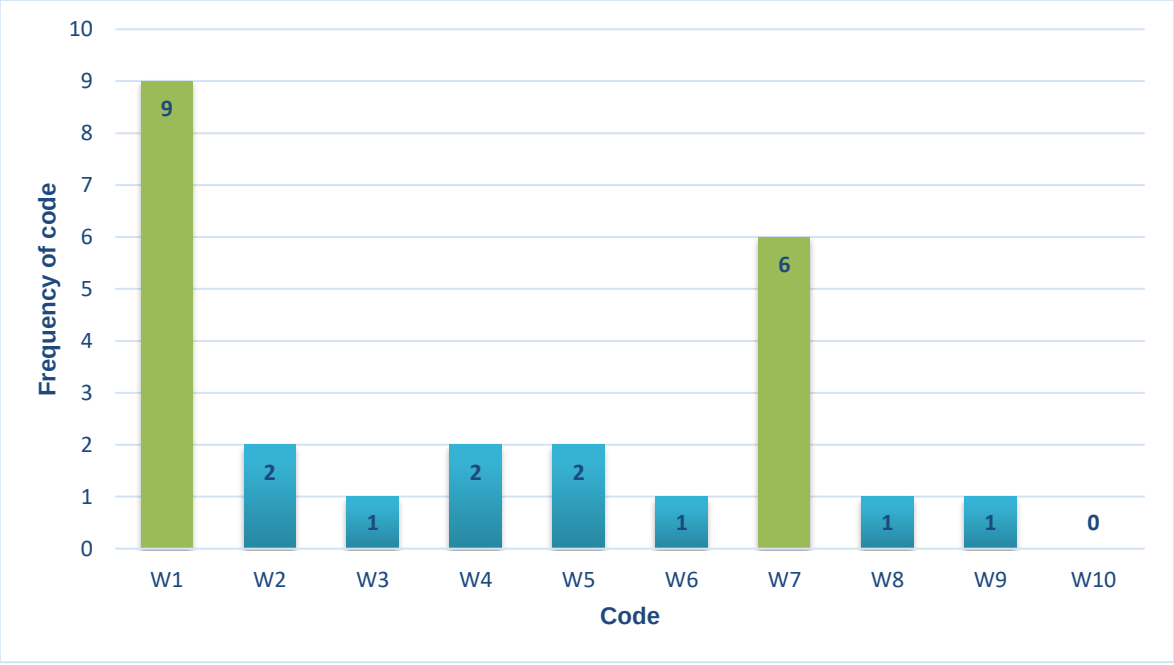


Figure 4.1: Frequency of codes found in interviews with learners at university museum (n=18)

Returning to a Science Museum

All the learners responded positively to this question. The majority said that they enjoyed it. Eleven learners indicated that they would return to a science museum and four indicated that they would bring their own children to a science museum one day.

> "This palaeontology museum, I'm not really interested in evolution and stuff, before today I would never have come, I would've gone to a chemistry museum or something like that. So, after today I would"

4.2.2.2 Interviews with learners at school-based workshops

The workshops that were conducted at school did not have the excursion element to it. As a result, their views on the museum, fossil preparation laboratory or if they would bring their children to a science museum one day, could not be asked. A total of 33 learners were interviewed at these workshops. The graph in Figure 4.2 summarises the codes obtained at these workshops.

These learners were asked the following two questions:

1. How do you feel about today's workshop? Do you feel that you've benefited or not?
2. Do you think that humans had a common ancestor with other animals?

As indicated in Figure 4.2, the most frequent answer (W7) was that the learners felt they learnt something new, or learnt about evolution, followed by the workshop caused a deeper/better understanding of the content (W4). Only one learner indicated that she/he got confused or didn't understand the content. The positive feedback (W7) is reflected in the following quotes:

> "It was enjoyable, and we learnt and it was more information about things that we didn't know"

> "It was beneficial because it taught a lot of people things they didn't know"

> "It expanded my mindset, that is all I can say to know more about where humans come from and possibly maybe where we are going and how it won't stay the same. From what we are now and how we weren't the same in the beginning and we won't be the same as right now"

The positive outcomes of the second frequent code (W4) are reflected in the following quotes:

> “It definitely helped, in the sense that we have more clarity on the different types of fossils that was there. It would have been more difficult if we didn’t have the different fossils with us, so I found it very helpful”

> “It is a practical way to see what we will be learning; it will shorten the learning time. We would’ve memorised this in parrot like fashion, but now we will understand in in a deeper way”

Many learners indicated that they enjoyed the workshop (W6). This could be seen by the following quotes:

> “It was fun, and I really enjoyed it. I enjoyed working with the people and gaining knowledge and maybe I would like to pursue it as a career”

> “It was pretty enjoyable, and informative and interesting. Especially the part when we asked questions and we actually got answered. It helped us to understand the knowledge more”

The fourth most frequent answer was that learners thought the workshop was beneficial (W8). The following quotes helps to illustrate this point.

> “It was very beneficial. we learnt things that we didn’t know”

> “Mam we hugely benefitted, I enjoyed it and I also gained so much knowledge, I found it enjoyable because we were interacting with the facilitators. So, it was enjoyable and I gained a lot of knowledge”

Learners indicated that the workshop benefitted them, because it was a hands-on activity (W1). This could be seen from the following quotes:

> “I think I benefited because I got to interact with the skulls on a physical level than reading from a hard copy and pictures. So, I was actually able to see more stuff by holding the skull myself”

> “It is always better to physically see things as compared to seeing a picture of it, it is easier to understand it this way.”

The learners found the workshop interesting (W5) and better than a lecture or textbook (W2). It could be illustrated by the following quotes:

> "It was educational. It was discovering, you don't get this opportunity in school to further your studies because the textbook limits you. So, it was nice"
>
> "It was definitely very educational and very interesting like, and it was a lot of fun"
>
> "It was interesting, and I liked the fact that it was simplified, unlike reading the whole textbook and it was practically so, we saw what he was talking about. We got better understanding and knowledge"
>
> "It was nice because it went a bit more in depth than just normal class. It was more interactive than just reading in the textbooks. You could see it very nicely; they were there, and you can touch them feel them"

One leaner indicated that she liked the fact that they could compare the skulls and pelvic bones and that it helped her understand. Only one learner indicated that the workshop wasn't enjoyable.

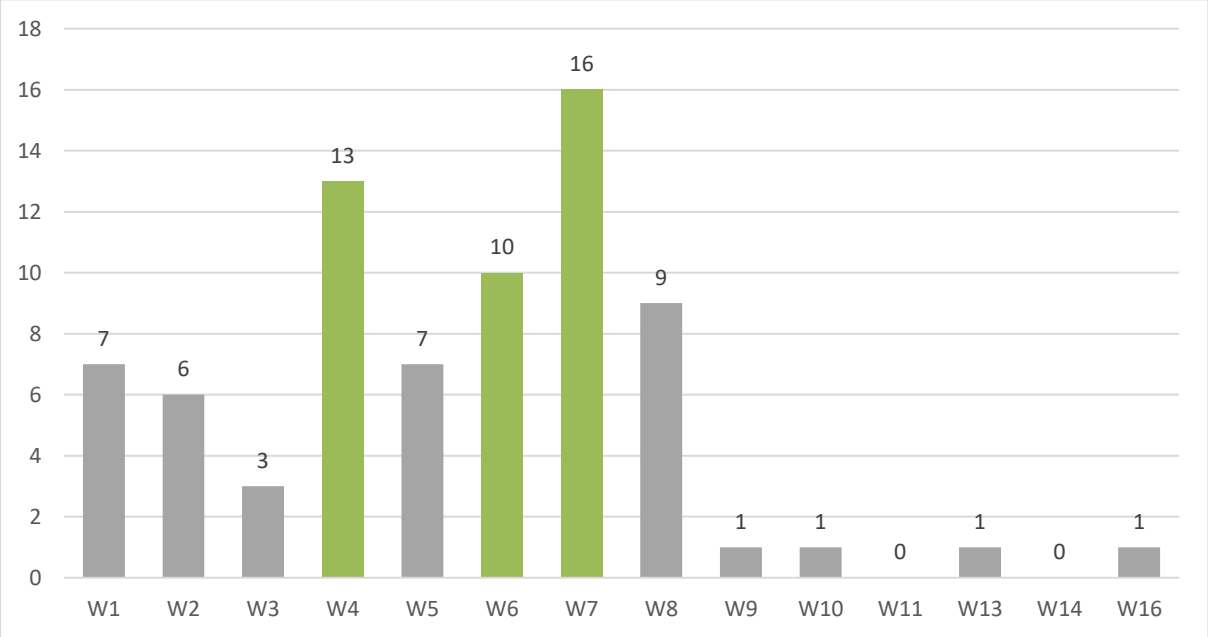


Figure: 4.2: Codes of interviews conducted after workshops held at school and code frequency (sample size = 33 learners)

.

4.2.2.3. Overall view of learners on the workshop

Overall, fifty-two learners were interviewed after they attended the workshop (Figure 4.3). Code W7 (they feel they learnt new things/things about evolution/learnt a lot) was clearly the most frequent code (44%). This was followed by 33% of learners pointing out that they enjoyed the hands-on approach of the workshop (W1). Furthermore, 29% of learners indicated that they had fun, while another 29% felt it gave them a deeper understanding of the topic (W4). This was followed by W5, which indicates that 21% of learners found it interesting and exciting. Nineteen percent of learners indicated that it was beneficial. Hence, the overall impression of learners of the workshop was very positive.

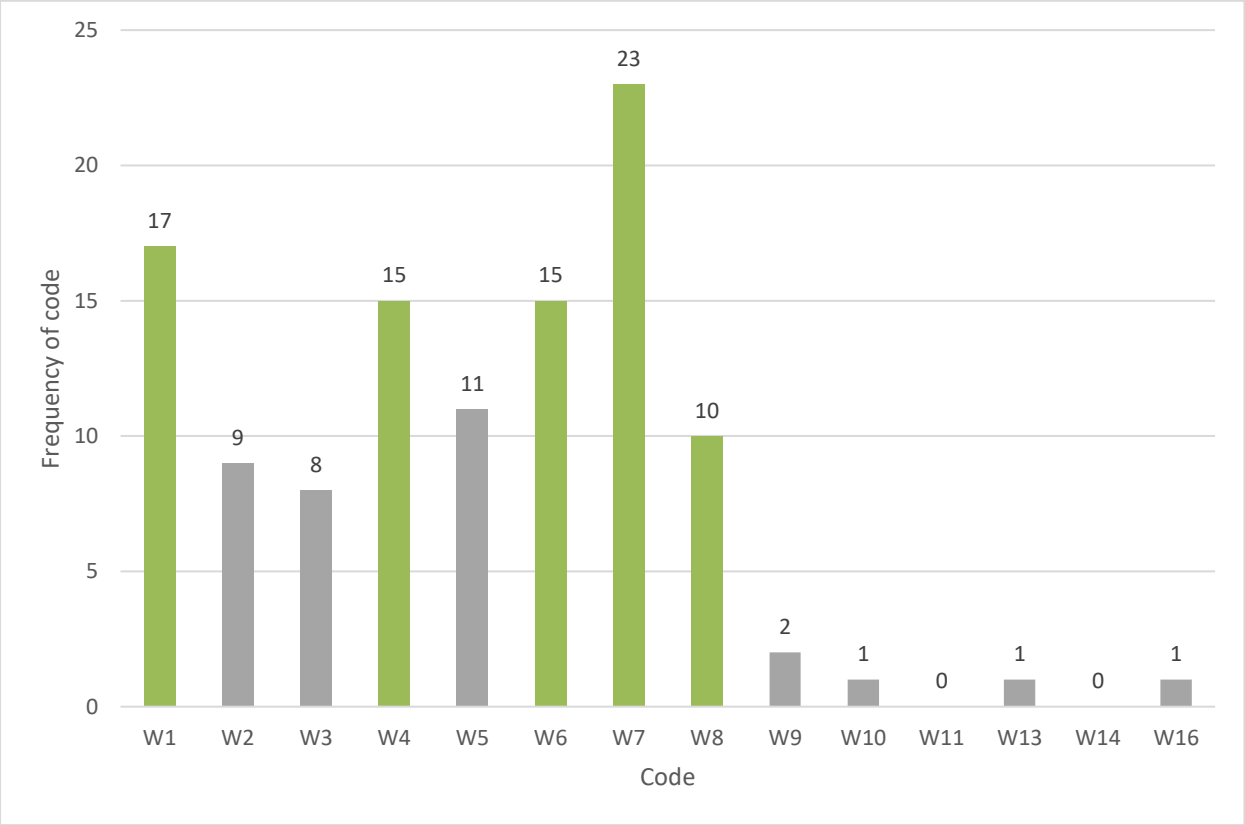


Figure 4.3: Frequency of codes from learner interviews with regards to view on workshop (n=52).

4.2.3. OPEN-ENDED QUESTIONS

There were two open-ended questions on the post-tests. The first question asks the learners to explain their answer to question seven, which was a multiple-choice

question where the learners had to indicated if they enjoyed the workshop. The last question asked the learners how they would improve the workshop. The responses to these questions were coded inductively. The answers are discussed below.

4.2.3.1. Enjoyment of the activity

This question was answered by 663 learners. The same codes were used (refer to Table 4.3), but additional codes were identified as some responses did not fit the existing codes. The most frequent answer (41%) was that learners felt that they learnt something new or something about evolution or learnt new things. The next most common answer (14%) was that learners found the workshop to be interesting or exciting. The following quotes serve as examples:

> "I learnt a lot, learnt about human evolution, interesting, great experience"
> "Discovery and information were excellent"
> "Had a great time, learnt a lot"
> "I learnt more about evolution and got to interact with different skulls"
> "I learnt a lot of new things during the activity about how animals are designed and different skulls of animals as well as humans. I would like to improve my understanding and focus on learning more about human evolution"
> "Got to learn more about evolution and that as humans we evolved from other species, and we have a common ancestor"

Some answers were present in near-equal representation. Firstly, learners indicated that the workshop provided them with a better or deeper understanding of the content. Secondly, learners liked the workshop being hands-on and interactive, and lastly learners found the workshop to be enjoyable and fun. The following quotes illustrate this:

> "Working with fossil and cultural evidence made it fun and interesting "
> "I enjoyed seeing different skulls, I don't believe in evolution but find the topic very interesting"
> "Saw fossils for the first time"
> "Nice; learnt while having fun"

"It was exciting to see that we share a common ancestor, it was fun and interesting"

"Very insightful about evolution"

"Helped to differentiate between hominins and differentiate between gorilla and humans"

"Very educational, entertaining"

"I learnt more about evolution of humans in a more practical way"

"It was fun working with the skulls and we learnt a lot"

"Seeing how we share a general ancestor is exciting."

"It was nice to experience it in a practical way; you understand it better and will remember it better."

"I had a chance to feel the skulls and the tools."

"The resources used made the activity interesting and fun to do."

Other codes that were common, stated that learners felt that the workshop was beneficial, helpful and educational. Also, learners enjoyed comparing the different skulls/pelvises and that the facilitator gave them a good explanation of the facts. This could be seen by the following quotes:

"Very educational, prof is passionate, he answered every question"

"The lecturer explained everything perfectly and gave us enough time to fill in the worksheets"

"Everything was explained clearly, and the facts were fun to learn"

"The presentation and the orientation were very good and we were part of it practically and we saw the fossils and tools"

"It is just that when it comes to school work, I started to enjoy it a bit"

"Saw fossils with my own eyes, learnt new things"

The lesser common answers are as follow: 1% of the learners found it better than a textbook/their teacher and that their questions were answered and that it would help with examinations. The following quotes illustrate this:

"I learnt much more information than I did from my teachers lesson"

"I've learnt more than I usually do in my classroom"

Only a small percentage of the learners gave negative feedback. Twenty-four learners (3.6%) indicated that they didn't enjoy the workshop or explanations or that it was boring. Three percent of learners felt confused or didn't understand the workshop materials, 1% of learners felt that the presentation/explanation style was not good, and 1% of learners indicated that it was not their interest. This is indicated in the following quotes:

"It was boring"

"Not my interest"

"At first it was boring, but as time went by, I started to like it"

When comparing the data from university-based and school-based workshops, the biggest difference was with code W7, where the school-based learners had a frequency of 12% less than the university-based learners. Six percent more learners at the university-based workshop indicated that the workshop gave them a deeper understanding. Furthermore, 5% of the school-based learners indicated that they would have preferred to go to the university.

Codes obtained	**University-based percentage frequency of codes (%) (355 learners)**	**School-based percentage frequency of codes (%) (308 learners)**	**Overall percentage of codes (%) (663 learners)**
W1 = Hands-on, interactive	**13**	**6**	**10**
W2 = Better than textbook/teacher lecture	1	0	1
W3 = Compared the different skulls/pelvises	4	3	4
W4 = Better/deeper understanding	**12**	**6**	**9**
W5 = Interesting/exciting	**14**	**13**	**14**
W6 = Enjoyable/fun	**9**	**8**	**9**
W7 = Learnt something new/learnt about evolution/learnt a lot	**47**	**35**	**42**
W8 = Beneficial/helpful/educational	**4**	**7**	**5**
W9 = Got confused/didn't understand	2	4	3
W10 = Didn't enjoy workshop/explanation/it was boring	3	4	4
W11 = Good explanation by facilitator	3	3	3
W12 = Questions were answered	1	2	1

W13 = Presentation /explanation not good/change presentation style	1	1	1
W14 = Not my interest	1	2	1
W15 = Worksheet is good/questions on worksheet clear/simple	0	0	0.3
W16 = Will help with the exams	1	1	1
W17= Enjoyed social interaction/group work	0	2	1
W18 = Add more fun activities	1	1	1
W19 =Want to learn more/motivated me	2	1	1
W20 =Should do content at school before the workshop	1	1	1
W21 = University is a better venue than the school	1	5	3

Table 4.3: Table indicating the codes obtained inductively from learners at university-based and school-based workshops on how they felt about the workshop (n=663).

4.2.3.2. Suggestions on how to improve workshop

The learners' responses on the last question were also coded inductively, and seventeen codes were generated (Table 4.4). Of the 687 learners that submitted their pre- and post-test, only 63% responded to this question. Twenty one percent of the learners indicated that they enjoyed the workshop as it was and would not change anything. Overall, 26% of the learners felt that there should be visual aids/video clips/slideshows added to the workshop. The following quotes from the test illustrates this point:

> "use visuals like photos or pictures of places of origin"
>
> "use video clips that shows physical appearance of the hominins"
>
> "use smart boards, play video clips"
>
> "use slide shows and video to demonstrate changes in changing environments"
>
> "show videos of when and where the actual fossils were found"
>
> "I think pictures of representations of what the organisms would have looked like would have been interesting"

Learners indicated that there were not enough skulls and tools (10%), and they had to wait their turn to get a specific artefact, which wasted time. They suggested more artefacts. The following quotes illustrate this:

“provide more fossils to save time”

“more skulls of the different species”

“more objects to compare, we had to wait and wasted time”

“get more of one fossil to make it easy for everyone to access”

The next frequent answer was that of adding more activities. Learners (9%) felt that there should be more activities added to the workshop as they enjoyed the hands-on experience. Five percent of the learners indicated that they would have liked to receive food at the workshop. They were used to receive food at school. Unfortunately, there was no funding to provide food to learners. The following quotes serve as illustration of this:

“More hands-on activities”

“more activities to do”

“Free food, obviously”

“food and drinks”

“snacks while we work”

“a good meal before starting otherwise you just hungry and unable to concentrate”

Learners (6%) also indicated that they wanted more information on the subject either as pamphlets, notes or summaries that they could take home. This is indicated by the following example quotes:

“More information about the common ancestor”

“Include more information on the skeletal structures”

“More info about fossils”

“Give more info about the evolution of the humans”

Learners (6%) indicated that they needed more breaks between the activities, while 5% of learners indicated that less time was needed for the workshop:

“Make it shorter, bigger groups for faster results”

"Shorter workshop, it was very long"

"A break in between"

"Two hours was too long"

"Breaks after each topic"

In contrast, 6% of learners wanted more time to complete the workshop:

"Provide the learners with more time to answer the questions"

"Allocate enough time to finish the activities"

"More time should be given for learners and breaking up workshop so that learners don't get restless"

If we only consider the suggestions from 10% and upwards of the learners, we could infer that the most frequent suggestions for improvements of the workshop are as follow:

1. Nothing, leave workshop as is.
2. Add visual aids, video clips and creative slide shows.
3. Add more of each type of artefact to cut down on waiting time.

Codes	**Percentage of learners out of a total of 436 (%)**
Need more time	6
Need less time	5
Add video clips in presentation	**12**
Add pictures of organisms	6
Use a slide show	5
Younger facilitators	1
More facilitators	3
Nothing, leave as is	**21**
Facilitator spoke too soft	1
More guidance needed	1
Add more activities	9
Supply food	5
Give more information pamphlets/notes/summaries	6
More skulls/artefacts/tools	**10**
Researchers should do a presentation	1

Change presentation style/be more creative with presentation	4
More breaks	6

Table 4.4: Codes obtained from learners' suggestions for improvements (n = 436).

4.2.4 SUMMARY OF CODES FOR SUBJECT

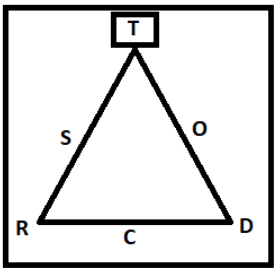
In summary, using the answers from all the sources (the interviews at the university museum, the interviews at the different schools, and the post-test) the frequencies of the codes were collated to determine overall patterns (Table 4.5). After triangulation of all the data sources, the four themes that were obtained from the learners on their views of the workshop are as follow:

1. Hands-on workshop with good explanations that are better than a lecture or textbooks (represented by 20.3% of the learners).
2. Beneficial workshop learnt new facts and gained a deeper understanding of human evolution (represented by 60.3% of the learners).
3. Enjoyable, exciting and interesting workshop (represented by 25% of the learners).
4. Small number of learners felt that workshop was not enjoyable, they got confused and some felt that the school was not suitable as a venue (represented by 8% of the learners).

Each theme is represented by a percentage, which is the percentage of learners who formed part of the theme. Learners attributed to more than one code, that is why each theme should be seen separately and not a composite of 100.

Codes obtained inductively	Overall Frequency of codes	Percentage frequency of codes (%)	Category	Theme
(**W1) Hands-on, interactive**	**78**	**11**	*Hands-on workshop*	**Hands-on workshop with good explanations that are better than a lecture or textbooks**
(W3) Enjoyed comparing the different skulls/pelvises	25	4		
(W15) Worksheet is good/questions on worksheet clear/simple	2	0.3	*Good explanations, workshop better than a lecture/textbook*	
(W2) Better than textbook/teacher lecture	11	2		
(W11) Good explanation by facilitator	19	3		
(W4) Better/deeper understanding	**75**	**11**	*Afforded a deeper understanding of evolution*	**Beneficial workshop learnt new facts and gained a deeper understanding of human evolution**
(W12) Questions were answered	7	1		
(W19) Want to learn more/ it motivated me	8	1		
(**W7) Learnt something new/learnt about evolution/learnt a lot**	**296**	**41**	*Beneficial workshop, learnt new facts about human evolution*	
(W8) Beneficial/helpful/educational	**46**	6		
(W16) Will help with the exams	4	0.3		
(**W5) Interesting/exciting**	**100**	**14**	*Exciting, interesting and enjoyable workshop*	**Enjoyable, exciting and interesting workshop**
(W6) Enjoyable/fun	**67**	**10**		
(W17) Enjoyed social interaction/group work	7	1		
(W9) Got confused/didn't understand	19	3	*Got confused during workshop*	**Workshop not enjoyable, some got confused and some felt** school wasn't a suitable venue for the workshop.
(W10) Didn't enjoy workshop/explanation/it was boring	25	4	*Did not enjoy workshop*	
(W13) Presentation /explanation not good/change presentation style	7	1		
(W14) Not my interest	9	1		
(W21) Need a better venue than school	19	3	*School not suitable venue for workshop*	

Table 4.5: Summary of codes obtained from interviews and post-test open ended questions on learners' views on the workshop, collapsed into categories and themes (n=714). The highest frequency codes are highlighted in black as well as the themes.



4.3 TOOLS

The tools that were used in this study are sociocultural theory, inquiry-based learning, nature of science, the university-based museum and teaching tools (artefacts). The palaeontology museum at Wits had different exhibitions. The exhibitions contained South African plant and animal fossils (Figure 4.4). The Afrovenator and Tapinocaninus reconstructions caused a lot of excitement. There was an isolated incident where a learner got a panic attack when she saw the Afrovenator. Overall, there was a lot of excitement when they were greeted by these two exhibits when entering the museum (Figure 4.1 a-c, g). The displays on plant and animal ancestors were used during the treasure hunt activity, where they had to search for the clues and complete the worksheet (Figure 4.1 d-f).



Figure 4.4: a) Learners enjoying taking photos with the Afrovenator at the palaeontology museum



Figure 4. :b) Two learners posing at the Afrovenator at the palaeontology museum



Figure 4.4: c) Tapinocaninus at the palaeontology museum



Figure 4.4: d) Learners busy with the treasure hunt with worksheet



Figure 4.4 e) Learners busy with the treasure hunt at mammal exhibition



Figure 4.4: f) Learners and teacher busy with the treasure hunt with worksheet



Figure 4.4: g) Briefing session in the museum.

The learners also went to the fossil extraction laboratory (Figure 4.5.). They were shown how fossils were extracted using specialised equipment by the lab technicians and had a briefing session with the university assistant on how fossils are extracted.



Figure 4.5: a) Learners looking through apparatus at fossils



Figure 4.5: b) Learner looking through apparatus at fossils



Figure 4.5: c) University assistant telling learners about the fossil being extracted on the table.

Sociocultural theory, inquiry-based learning and the nature of science were built into the workshop. Learners were working together in groups, gathering information through scientific observation and measurements. They were interacting with the artefacts, each other, the facilitators and the worksheet. Observing them while they were busy with the workshop was a way to ascertain their involvement, and whether they were interacting with each other and the artefacts. The workshops generally consisted of three phases. First, the orientation phase, where the worksheet was discussed with the learners. They were given some background information on the different hominid features, stone tools and the genetic sequences. They were shown where they could get the artefacts and how to measure the skulls. In the second phase of the workshop, learners did the activities. This part usually took an hour and thirty minutes. Some schools took longer than others. The last phase, namely the feedback session, was where the learners had to compare their values obtained for the skulls with those that the university lecturer gave (Figure 4.6). This part always had the learners' full cooperation. Firstly, the volume of the hominid brain was discussed. The lecturer took an average of the learners' measurements and explained that this was a practical way to compare the sizes of the brains. The lecturer then continued to give the scientific accepted values. The different units of

volume were discussed, namely cm^3 and cc. After this the position of the brain was discussed, the learners had to decide if the brain was more to the back (B) or on top (T) of the skull. The third feature that was compared, was the size of eyebrow ridges. Learners had to decide whether it was extra-large (XL), large (L), medium (M) or small (S). The type of locomotion was the fourth feature discussed. They compared the position of the foramen magnum and decided whether the hominid was quadrupedal or bipedal. The next feature was the angle/slope of the face. They had to sequence the skulls from least sloping (1) to most sloping (7). The shape of the palate was the next feature discussed. They discussed whether the palate was rectangular or rounded. In Figure 4.6 below the shape of the palate was drawn. The last feature was the size of the canines. It should be noted that the casts of *Australopithecus africanus* and *Homo erectus* did not have teeth. On the day that the photo in Figure 4.6 below was taken, the *Pan troglodytes* and *Gorilla gorilla* were indicated as having big (B) canines and *Australopithecus africanus* and *Homo erectus* had a X for no data.



Figure 4.6: The answers of the table comparing the different features of the different skulls.

This was followed by an activity where the learners had to sort the skulls from gorilla to human, sequencing them from less human to more human (due to time constraints and the venue location, it was only done at the university-based workshops and not at the school-based workshops). One or two learners were usually nominated for this activity by the learners, but they were helped by the rest of the class if they put the skulls in the wrong order. In one group, the lecturer placed 2 litre soda bottles filled with coloured water to the volume corresponding with the different brain volumes (Figure 4.7.a). Learners seemed to enjoy this activity. In this session, they also had to sort pictures of the organisms instead of the skulls. They seemed to struggle with this particular activity (Figure 4.7.b).



Figure 4.7: a) Two litre soda bottles filled to specific volumes which coincides with the brain volumes of the different skull



Figure 4.7:b) Learners and teacher with the skulls, pictures and soda bottles.

After this, the answers related to the pelvic bones, cultural tools, and DNA sequencing were discussed and answered corrected (Figure 4.8). The learners had to count the number of differences between the DNA sequences of each species.

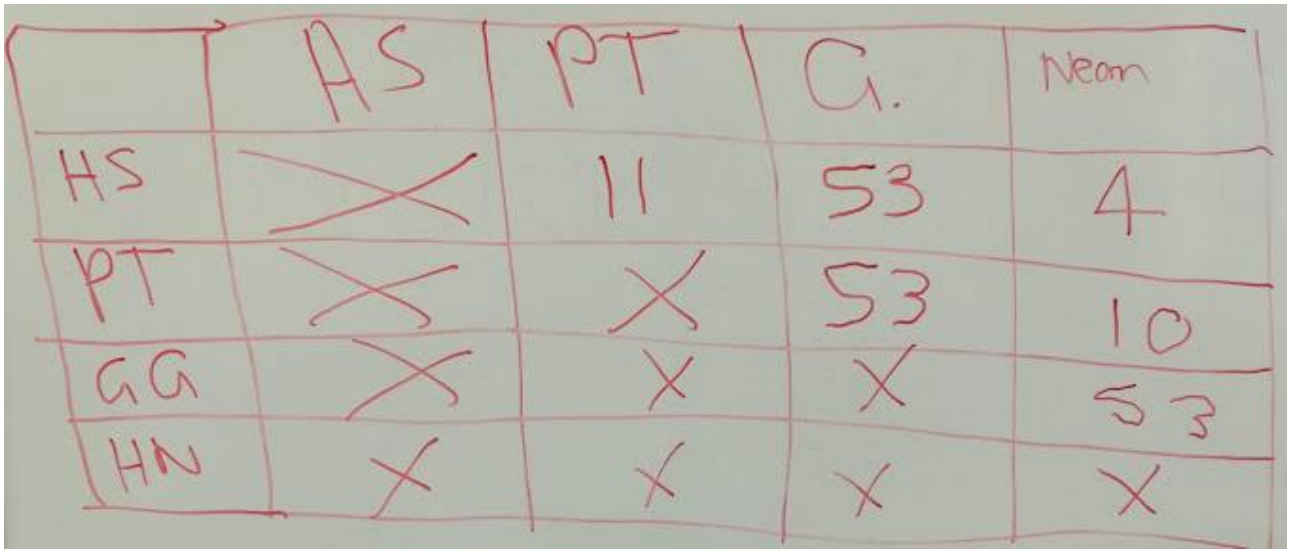


Figure 4.8: The answers for the DNA sequencing activity, indicating the number of differences in DNA sequence between the different organisms.

The session was concluded with the completion of a phylogenetic tree. Learners had to suggest which organism fit at which point on the phylogenetic tree. The common answer at each node were discussed by asking learners which features all of the organisms share (Figure 4.9). The difference between hominins and hominids was also discussed. Transitional fossils, extinction and speciation were some of the other concepts that were discussed.

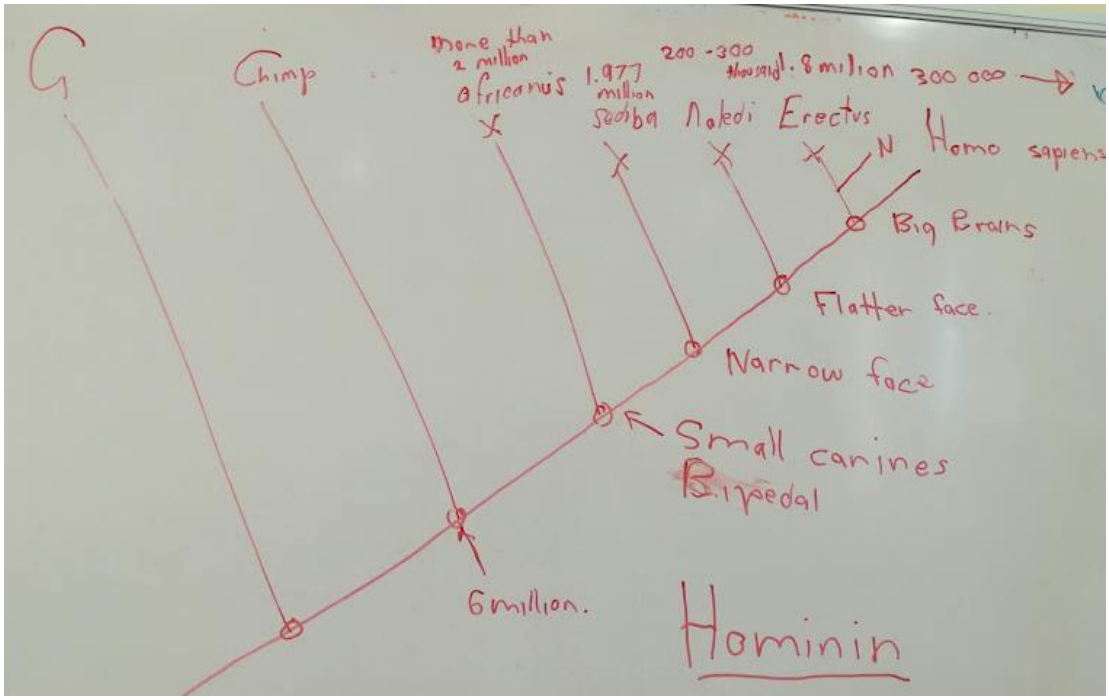


Figure 4.9: The answer to the phylogenetic tree.

4.3.1. OBSERVATIONS MADE BY RESEARCHER DURING THE WORKSHOPS

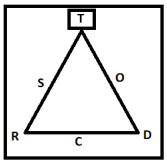
During the workshop, the researcher acted as one of the facilitators helping learners with their questions and asking questions to determine whether they understood. During the feedback session, the researcher was on the side-line taking notes and recordings. Observations of the interactions between the learners and other facilitators were also made during the workshop as well as during the feedback sessions. Other observations pertain to logistics and teacher involvement.

During the different phases of the feedback session, the input and questions from learners were observed. How learners understood the different concepts and how

they made sense of it all, could be seen during the feedback session. Handwritten observation notes were made by the researcher.

Photos and video recordings were used to help with observation. During the first year of the study, video cameras were placed in the museum as well as the laboratory, to analyse learners' interaction with the artefacts. Unfortunately, the sound quality was poor making it difficult to hear the learners. It was then decided to set up the camera equipment at one table. A microphone was also used. This changed the behaviour of the learners. They knew they were being recorded and they were too shy to discuss anything. They often spoke softly to each other, or not at all.

Following this, it was decided to remove the video camera, and rather take photos using a cell phone. Every time the learners were asked permission to take a photo. This influenced some learners as they immediately started to pose for the camera, it was as if they were taking selfies with fossils. In contrast to this, some learners were unaffected as they were busy unravelling the mystery in front of them. The feedback session was recorded using a cell phone. The recordings were taken from the back, which was not in the line of sight of the learners, hence they were unaffected by this. The recordings were viewed afterwards, and observations notes were made, and the observation notes were coded using socio-cultural theory.



***Workshop at university*:**

Arrival at university

The majority of schools arrived an hour or more after the proposed time. This could be attributed to buses getting lost, or busses arriving late at the schools. This had a negative effect on the second session of the day. The first session would continue as normal, but then after the lunch break, the session had to be shortened because busses had to leave at a certain time. One school only started the second session at half past one, while the other started at two o'clock. Two schools left very late due to this problem, which impacted on the time management and learners' participation.

Briefing session

Learners usually listened attentively, and some asked questions. The terminology was clarified in order to help the learners. The facilitator went through the worksheet with the learners explaining what is expected of them in each section.

Learner involvement

Learners always seemed interested in the skull measurement part of the workshop (Figure 4.10 a-h). They enjoyed holding the skulls and measuring it. Learners enjoyed taking “selfies” on their cell phones with the skulls and with the group. They seemed to like drawing the pelvic bones as well. The DNA activity was easy, as they divided it amongst their group members.



Figure 4.10 a: Learners busy with hands-on workshop in the university laboratory.



Figure 4.10 b: Learners busy with hands-on workshop in the university laboratory.

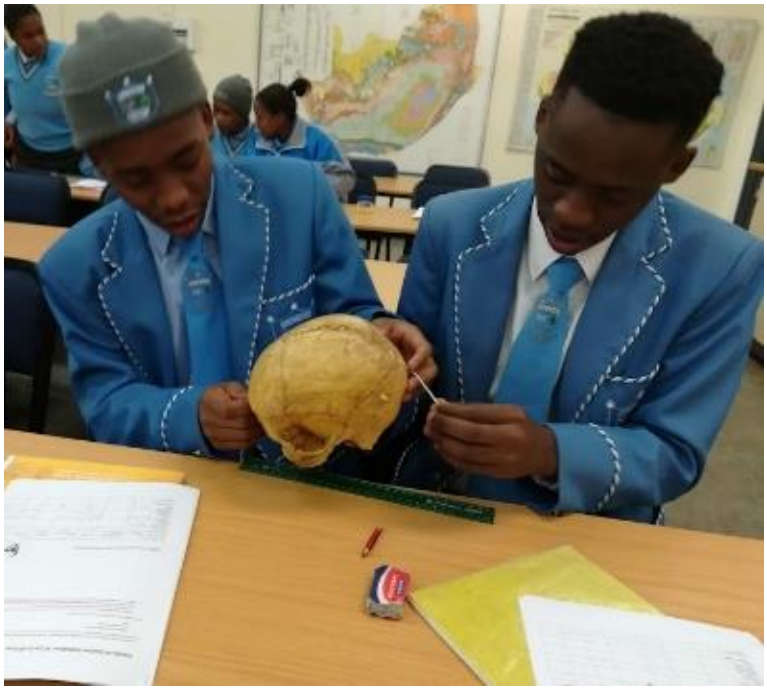


Figure 4.10 c: Learners busy with hands-on workshop in the university laboratory.



Figure 4.10 d: Learners busy with hands-on workshop in the university laboratory.



Figure 4.10 e: Learners busy with hands-on workshop in the university laboratory.



Figure 4.10 f: Learners busy with hands-on workshop in the university laboratory.



Figure 4.10 g: Learners busy with hands-on workshop in the university laboratory.

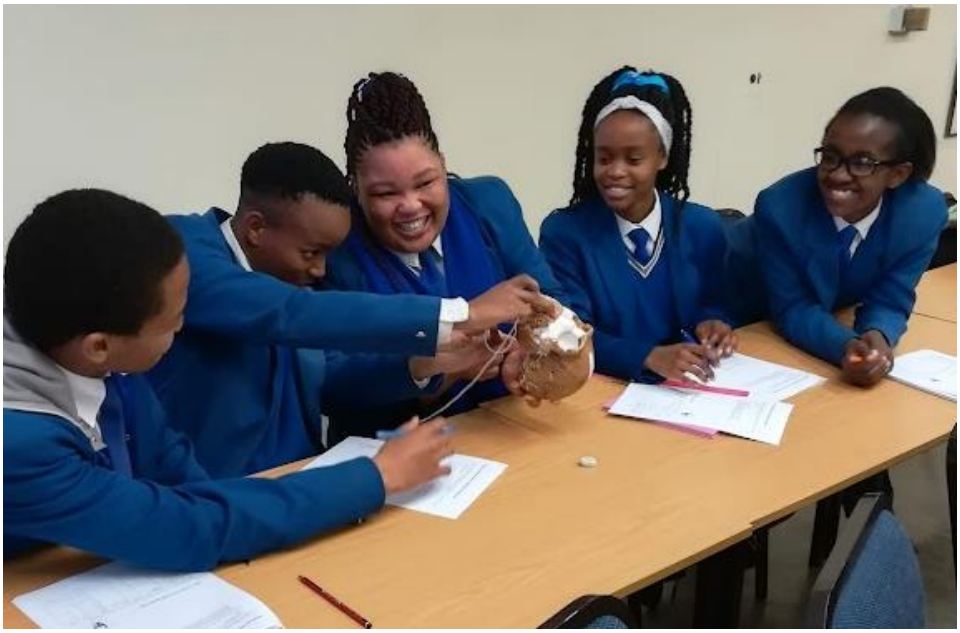
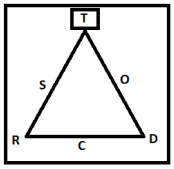


Figure 4.10 h: Learners busy with hands-on workshop in the university laboratory.

Second session

The second session at the university laboratory usually had a different energy level. Learners that were in the museum during the first session, participated in the hands-on activity, but seemed listless during the feedback session, even tired. They did however, answer and participate during the part where they had to give their values of the skulls' measurements. One school that came during the school holiday were participating very actively. They were taught the content before the workshop, and when the lecturer spoke about *A. sediba,* one learner exclaimed excitedly that it means source, and they all agreed. A learner from a disadvantaged school could answer the question during the feedback on phylogenetic tree about why humans and chimpanzees are more genetically similar than gorillas and chimpanzees. Moreover, he could point out that we had a common ancestor. This was quite impressive because most learners struggled with this part. Another learner could talk about occipital pinch behind the eyes. This was obviously information that the learner obtained from the morning session in the palaeontology museum. One school was asking a lot of questions during the feedback session and debating answers. They also wanted to know where the different fossils fit in with Adam and Eve.



Workshops at schools:

First workshop

The workshops conducted at schools had a different energy level all together (Figure 4.11). More artefacts were made to accommodate bigger groups. At the first workshop, we combined the three Afrikaans-speaking schools in a single school hall. Three university assistants came along to help with the mediation (Figure 4.11.a). There was a power outage, and the facilitators could not use a microphone. This had a negative effect on the audibility of the lecturer, so we obtained a xylophone from the school, but it was not as effective as a microphone. The learners arrived at one o'clock, and there were more than a hundred learners in the hall. They were excited because they saw their friends from other schools. Overall, they cooperated in the activities, but seemed listless during the feedback session. They asked for a break at two o'clock, because they were hungry. This affected the time management. A small group of learners seemed to lose interest towards the end, as it was getting late.



Figure: 4.11 a) Fossils in front of hall with university staff



Figure: 4.11 b) University lecturer using xylophone to be heard



Figure: 4.11 c) Learners busy with skull measurement, mediation of activity can be seen in background



Figure: 4.11 d) View from above indicating how learners were seated.

Second workshop

After reflection, we as facilitators decided not to have such a big group again. Our second group was composed of 80 learners, and it was also held in the school hall. These learners seemed very interested, and the teacher also assisted with the practical activities. The teacher indicated afterwards that the learners who normally did not participate in class, surprised her by participating in this workshop. Overall, the learners seemed to enjoy the workshop (Figure 4.12).



Figure 4.12 a) Skulls and stone tools in front.



Figure 4.12 b) View from above, indicating how learners were seated in school hall



Figure 4.12 c) University lecturer busy with preamble



Figure 4.12 d) Learners busy with skull measurements



Figure 4.12 e) Learners busy with skull measurements



Figure 4.12 f) Learners busy with skull measurements



Figure 4.12: g) Teacher mediating activity.

Third workshop

The next workshop had 60 learners in a school hall. These learners seemed disinterested from the start. We struggled to keep them focused on the activities. Some groups were very interested, and asked a lot of questions, while others were clearly not as interested. The teacher was sitting at the back of the hall, doing other work. Surprisingly, there were some interesting questions during the feedback session from one/two of the learners (Figure 4.13).



Figure 4.13: a) Learners in school hall busy with activity



Figure 4.13: b) Learners busy with pelvic bone



Figure 4.13: c) Learners busy with cultural tools activity.

Fourth workshop

The next school did not have a hall, and we conducted the workshop in the school laboratory. Sixty learners attended this workshop (Figure 4.14). In the beginning, the learners were very cooperative, but after an hour, they became restless, and we had to make sure that we rotated between the groups to keep them focussed on the activity. They did participate enthusiastically during the feedback session (Figure 4.14. d).



Figure 4.14: a) Learners busy measuring gorilla skulls



Figure 4.14: b) Learners busy with *A. sediba* skull



Figure 4.14: c) Learners busy with pelvic bone



Figure 4.14 :d) University lecturer giving feedback using xylophone to be heard.

Fifth workshop

The next workshop was conducted very late in the year (Figure 4.15). The learners were preparing for their final examinations. The workshop was conducted in the laboratory, as only 30 learners attended (of which 6 leaners were in grade 11). As the workshop progressed, learners had to leave to attend other subjects' extra classes and we ended up with only 24 learners at the end. They seemed very involved with the activities but didn't ask many questions. There was a situation where a learner was asking how this fit into his Christian religion (I could see that he was trying to be difficult, he also left shortly afterwards). We tried to explain that this is not disproving his religion, but somewhere in the discussion some learners who listened in were offended. It once again reminded me to tread very carefully when learners ask questions about religion.



Figure 4.15: The school laboratory with learners.

Sixth workshop

The last workshop was also held very late in the year on a Saturday with grade 11 and 12 learners. The reason for these workshops being so late was that it was at the request of the teacher. They were very interactive and asked a lot of questions (Figure 4.16).



Figure 4.16: a) The laboratory layout



Figure 4.16: b) Learners drawing pelvic bones

Observed differences between university and school-based workshops

Overall, each type of workshop had its benefit and drawbacks. At the university, the arrival time of the busses impacted on the workshops. When busses arrived late, we had to shorten the workshop. The learners were very enthusiastic and energetic, because we had them from the morning, and they enjoyed being in a different environment. They were exposed to the museum and fossil laboratory and sometimes they linked what they have learnt there to the workshop questions. The school-based workshop was more convenient for the schools, but the learners seemed tired because they attended a whole day of normal schooling. They were hungry and listless, and we had to work much harder in keeping them focused on the activities and during the feedback session. The learners were more focused during the Saturday workshop at school.

Mediation

The university lecturer as well as the university staff moved between the groups and assisted the learners where they struggled (see Figure 4.17 below). After the first two workshops, I started helping with the mediation. Learners needed help with the skulls, since they didn't always know which skull was which, and they needed help with the identification of the pelvic bones. Discussing bipedalism and quadrupedal locomotion were used as scaffolding ideas at the pelvic bones (e.g., a bipedal organism must have a shorter and wider pelvic bone while a quadruped has a longer and more narrow pelvic bone). They then had to look at the three bones and sequence the bones from widest to most narrow.

The genetic sequence activity needed the least mediation, as learners understood what to do. In contrast to this, the phylogenetic tree needed the most mediation. We started at the bottom of the phylogenetic tree and told them that the oldest organism or common ancestor should be located there, and then each node is where an organism branched off. We would then refer them back to the genetic sequencing and they had to use the organisms and place them in the correct order on the tree.



)

Figure 4.17: a) University assistant mediating the activity



Figure 4.17 :b) University assistant mediating the activity



Figure 4.17:c) University lecturer mediating the activity.

Language barriers

The language used in the worksheet was English. In all the schools except one, the learners were English second language speakers. Language of teaching was important because the workshop was done in English, and no code switching was done. Language code switching is an international phenomenon where teaching happens in a multilingual context and could be used to empower learners (Auerbach, 1993). According to Numan and Carter (2001), code switching was the alternating use of two or more linguistic varieties at the word, phrase or clause, or sentence level in the course of a discourse. In South Africa, it was used by teachers in most rural schools to empower learners even though it was against policy (Kretzer & Katchula, 2019). All facilitation was done in English. This impacted on some of the learners who were used to asking questions in their home language and being answered by their teachers in the same language (mostly the township schools).We noticed during our mediation with the groups, that some of the learners did not clearly understand the instructions. I could see that while I was explaining a concept to them they didn't understand what I was saying, so I requested assistance from their teachers.This was not the case with the ex-model C-schools, where the learners were taught in

English from primary school. The Afrikaans-speaking learners did not seem to struggle, only a few had troubles with English, and one learner indicated in the interview that they would prefer the worksheets in Afrikaans.

Teacher involvement

At the university laboratory, the teachers were very involved with the activities. Some participated in the activities, while some assisted their learners when they struggled (Figure 4.18 a-d). Only one teacher was not involved at all. Furthermore, I overheard conversations on three separate occasions between learners and their teacher at the human evolution exhibition in the museum, where the learners asked questions and the teachers answered and discussed the different concepts. At the school-based workshops (Figure 4.18 d and e), we only had one school where the teacher was not involved with the activities. The rest were helping to maintain discipline or helping learners with questions.



Figure 4.18 a) Teachers mediating activity in university laboratory



Figure 4.18 b) Teacher mediating activity in university laboratory



Figure 4.18 c) Teachers mediating activity in university laboratory



Figure 4.18 d) Teacher mediating activity in school hall.



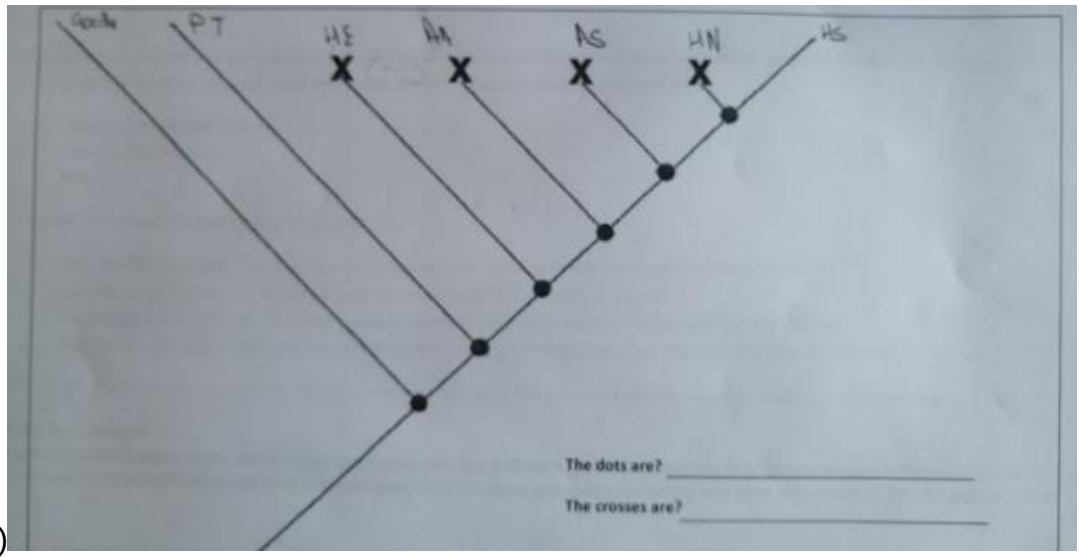
Figure 4.18 e) teacher mediating activity in school hall.

Time management

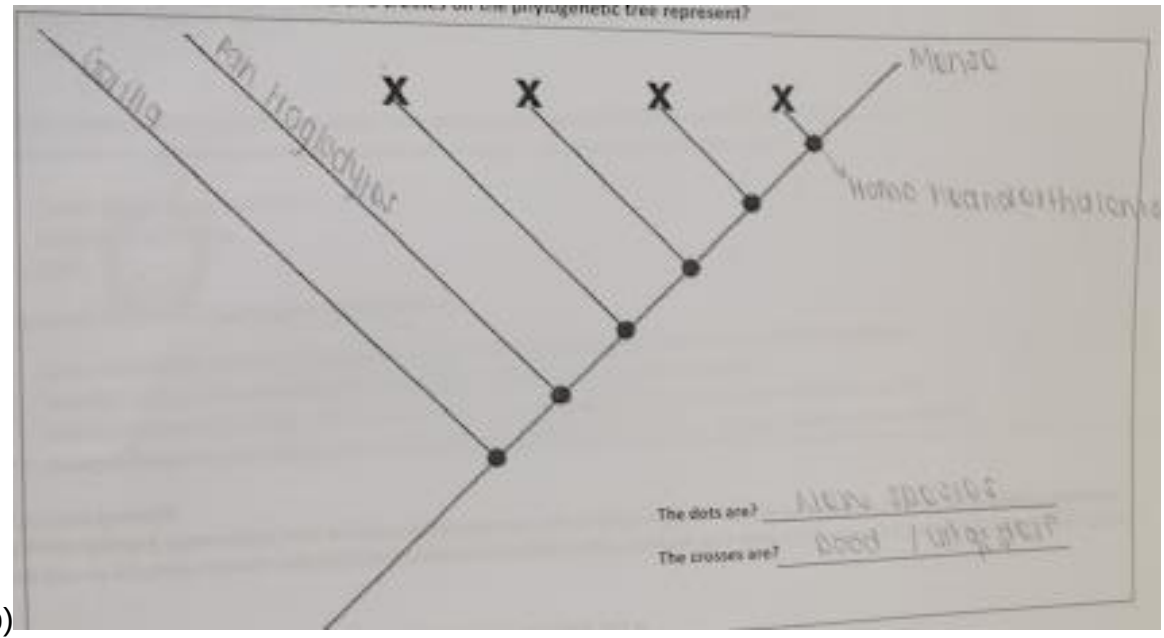
Overall, a session's duration was between two and two and a half hours. One school managed to complete the activities in one and a half hour. That was the same school that also asked a lot of questions during the feedback session. The second session at the university laboratory was usually shortened, because of time constraints or busses arriving late. They had a shorter time to complete activities and the feedback session was shortened. The afternoon sessions at the schools also ran up to two and a half hours. We couldn't keep them longer as it was getting too late and it impacted on learners' transport home.

The phylogenetic tree activity

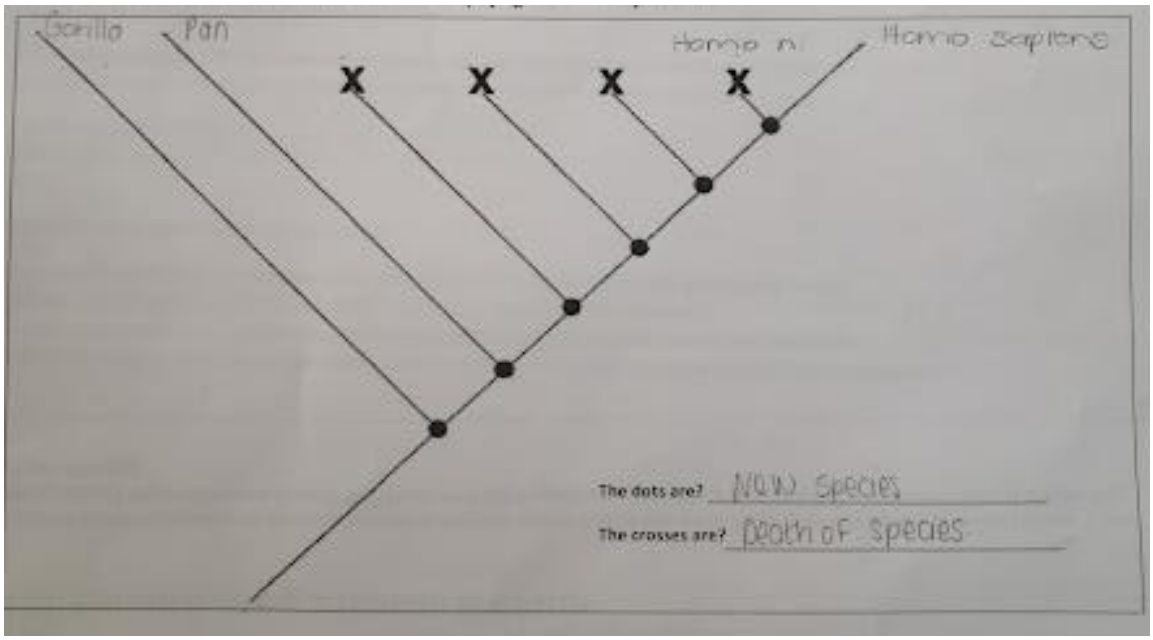
The phylogenetic tree activity was the most challenging. As facilitators, we always had to do a lot of mediation with this activity as they struggled to understand what it was that they were supposed to do. Below (Figure 4.19) are some examples of learners struggling with the phylogenetic tree. It should be noted that they were still busy, and I stepped in to mediate the activity. The first (a) photo indicates learners who has the genus *Homo* following *Pan* followed by *Australopithecus*. The dots and crosses were not identified. The second and third photo (figure 4.19 b-d) shows learners knew *Homo neanderthalensis* and *Homo sapiens* were last and could identify what the crosses were. The dots were indicated as new species. The last photo (d) indicated that *A. sediba* and *A. africanus* were switched around, but the learner correctly identified the dots as common ancestors.

a) 

b)


Gorilla
Pan troglodytes
Homo
X
X
X
X
The dots are? New species
The crosses are? Death / extinction

c)


Gorilla
Pan
Homo n.
Homo sapiens
X
X
X
X
The dots are? New species
The crosses are? Death of species

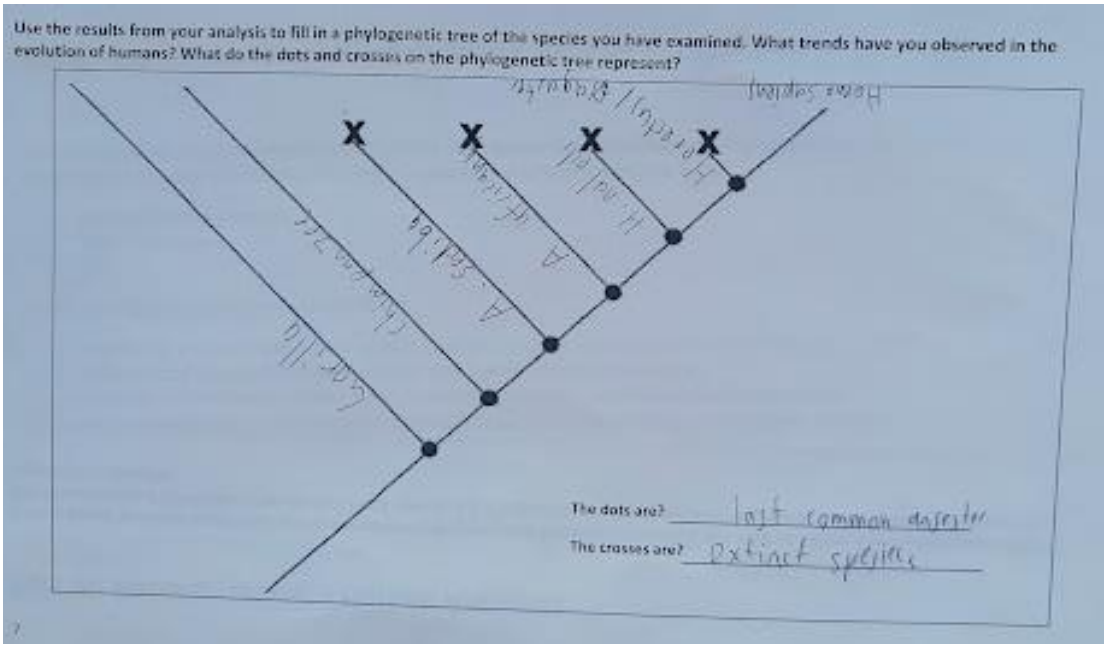


Figure 4.19 a-d: Examples of the phylogenetic tree activity.

4.3.2. DATA FROM VIDEO FOOTAGE

At the start of this research, I set up cameras in the laboratory between the learners to see how they interacted with the tools. It never seemed to work, since the sound didn't work because the noise from all the groups working simultaneously drowned out the voices of the specific group we were trying to film. It also seemed like they were whispering, very aware of the camera. This influenced the overall value of the recording. Sometimes the camera malfunctioned, and I tried different kind of cameras. After many attempts, I gave up on the stationary camera in the workshop. I then resorted to taking video clips of the feedback session at the end of the workshop with my cell phone. This is the reason why there is only data for 7 schools. The workshop at schools did not contain this part. Learners had to sequence the seven skulls from least human to most human. The correct sequence is as follow:

G. gorilla, Pan troglodytes, A. africanus (Mrs Ples), A. sediba, H. naledi, H. erectus, H. sapiens

This is a cognitively challenging activity, as the learners had to use the data, they obtained through measuring the craniums, eye-brow ridges and jaws protrusion, to

decide on the sequence. The videos were coded using sociocultural theory (Rowe and Bachman, 2012).

The codes for this activity were as follow:

1. Agency
2. Social interaction, scientific thinking
3. Signs and symbols, interaction with tools, body language
4. Mediation

The videos were coded by looking at instances where there were social interaction, signs and symbols (other learners pointing or giving their opinions), interaction between the learners and the artefacts, debating using scientific knowledge, body language, change of agency and instances where the lecturer mediated the activity (Figure 4.20. a-e).



Figure 4.20: a) Learner moving skulls with peers looking on



Figure 4.20: b) A learner moving skulls with another learner indicating where it should go, teachers also looking on (left front of photo)



Figure 4.20: c) University lecturer(facilitator) watching the learners, waiting to mediate activity

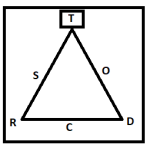


Figure 4.20: d) A learner moving skulls with peers looking on



Figure 4.20: e) Learner moving skull with other learner interacting indicating where it

The video activities will now be discussed with their coded transcripts. Only seven schools were used due to the fact that the camera malfunctioned during the first sessions and the footage was not always audible. After a while I decided to use my cell phone and it worked well.



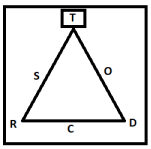
Coded video recording transcript: School number 1:

Agency: girl and boy in front is leading the activity.
Social interaction: rest of class quiet, fixated on what they are doing.
Sign and symbol: Body language of girl: fixated seem a bit unsure.
Sign and symbol: pointing at skull saying something.
Interaction with tools: Sequence: *P troglodytes, A. sediba, Mrs Ples, G. gorilla, H. naledi, H. sapiens, H. erectus.*
Social interaction: learner in front row telling them to move a skull.
Social interaction: they respond by giving reason why it is arranged like that.
Sign and symbol: Body language: both look unsure.
Agency: another girl is now in front.
Interaction with tools: switch *H. sapiens* and *H. erectus* around, human now at the end.
Sign and symbol: Body language of girl: self-assured.
Agency: two learners leave.
Agency: classmates don't agree with sequence.
Agency: original girl comes back.
Interaction with tools: switch *G. gorilla* and *H. naledi*, move *G. gorilla* closer to human.
Social interaction: classmates disagree.
Interaction with tools: want to switch *A. sediba* and Mrs Ples, move Mrs Ples closer to *G. gorilla* side, but return Mrs Ples back to original position.
Mediation: facilitator asks why gorilla is in that position.
Social interaction: looking for support from classmates.
Social interaction: learners from second row giving input.
Interaction with tools: picks up *G. gorilla,* wants to put it next to human.
Social interaction: classmates say no.
Scientific reasoning: learners in front is telling her to look at eyebrow ridges and jaw protrusion.
Social interaction: she asks the girl in front where gorilla should go.
Interaction with tools: moves *H. naledi away*, insert *G. gorilla* next to *P. troglodytes*, but stop halfway.
Social interaction: she asks learner if *G. gorilla* goes that far.
Body language: looks like she doesn't agree, keeps *G. gorilla* in her hand.
Scientific reasoning: lots of learners pointing at their faces indicating protruding jaws.
Agency: two boys join girl.
Interaction with tools: original boy places Mrs Ples next to chimp and A. sediba next to Mrs Ples.
Interaction with tools: sequence: *P. troglodytes*, Mrs Ples*, A. sediba, H. naledi*, *H. erectus, H. sapiens.*
Social interaction: original girl asks him where gorilla goes.
Interaction with tools: new boy is touching each skull checking their position.
Social interaction: original boy asks new boy if *G. gorilla* should go next to *P. troglodytes*
Signs and symbols: points to correct position of *G. gorilla*.
Social interaction: new boy says yes to new position of *G. gorilla*.
Mediation: facilitator ask all learners: what do you think of this?
Social interaction: some learners agree.
Signs and symbols: many learners pointing at their own faces indicating jaws protruding and flatness of face.
Scientific reasoning: position of *H. erectus* is decided based on flatness of face.
Interaction with tools: *G. gorilla, P. troglodytes*, Mrs Ples*, A. sediba, H. erectus, H. naledi, H. sapiens*.
Mediation: facilitator asks all learners how they feel about new sequence.
Social interaction: most learners agree.
Agency: two girls in front row now acts. It seems they agree on a matter.

Interaction with tools: One girl switches H. erectus and H. naledi around.
Social interaction: the other girl agrees.
The sequence is now correct and video recording ends.

As could be seen from the coded transcript of the video recording above, there was a lot of social interaction in this activity. Learners agreed and disagreed with what they saw. They interacted with the learners in front and the learners in front also asked for input from their peers. The skulls were the obvious sign and symbols in this activity, as they were the main object in this activity. Other signs and symbols that were regularly seen were gestures, such as learners pointing to the skulls and then pointing to their own faces, indicating protrusion of jaws and eyebrow ridges. Body language indicated when learners were unsure, or if they disagreed with a move.

Agency was changing all the time. The original learners in front decided on a sequence, but this was influenced by other learners explaining and indicating which skulls should change. The original pair leaved, but then came back with the help of a new boy, which then changed the line-up again, and influenced the placement of skulls. Mediation of the activity happened with carefully placed questions from the lecturer, like “why do you place it there?” and “are you happy with the sequence”. This also prompted change, as learners thought about their choices, or other learners gave their opinions on the sequence. Overall, through collaboration, of social interaction and mediation the learners found the correct sequence of the skulls.



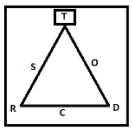
Coded video lesson transcript: School number 2:

Agency: two girls in front rearranging skulls.
Signs and symbols: **Body language**: they look self-assured.
Interaction with tools: **Sequence**: G*. gorilla, P. troglodytes*, Mrs Ples, H*. erectus, H. naledi, A. sediba and H. sapiens.*
Social interaction: girls in second row discussing with each other.
Signs and symbols: they are gesturing with hands which skulls should be switched around.
Signs and symbols/change of agency: two girls in front row gesturing A. sediba should move between H. erectus and Mrs Ples.
Social Interaction: other girls in front agrees.
Interaction with tools: they place *A,sediba* between *H.erectus* and Mrs Ples.
Social interaction: two girls says *H. naledi* and *H. erectus* should be switched around.
Social interaction: disagreement between classmates.
Interaction with tools: move *H. naledi* back next to *H. sapiens*.
Social interaction: learners in front actively participating, learners on left hand side at the back seem disinterested.
Mediation: facilitator tells them to look at eyebrow ridges.

Signs and symbols: girls in front row pointing at the skulls and discussing between each other.
Social interaction: a girl in front says *H. erectus* and *H. naledi* should be switched around.
Mediation: facilitator hands them a ruler, says they should put it in front of the skulls' faces.
Social interactions: learners discussing in their groups.
Scientific thinking/change of agency: girl tells them to measure *H. naledi's* eyebrow ridges.
Interaction with tools: they take two skulls and look at their faces.
Interaction with tools: place *H. erectus* next to human followed by *H. naledi*. Sequence is now correct.

There was a lot of social interaction in this video clip. Learners were giving input to the girls in front, regularly changing the agency of the activity. One girl argued *for H. erectus* to be placed next to human, hence having *H. naledi* and *H. erectus* switched. She told them to measure the eyebrow ridges. There was a lot of gestures being used. Learners were discussing in their groups and gesturing where they thought skulls should be. Mediation by the facilitator also helped to change the agency by directing the learners in the correct direction.

Overall, most the learners participated actively in this activity, some of them gave verbal input by agreeing or disagreeing. Some gave input by pointing at skulls and gesturing that they should be switched, all the while discussing it with their partners.



Coded video lesson transcript: School number 3:

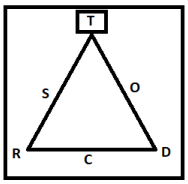
Agency: one boy in front.
Interaction with tools: touching skulls and thinking.
Interaction with tools: G*. gorilla, P. troglodytes*, Mrs Ples, H*. naledi, A. sediba, H. erectus, H. sapiens.*
Social interaction: learners disagree with the arrangement of skulls.
Signs symbols: points/gesture which skulls they want to be switched.
Social interaction: learners from back move forward to see better.
Interaction with tools: he moves *A. sediba* between *H. erectus* and *H. naledi*.
Signs symbols: classroom learners look unsure.
Social interaction: one learner tells another to take over.
Interaction with tools: learner switch *H. naledi* and *A. sediba* around.
Agency: another boy joins in front.
Scientific thinking; consults worksheet with data.
Interaction with tools: takes an extra *A. sediba* skull which is not part of the activity.
Mediation: facilitator tells him he already has a *A. sediba* skull in line up.
Social interaction: learners reiterate what facilitator says, explain that he must only have one of each skull.
Interaction with tools: new boy exchanging *P. troglodytes* and *G. gorilla*, moves *H. naledi* closer to *P. troglodytes*.
Social interaction: learners disagree.
Sci thinking: One learner indicating that they must look at data on worksheet
Interaction with tools: new boy places gorilla at opposite end and take human out
Agency: another learner sitting in front joins in

Interaction with tools: sequence is *P. troglodytes,* Mrs Ples, *A. sediba, H. erectus, H. naledi, G. gorilla*. No *H. sapiens.*
Interaction with tool: new boy takes and extra skull.
Social interaction: learners start to laugh.
Social interaction: boy sitting in front is still helping them with sequence.
Interaction with tools: keep on switching skulls.
Agency: a girl comes to the front.
Interaction with tools: place *G. gorilla* and *P. troglodytes* on one side, and *A. sediba, H. naledi* and Mrs Ples on other side.
Social interaction: boy sitting in front still touching skulls and telling her where to put it.
Interaction with tools: doesn't know where human goes.
Social interaction: lots of verbal inputs from the classmates.
Interaction with tools: puts *H. erectus* between *H. naledi* and Mrs Ples
Scientific thinking; look at bottom of skulls and facial features.
Social interaction: boy in fronts give input.
Social interaction: she says that he must keep quiet.
Interaction with tools; places human in between H. naledi and *H. erectus*.
Social interaction: looks at facilitator for verification.
Social interaction: a boy says no.
Agency: another boy in front now.
Interaction with tools: moves *H. naledi* and *A. sediba* and put human at the end. *H. sapiens. A. sediba, H. naledi, H. erectus*.
Social interaction: disagreement from classroom.
Interaction with tools: move human back again.
Social interaction: other learners telling boy in front that human should be at the end.
Agency: another boy approaches front.
Interaction with tools: want to use extra skulls.
Mediation: facilitator says no.
Interaction with tools: Move *G. gorilla* and *P. troglodytes* closer to human.
Mediation; facilitator says "you are making it worse".
Sign and symbol: he looks unsure.
Social interaction: two boys in front row shows him where to put it.
Scientific thinking: another boy in front touch front part *of A. sediba* and *H. sapiens*, feeling the protrusion of the jaws.
Sign and symbols; boy touches his own jaw indicating to friend that they must look at protrusion of jaws.

Activity ended

In this video activity, the agency changed many times. The boy that was in front at first, only had one mistake, that of *A. sediba* and *H. naledi*. In this activity, the learners were very involved. There were a lot of gestures, agreements, disagreements and trying to rectify the sequence. One or two learners realised that it had to do with the data that they obtained in the workshop and indicated as much. Unfortunately, some of the learners that went to the front had no idea what they were supposed to do and were taking extra skulls from the side and tried to insert them into the sequence. The mediator stopped them from doing that. Even though this activity showed that they went from almost right to very wrong, one can see how they were interacting with the tools, and with each other. Using their scientific thinking skills, some of the learners kept on referring to the degree of protrusion of the jaws, which showed that they were

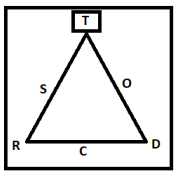
thinking scientifically about the activity. In my opinion, more mediation would have helped them to not steer so far from the correct sequence. The learners were shown the correct sequence afterwards.



Coded video lesson transcript: School number 4:

Agency: girl in front.
Interaction with tools: not correct sequence.
Interaction with tools: looks at *H. naledi*.
Social interaction: learners point at it and says something.
Interaction with tools: puts *H. naledi* outside of line up.
Interaction with tools: a learner hands her *A. sediba.*
Interaction with tools: puts *A. sediba* next to chimp.
Social interaction: ask learners where *H. sapiens* and *G. gorilla* must be.
Interaction with tools: place gorilla in middle.
Interaction with tools: another girl picks up *A. sediba* and looks at it.
Interaction with tools: she puts human next to *G. gorilla.*
Signs and symbols: they point to Mrs Ples and tell her that it should be next to human.
Social interaction: boy touching skulls asking friend if they agree.
Social interaction: it seems if the learners agree with sequence.
Social interaction: boy asks if it should be arranged per sequence in table.
Mediation: facilitator clarifies misconception and tells them what the goal is.
Signs and symbols: two learners in front row are pointing at skulls showing that they should be switched around. Also, telling the girl what to do.
Agency: two boys joined the girl in front.
Interaction with tools: she picks up *P. troglodytes* looking at the mouth.
Scientific reasoning: referring to brain size of *P. troglodytes*.
Interaction with tools; boy picks up *A. sediba*, touch teeth, look at palate and then the face.
I**nteraction with tools**: *G. gorilla* is now on opposite side of human.
Interaction with tools: they place chimp next to *G. gorilla*.
Scientific reasoning: looking at skull, palate, eyebrow ridges.
Social interaction: other learners invested, giving suggestions pointing to skulls.
Interaction with tools: place Mrs Ples next to *P. troglodytes.*
Interaction with tools: another learner hands them an extra *P. troglodytes*.
Signs and symbols: extra skull confuses them.
Mediation: facilitator indicates that they already have the skull and takes it away.
Interaction with tools: **Sequence**: *G. gorilla, P. troglodytes, A. sediba, Mrs Ples, H. naledi, H. erectus, H. sapiens.*
Scientific reasoning: boy picks up two skulls and looks at their faces, while other learners point at jaws and brain.
Interaction with tools: boy leaves sequence as is.
Interaction with tools: keep touching craniums of three skulls.
Scientific reasoning; seems they arranged them from small to big cranium after the *P. troglodytes*.
Scientific reasoning; not sure about *A. sediba* and Mrs Ples.
Social interaction: boy ask learners which one should be next to *P. troglodytes*.
Social interaction: four boys says that Mrs Ples should be next to *P. troglodytes*.
Social interaction: they switch them around Mrs Ples is next to *P. troglodytes*.
Social interaction: girls in front confirms the sequence by talking about the sloping of the faces.

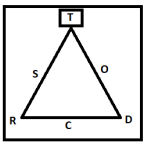
In this activity, the agency changed after they realised that their original goal was not what was asked. So, after mediation, they started with the goal of the activity. The agency only changed once afterwards when two boys joined the girl in front. There was a lot of interaction with the tools as learners were picking up the skulls and using scientific reasoning by looking at the skull, eyebrow ridges and even the palate. There was a lot of social interaction with the rest of the class, as they asked their opinion on the position of one of the skulls. Learners in class also gave their opinions on where the different skulls should be. They used signs and symbols such as gestures and pointing to skulls, indicating where they should be. Other signs and symbols in this activity was the body language of learners indicating when they were confused or unsure. Overall, this social interaction along with the interaction with tools, a bit of mediation and scientific thinking tools worked perfectly to get the learners to the correct sequence. Overall, it was a very successful learning opportunity as the learners were all involved.



Coded video lesson transcript: School number 5:

Agency: girl in front.
Signs and symbols: **Body language**: very sure of herself.
Scientific reasoning: using the results from her worksheet.
Interaction with tools: places *G. gorilla* first.
Mediation: facilitator gives clues, pointing at worksheet.
Interaction with tools: picks up Mrs Ples.
Signs and symbols learner in front, touches *P. troglodytes* and points at the position it should be.
Interaction with tools: put *P. troglodytes* next to *G. gorilla*.
Mediation: facilitator helps with placement of *P. troglodytes.*
Signs and symbols: another girl pointing at Mrs Ples indicating position.
Interaction with tools: places Mrs Ples next to *P. troglodytes.*
Interaction with tools: pick up *H. erectus* and *A. sediba*.
Scientific reasoning; look at faces of two skulls, look at level of protrusion of jaws.
Interaction with tools: place *H. erectus* next to Mrs Ples, then *A. sediba*.
Social interaction: learners disapprove.
Interaction with tools; place *H. Naledi* next to *A. sediba* and then *H. sapiens*.
Signs and symbols: learner in front indicates with hands that she must switch skulls around.
Interaction with tools: place *A. sediba* between *H. erectus* and Mrs Ples.
Social interaction: agreement from learners.
Mediation: facilitator asks to look at faces and points to protrusion and say what she sees.
Interaction with tools: she looks at faces of skulls.
Signs and symbols: girl in front indicate that *H. erectus* and *H. Naledi* should be switched around.
Interaction with tools: she switches *H. erectus* and *H. naledi* around.
Video ends.

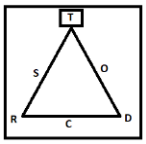
The agency in this activity did not change, since the girl in front directed the activity with a lot of mediation from the facilitator. She used scientific reasoning, as she looked at her data from the workshop. Learners in class also interacted with the activity by using gestures and pointing to indicate positions that they thought skulls should be in. They also disapproved loudly when they did not agree with the sequence. In this activity, the mediation and social interaction of the learners assisted a lot to get to the correct sequence. The facilitator mediated a lot with questions and signs (pointing etc).



Coded video lesson transcript: School number 6:

Agency: one boy in front is leading the activity.
Social interaction: rest of class quiet, fixated on what he is doing.
Signs and symbols: **Body language of boy**: self-assured.
Scientific reasoning: looking at the front of the skulls (how much they are protruding).
Interaction with tools: he starts out correct, then starts to doubt himself at *H. naledi* and *H. erectus*.
Social interaction: ask classmate to help him out.
Social interaction: learners start to give input, not very loudly.
Signs and symbols: some point but don't say anything constructive unsure.
Interaction with tools: he decides to place *H. naledi* after *A. sediba*, then *H. erectus* then *H. sapiens*.
Social interaction: some learners disagree.
Signs and symbols: pointing to skulls, indicating that they should be switched.
Social interaction: discussions amongst learners.
Change of agency: another boy volunteers to arrange skulls.
Interaction with tools: he switches *A. sediba* and *H. naledi* around.
Scientific reasoning: he argues H. naledi has a more protruding face.
Social interaction: girl argues that it cannot be used as an argument to move *H. naledi* away from human side.
Scientific reasoning: girl argues that *H. naledi* has a more protruding face than some of the other skulls closer to *G. gorilla.*
Scientific reasoning: boy points at *H. naledi's* eyebrow ridges, says its bigger than *A. sediba*.
Scientific reasoning: girl points at *H. erectus* and says look how big his eyebrow ridges are.
Interaction with tools: boy moves H. erectus between *A. sediba* and *H. naledi*. *A. sediba* is now next to *H. sapiens.* .
Social interaction: classmates in disagreement.
Social interaction: another girl says *H. erectus* must be next to *H. sapiens*.
Sci reasoning: she says *H. erectus* is the first to be upright.
Change of agency: girl comes to the front.
Interaction with tools: she puts *H. erectus* next to human.
Scientific reasoning: looks at facial features of *A. sediba* and *H. naledi.*
Interaction with tools: switch *A. sediba* and *H. naledi. H. naledi* is now next to *H. erectus*.
Social interaction: prompt from another learner.
Scientific reasoning: looks at the bottom of *A. sediba* and *H. naledi's* skull at position of foramen magnum.
Interaction with tools: leave the sequence as is.
Social interaction: rest of the learners now look satisfied with the sequence of the skulls.

This activity started out with the learner being sure about himself, using scientific reasoning and asking for assistance from his peers when he was unsure. When there was a change in agency, the new arrangement caused scientific debate between two learners, as the one argued against placing *H. naledi* in a specific place, while the new boy defended his decision by referring to the size of the eyebrow ridges. Another girl used scientific reasoning to state that *Homo erectus* should be next to the human and referred to bipedalism. After another change in agency, the *H. erectus* was moved next to the human. The girl also used scientific thinking and compared *A. sediba* and *H. naledi* by looking at facial features and the position of the foramen magnum. In this activity, there was a lot of social interaction with the learners in front and their peers. Scientific reasoning was also used regularly.



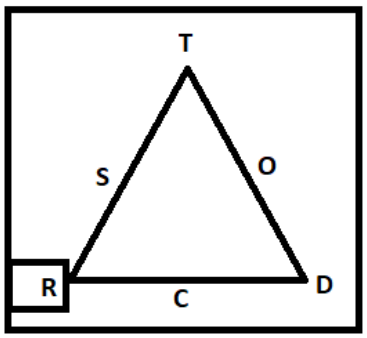
Coded video lesson transcript: School number 7:

Agency: facilitator is sequencing skulls according to learners' instructions.
Agency: learners decide *G. gorilla* first and then *P. troglodytes*.
Mediation: he asks who should be placed first after *P. troglodytes*.
Agency: a boy says Mrs Ples is first.
Signs and symbols: boy in front row points at two skulls.
Sci thinking: boys says they are very similar.
Agency: original boy says Mrs Ples is first, again.
Mediation: Facilitator places ruler on Mrs Ples's face, says they must look at eyebrow ridges.
Agency: learners agree Mrs Ples must be next to *P. troglodytes*.
Mediation: facilitator lines up skulls that remain.
Mediation; the eyebrow ridges are measured.
They have to now arrange it according to this.
Interaction with tools: boy in front row touches one skull and says that it should go right.
Social interaction: one girl disagrees.
Mediation: facilitator puts ruler in front of skulls' face.
Mediation: he says that the one in the middle's face sticks out the most.
Signs and symbols: learners in front and second row nod their heads in agreement.
Signs and symbols: boy in front row now staring at skulls, deep in thought.
End of the video

In this video clip, the facilitator wanted to save time, since learners had to depart soon. The workshop had to be shortened. The facilitator was an agent in this activity, but the learners in class interacting with him were directing the sequence of the skull, thus being agents themselves. After the placement of the *G. gorilla* and the *P. troglodytes*, two boys directed the activity, the one indicated that Mrs Ples must go next, while the other looked at the skulls and said that they were similar. The facilitator

mediated the activity by placing a ruler in front of the skulls' faces. After this, all the learners agreed that Mrs Ples should be placed next. So, in this scenario, there was scientific thinking, mediation and social interaction at play. The next part of the activity was highly mediated by the facilitator, indicating the flatness/protrusion of the skulls with a ruler. Learners interacted by indicating which skulls should be next and agreeing/disagreeing with each other. In this scenario, the fact that the facilitator acted as an agent, influenced the social interaction of the activity. More learners were passive and only a few directed the activity.

In the seven video transcripts and discussions, it is clear that socio-culturalism was a major part of this activity. Learners were not sitting idly receiving information; they were constructing their new knowledge together by interacting with the tools and using scientific thought. By viewing the activities, non-verbal ques indicated how learners' body language indicated when they were feeling cognitively challenged, or when other learners used gestures to indicate their positions on the arrangement of skulls. In some scenarios, the mediation was just the right amount and helped learners to come to the correct sequence on their own. In others, there were too much mediation and learners should have been left to figure it out more on their own. In one case, the mediation should have been more, as learners went from the almost correct sequence to a totally wrong position. It seemed as if they didn't understand what it was that they were supposed to be doing. This points to the importance of mediation in sociocultural activities.



4.4 RULES

The rules of this activity system are as follow:

Life Sciences Caps policy document (DBE)

The effectiveness of this workshop lies in the fact that it was totally aligned to what the Caps policy document required grade 12 learners to know about human evolution. Before we started the programme, the existing workshop material was relooked at and aligned to make sure that all the required content was addressed. The learners had to use the scientific skills required by the Caps document to obtain knowledge about human evolution.

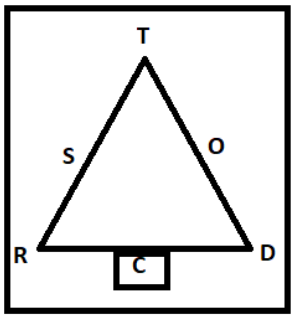
University rules

The workshops at the university laboratory and museum had to adhere to the university requirements. There were a lot of scientists working at the Evolutionary Sciences Institute (ESI) and the laboratory was situated within their midst. Learners had to behave in a disciplined manner. We had an incident with one school where there were some learners that were very ill-disciplined and they were subsequently chased out of the museum by the museum facilitator. Following this, they went to the ESI building where they continued to make noise and run around, upsetting some of the staff members working there. We were still busy with the other group in the laboratory. This was one of the grade 10 groups, but it had a ripple effect on the programme. The schools were notified that, when they bring learners, there should be enough teachers to help maintain discipline. Another aspect of university rules was with the procurement of busses. The university had strict rules on the procurement of busses and we were only allowed to use the transport companies approved by the university. The funding was provided through university channels and this is why we had to adhere to their rules and regulation. The first phase of the programme was operated with research funding, which funded the transport.

Unfortunately, the funding was depleted quickly because of the high costs of the transport companies prescribed by the university.

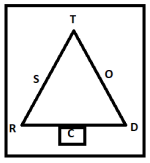
School rules

Schools also had rules regarding field trips. Learners had to dress in school uniform and behave in a disciplined manner. The workshops conducted at schools also required learners to adhere to their school's code of conduct. Overall, learners were well behaved at their schools. The teachers were at school and assisted with the discipline.



4.5 COMMUNITY OF PRACTICE

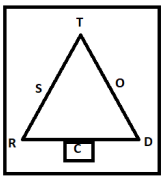
This community of practice was composed of the university lecturer, university assistants, district subject advisor (also the researcher), teachers and principals. Each member of the community of practice will now be discussed separately.



4.5.1. UNIVERSITY LECTURER

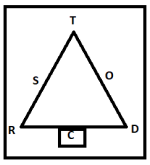
The university lecturer was the person responsible for the whole programme. The program of the day was also decided after a school arrived at the university. If a school arrived very late, they would not be able to go to the fossil extraction

laboratory. In our busy weeks, we had schools every day, the staff working at the fossil extraction laboratory started to complain about the disturbance and some schools were subsequently not taken to the extraction laboratory. After each field trip, we had a reflective discussion on the days' activities. I would give feedback on the views of the learners and teachers. We would discuss possible changes to the programme. Some examples of changes made due to reflection sessions were the introduction of two litre soda bottles, filled with green coloured water and pictures that are representative of each species (Figure 4.7). After interviews with principals, we decided to take the workshop to the schools. We started with six schools during the next year, and we found that it was difficult to conduct a workshop with more than 60 learners after we conducted a few of them. We then tried workshops with 60 or less learners. In the last feedback session, the lecturer indicated that we should introduce a break in the middle of the workshop as learners got tired after 1,5 hours. He also indicated that the learners had more energy and were more engaged on Saturdays as compared to a weekday afternoon. We were planning to do more than one workshop at our big schools, but unfortunately, we were halted by Covid-19 restrictions.



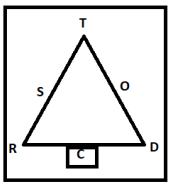
4.5.2 UNIVERSITY ASSISTANTS

There was a total of five assistants that assisted throughout the years. They assisted with the activities and sometimes helped with the facilitation/mediation in the groups. One assistant always led the activities in the museum. She gave me feedback on what she saw and the type of questions the learners asked. She was fluent in most of the languages and could understand what they were discussing in their groups. Feedback from these assistants was that overall, the learners participated in the activities and that they seemed to enjoy the activities.



4.5.3. DISTRICT SUBJECT ADVISOR (ALSO THE RESEARCHER)

As district subject advisor, I was the link between the schools and the university. The formation of a community of practice that would continue after this programme was one of my goals. I made sure the schools had the contact information of the university lecturer so that they could book their own excursions in future. A WhatsApp group was created where all information such as dates were communicated. Teachers also posted photos of their field trips and gave feedback. Regular communication took place between the university and me and we reflected on how we could improve the working relationship between the schools and the university.



4.5.4. TEACHERS

Ten of the teachers in the programme were interviewed. The interviews were coded inductively, and the percentage frequency of the codes is depicted in Table 4.6 below shows the frequency of the codes:

All the teachers thought the workshop and the hands-on activities were beneficial. Coupled with this, the scientific skills used in the workshop were mentioned as being beneficial by three teachers. Following is a quote from one teacher:

> "..because they could literally see exactly what is happening and it is not just talk, they can touch it and they can take part in the experiment, which is not something they are exposed to at school"

Teachers (90%) referred to the fact that the learners could link what they saw in the workshop to the theory taught at school. They saw this as very beneficial:

> “Now the child can study the content, he already has a picture about the skulls in his brain, it links theory to practice. This is what I like, it was excellent”

Forty percent of the teachers said that it was very educational. One teacher referred to the fact that she had to leave the workshop for 40 minutes (it was the first school hall session), and when she returned, the learners were able to explain the link between the foramen magnum and bipedalism to her. The learners were not taught this content yet. So, she was surprised at how much they have learnt during a short space of time.

Forty percent of teachers referred to the lecturer as being very knowledgeable and able to answer all the learners’ questions. They also found the mediation that he gave in the groups during activities very beneficial:

> “I think it is good as is, because we are interacting with the lecturer who is very informative and willing to share, willing to assist and willing to teach”

> “I found the workshop very educational because the lecturer gave more specialised information, even more than is normally required”

> “The workshop was crucial for the learners to see the different kind of skulls as well as hear the explanation. There was a facilitator that side who is mediating and explaining things to the learners”

Fifty percent of the teachers indicated that the workshop was beneficial as the learners could refer to this workshop when they were studying for the exams, because the learners also took photos of the artefacts. Three teachers indicated that this workshop would help the learners with the exams.

Five teachers were interviewed a year after the workshop, and they were asked whether they saw a difference in the group that attended the workshop and the groups that did not attend the workshop. The teachers indicated that the learners understood the topics better than the ones that did not attend. The learners could visualise the content better than the learners who had only the textbook. The fact that they took photos also helped. One teacher who took the learners on the fieldtrip during their grade 11 year, reported that learners could link the content being taught in class to the photos they took during their workshop. They could remember some facts taught during the fieldtrip and link their experiences to the content being taught.

Three teachers indicated that learners usually struggle with this topic, and that the workshop was beneficial in that regard. The following quote illustrate this point:

> "The learners don't understand evolution at all. If you give them a piece of paper with all these words like *Australopithecus* and other names. They don't understand it and they block it out. Most of them link it to their religion and rejects it. So now they in the workshop and they see it, hold it and ask questions about it and there is someone who can give them the answers. In class they only have the textbook, but now they are able to link it to what they saw"

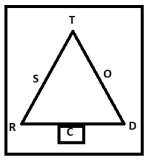
Another teacher was interviewed on how the workshop at the university differed from the workshop at school. Her learners attended the workshop at the university two years prior and now the workshop was conducted at her school. Her view was that the workshop's content wasn't different and that it was still beneficial and educational. She alluded to the fact that it was easier to conduct it at school but that some of the enjoyment was lost:

> "I think the learners enjoyed the excursion to the university more, maybe it was nicer to do something away from school. The value of the workshop however stayed the same, whether it was at university or at school. It was easier for us as teachers as well as cheaper to host it at school. More learners were able to attend because we didn't have to arrange for a bus"

Another teacher who had the workshop in her laboratory indicated that the workshop was beneficial, but that some of the learners indicated that they would have preferred it to be in Afrikaans. Some of these learners also complained about the fact that religion was mentioned. This was discussed under my observations, where a learner asked this question and when we answered, some learners were listening and got offended. Unfortunately, it was not possible to translate everything into Afrikaans as Wits was an English medium university and the lecturer also spoke English. Fifty percent of the teachers indicated that they want to be part of this project in future and would like their learners to attend the workshop every year.

Code	Percentage frequency of the codes (n=10) (%)	Themes
Linking theory to practice	90	Workshop links theory to practice
Beneficial	100	The hands-on activities and scientific skills are beneficial to learners
Hands-on activities beneficial	100	
Scientific skills beneficial	30	
Enjoyable	30	Workshop is enjoyable and educational
Educational	40	
Lecturer knowledgeable	40	Lecturer is knowledgeable and the mediation during activities is beneficial
Mediation beneficial	30	
Will help with exams	30	Workshop will assist learners with examinations, and they can refer to what they saw when they study, it's better than textbook
Learners can refer back to what they saw when studying	50	
Better than just textbook	20	
Learners usually struggle with evolution	60	Learners normally struggle with evolution
Want to return every year	50	Would like to receive workshop every year.

Tabel 4.6: Codes and themes from interviews conducted with teachers (n=10).



4.5.5. PRINCIPALS

Ten principals were interviewed, and they were asked the following questions:

- Do you allow your learners to go on educational excursions?
- What challenges do you have with educational excursions?
- If a programme was proven to be educationally beneficial, will you send your learners?

The principals were representative of well performing and underperforming schools. Well-resourced as well as financially constrained schools are represented in this sample. The interviews were coded inductively.

All the principals were in favour of sending learners on field trips (Table 4.7). They indicated that field trips have benefits, but 70% indicated that field trips had to be educationally sound before they would send learners on these trips.

> "Excursions broadens learners frame of reference with regards to learning. The child has to link theory and practice. The excursions usually give them that opportunity."

> "It is great when the learners come back and say, sir now I see the bigger picture. I take learners to universities in order to help them make decisions regarding the degree they want to study, for example bio kinetics or microbiology. They need to be exposed to both these to decide. It is important for the learners' life choices. When they have seen the university, they come back motivated because they have seen what it is all about. So, it has to have value. I attended excursions in the past that was organised by the department of education which was really bad. If the excursions are educational and the learners benefit, I'm a hundred percent for it"

Challenges with transport were mentioned during the interviews and 80% of the principals indicated that excursions cause problems with discipline. Learners saw this as an opportunity to act out. Lack of funding was identified by 90% of principals as a major challenge as far as excursions were concerned. Refer to the quotes from two principals below:

> "The majority of our learners are situated in an area where parents are unemployed, they are not working. You will find the challenge of transport and also the issue of discipline. Even though they are exposed to a different environment, but the issue of discipline is still a challenge because you have to be there each and every second watching them, anything can happen if you are not there next to them."

> "The biggest challenge is money and learners missing out on a school day. It is very expensive to hire a bus. The expenses are the most important part, people in our community cannot contribute financially. We do not have a budget to pay for such expenses."

Thirty percent of principals indicated that field trips caused a loss of teaching time for the other subjects that were not involved. It also caused a shortage of staff at school because of teachers attending the excursion and their classes then having to be attended to:

> "Looking after the other classes of learners whose teachers left to go on the excursion is a big challenge at this stage. It causes a disruption at school. Also, the teachers have to compile worksheets for the learners who didn't attend the workshop"

> "Some of the teachers are unhappy when they hear a specific subject's learners are going on an excursion, they feel the learners are losing teaching time in their subject. They have to assist the learners to catch up with the work missed on that day"

Principals (20%) complained about administrative challenges before a field trip takes place. They had to complete a lot of forms and submit it three months in advance in order to be granted permission to take learners on an excursion. Twenty percent of principals spoke about the responsibility that lies on their shoulders and that anything could go wrong during such a field trip.

> "For example, learners have attended excursion at Nasrec, where found wanting by the educators, some learners did not come back in the same bus it is a huge challenge. Later on, the evening some parents phoned and said that my child has left with the bus and is not yet back. Fortunately, the teacher reported to me that when they wanted to come back the learners just disappeared"

> "It is the responsibility that goes with it. A tyre can burst on the way, who is responsible? So as principal I can only relax when the bus has returned and all my learners are safe."

Principals (4%) indicated that the teachers at school were able to catch up with lost teaching time caused by an excursion and that this was not a big deterrent:

> "Normally there will be plans around that to catch up with those days, normally it becomes a one day situations and if the teacher then goes to the head of the department and make plans for catch up for that day that the learners are not in class."

> "But learners will also miss out on a day of teaching if the teacher is absent for illness for example. So, it is exactly the same situation, and we don't have a problem at our school. The teachers find ways to catch up with the lost work. I think the teachers just have to give the go ahead and if you say its educational then it won't be a problem. You have to see the bigger picture"

As far as the lack of funding was concerned, 50% of principals indicated that they had fund raising events to help the learners:

> "We try to basically make up the money with other children contributing and a sponsor will maybe give a quarter of the total cost and that's how we get the funds."

One principal indicated that if there was no funding, he would not send the learners as can be seen from the following quote:

> "It will be a little bit of discrimination in the sense of money, because there are those learners who will be able to pay and there are learners who won't be able to pay. So, for us to segregate our learners based on finance is not ok."

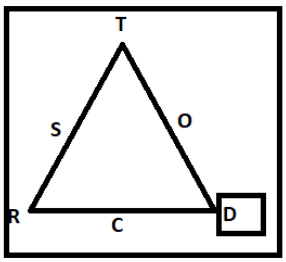
Thirty percent of the schools' principals indicated that the school could help these learners. One principal indicated that the learners that could afford it would attend the excursion while those that could not afford it would stay at school. They were a non-fee paying school and the school did not have money to help the learners.

> "Learners are paying, that is the challenge, you won't have that 100 percent that are able to pay, usually it's between 90 and 95 percent learners that can pay, then it means as a no fee school we cannot subsidise the child that does not have money. So, they stay at school."

When looking at the data, the biggest challenge was finance and transport. Most of the schools indicated that they could deal with the challenges. All the principals were very positive towards educationally beneficial excursions and supported it.

Code description	**Percentage frequency (%) of the codes**	**Themes**
Lack of money	**90**	**The challenges impacting on fieldtrips are lack of money, discipline of learners, manpower, administrative challenges transport and loss of teaching time when sending learners on fieldtrips.**
Loosing teaching time	30	
Discipline problems with learners	**80**	
Challenges with manpower	20	
Responsibility anything can go wrong	20	
Administrative challenges	20	
Challenges with transport	**40**	
Prefer workshops at school	10	
Only send learners if funding is available	20	
Teachers can catch up with lost teaching time	**40**	**Schools raise funds to sponsor learners to attend fieldtrips and teachers can catch up with lost teaching time**
School raise funds/get sponsors	**50**	
In favour of sending learners on fieldtrips	**100**	**Principals are in favour of sending learners on fieldtrips, they view it as beneficial as long as it is educationally sound.**
Fieldtrips have benefits	**100**	
Fieldtrips have to be educationally sound	**70**	

Table 4.7: Codes and themes generated from interviews with ten school's principals regarding their views on excursions.



4.6 DIVISION OF LABOUR

,

This programme had two distinct phases, namely workshops conducted at the university and workshops conducted at schools. During the first year of the programme the workshops were conducted at the university. The division of labour was as follow:

4.6.1. UNIVERSITY LECTURER

The university lecturer organised the workshop material and conducted the workshop. He liaised with the university staff regarding the workshop. He had more responsibilities when the workshops were conducted at schools. He had to book a university vehicle to transport the artefacts to the schools.

4.6.2. SUBJECT ADVISOR

The subject advisor was also the researcher of this study. I had to obtain permission from the director of the educational district that participated in this study. This was usually frowned upon by GDE as grade 12 learners were not allowed to miss out on a day of school.. After this, schools were chosen randomly to be part of the programme. Letters had to be sent out to the schools informing the principals. A special meeting was held with the teachers at the schools involved to inform them what the programme was about. Dates were plotted for each school. It should be mentioned that this programme had a grade 10 and 12 component, and each school had to send their grade 10 learners on a specific day, while the grade 12 learners had to be sent on another day. The grade 10 component does not form part of this study. During April of that year, there was a national bus strike, and no busses were available. The whole programme had to be rescheduled. This was very difficult to do,

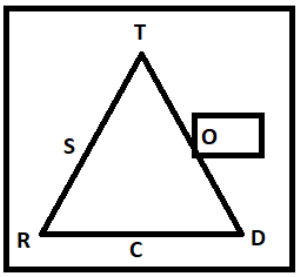
as schools and the university staff had other programmes and priorities. Each school had to be accommodated on a date that suited them after the bus strike ended in May. The first school that attended a workshop after the bus strike sent their grade 12 learners, instead of the grade 10 learners, as was indicated on the programme. We only found out that it was grade 12 learners after we conducted the grade 10 workshop (which is not part of this research). To add to the misery, these learners had to wait until one o' clock at school because there was miscommunication between the university and the bus company. This led to a very unhappy principal. On another occasion, there was a miscommunication between the bus company and the university, and no bus was sent to the school. As subject advisor, I had to intervene, and I phoned a neighbouring school and organised their bus for this school. As subject advisor and researcher, I attended every workshop and helped with the facilitation during the workshop. During the second phase where the workshops were held at the school premises, I had to ensure that the schools arranged the correct venue and organise the date, time and duration of workshop with the teachers.

4.6.3. UNIVERSITY STAFF

One lady (an Honours student) was tasked with the arrangement of all logistics. She had to liaise with the bus companies and schools. I, as subject advisor, supplied her with dates and numbers of the responsible teachers. She had to deal with administrative challenges of the university, as well as the bus companies. I sometimes had reflection sessions with the students that helped with the facilitation of the activities, or the lady that conducted the museum session with the learners. I asked them what they observed. They observed the learners' participation and listened to what they were talking about. They usually indicated that learners from a certain school were very inquisitive and discussed the exhibits in the museum and asked interesting questions, or the learners were not interested and were just playing around.

4.6.4. SCHOOL TEACHERS AND PRINCIPALS

The principals had to give permission for their grade 12 learners to attend the workshop. They had to arrange with teachers of the other subjects to catch up with lost time due to the excursion. This was not the case where the workshops were conducted at school, as it was done after school hours. The teacher had to ensure that the learners received the information leaflet regarding the workshop, and that they returned the indemnity forms, as well as the consent and assent letters before they could attend. They had to inform the learners what the workshop would entail and some felt that they needed to teach the topic first, before the learners attended the workshop. They were also responsible for the learners' discipline during the workshop. They had to ensure that all learners were on the busses when it left, so that no learners were left behind. With workshops at schools, the teachers were responsible for the venue, learner attendance and discipline. Some teachers also assisted with the mediation of the activity.



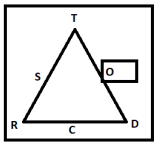
4.7 OBJECT

The object of this activity system was to improve learners' performance in the topic human evolution. This will be discussed in three sub-sections, namely:

-Learner's acceptance of human evolution.

-Challenges with phylogenetic trees.

- Pre- and post-test results.



4.7.1. LEARNERS ACCEPTANCE OF HUMAN EVOLUTION

As previously stated, South Africans had a low acceptance of human evolution (Lelliott, 2016). Religion, specifically Christianity, was a stumbling block, which hindered the understanding of evolution by South African teachers (Sutherland and L'Abbè, 2019) and this impacted negatively on the teaching of the topic. Collaborative activities that necessitated students working together to analyse data and generate their own evolutionary explanations were more successful in helping learners understand and accept evolution (Legare et al., 2018; Shtulman & Calabi, 2013). This was the approach followed in the workshop. To determine the impact of the workshop on the acceptance of human evolution, the following question was included in the pre-and post-test:

In your opinion, did humans evolve from other species of animals?

a) Strongly disagree
b) Disagree
c) Neither agree or disagree
d) Agree
e) Strongly agree

The data (Tabel 4.8) indicate that the majority of learners chose the agree option in the pre-tests (30%) and it even increased to 34% in the post-test. The second most popular option was "neither agree or disagree" in the pre-test (26%) and it decreased with 6% in the post-test. Hence, 6% of the learners who did not have an opinion before the workshop had one after the workshop.

There was a decline of 3% in the disagree option, but learners with a strong opinion against evolution stayed the same before and after the workshop. It could be an indication that it is not so easy to change the opinions of people with strong convictions.

Looking at the overall results, the majority of the learners agreed or strongly agreed with the statement that humans evolved from other species of animals in the pre-test (41%) and it increase after the workshop to 51%. The learners who disagreed or strongly disagreed decreased from 31% to 28%. Showing that the workshop had an impact on learners' acceptance of human evolution.

Option chosen	Pre-test		Post-test		Variance
	Number of learners	Percentage (%)	Number of learners	Percentage (%)	
Strongly disagree	90	15	92	15	0
Disagree	99	16	76	13	-3
Neither agree/disagree	157	26	119	20	-6
Agree	181	30	205	34	+4
Strongly agree	68	11	101	17	+6

Table 4.8: Number and percentage of learners (n=595) who chose the different options in pre-and post-test.

Considering the results (Table 4.9), the majority of the learners stayed with their original choice made in the pre-test. This Indicates again that it is not so easy to change people's opinions. Learners who chose agree or strongly agree, mostly stayed with their option of agreement, 14% moved from agree to disagree and 11% moved from strongly agree to disagree, which is relatively small change in opinion. Learners who disagreed and strongly disagreed showed a 18% movement to agree from strongly disagree and 30% movement from disagree to agree. So, there was a larger movement from disagree before the workshop to agree after the workshop. The learners who didn't have a strong opinion before the workshop either stayed with no opinion (43%) or changed to agree/strongly agree (38%). Hence, the workshop was able to have a significant increase in the acceptance of human evolution of people with no particular opinion about the topic.

Option that individual learners chose in pre-test	Option the same learners chose in post-test	Percentage of learners who chose this option in post-test (%)
Strongly Disagree (90 learners)	**Stay at strongly disagree**	58
	Disagree	8
	Neither agree or disagree	16
	Agree	14
	Strongly agree	4
Disagree (99 learners)	Strongly disagree	14
	Stay at Disagree	35
	Neither agree or disagree	20
	Agree	25
	Strongly agree	5
Neither agree or disagree (157 learners)	Strongly disagree	5
	Disagree	12
	Stay at neither agree or disagree	43
	Agree	29
	Strongly agree	9
Agree (181 learners)	Strongly disagree	9
	Disagree	5
	Neither agree or disagree	6
	Stay at agree	55
	Strongly agree	24
Strongly agree (68 learners)	Strongly disagree	2
	Disagree	9
	Neither agree or disagree	7
	Agree	31
	Stay at Strongly agree	49

Tabel 4.9: Changes in choices regarding acceptance of human evolution, made by learners in the pre-test and post-test.

The data obtained during the interviews and comments made by learners in the post-test represented a much smaller sample group. The data are indicated in table below:

Code	**Post-test (n=29)**	**Interview (n=52)**
Don't believe in human evolution	16	18
Need more evidence	13	15
Evolution is against my religion	3	9
Animals can evolve, but not humans	0	1
Humans evolved with our species/or adapted to environment	0	2
Believe in human evolution	1	20
Quote scientific evidence to explain evolution	0	13
There is enough evidence to support evolution	1	8
God enabled evolution	1	1
Not sure about evolution	0	8
Keep science and religion separate/believe science but not religiously	0	6
We evolved from hominins but not hominids	0	2

Tabel 4.10: The codes regarding evolution obtained from post-tests and interviews

There was no specific question on how learners felt about human evolution on the post-test, so the codes were obtained from comments that twenty-nine learners made out of their own free will. When looking at the data, thirty-four of the learners indicated that they don't believe in human evolution. They indicated that they need more evidence to convince them. Twelve learners indicated that human evolution is against their religion, this concurs with Sutherland and L'Abbè (2019) view that religion, specifically Christianity, is a stumbling block which hinders the understanding of evolution by South Africans.

> "No, I strongly disagree because I believe we were made in the image of God so I don't understand how God can be an ape or gorilla. It doesn't say in the Bible that we were made in the image of an animal. So, I strongly disagree with it"
>
> "I would not agree with this evolution. I come from a Christian family, I believe in God. I think the evolution theory is based on imagination. Cause Albert Einstein said that imagination is much more beautiful than intelligence. So I

just think in this way Scientist was just trying to show the people around them that they were intelligent but were just using their imagination”

Among these were the essentialist tendency to view species as unchanging (Emmons & Kelemen, 2015; Herrmann *et al*., 2013):

> “I totally disagree because, they are telling us that we evolved from the animals but why don’t they evolve now, why did they stop.”
>
> “I like to be neutral on this matter. For me like I would like proper clear evidence and then I also feel if these humans…. why can’t they evolve further in something else? So, they need to be clear like although there are discoveries there are a lot of blank spaces that still needs to be divulged. “
>
> “with me I feel like scientifically I could believe it, but I have this feeling that it’s not real. I feel like it is just not real. I want some more evidence.”
>
> “I think, no. My answer is no actually. Cause ...the apes didn’t give birth to Sediba”

One learner felt strongly about the rejection of evolution and wrote the following on the post-test:

> “not my cup of tea, don’t believe in this (swearword), stop trying to make non-believers believe”

Twenty-one learners indicated that they do believe in human evolution and thirteen of them quoted scientific evidence to support their opinion:

> “Natural selection, I think it change through natural selection, because they had to adapt to different environments.”
>
> “At first I was very neutral about it, I didn’t have a fixed opinion about it but after looking at it more interacting with things such as the skulls and the DNA stuff as well, I’m much more convinced with it and I start to feel more in agreement with the evolution of humans”
>
> “I agree with evolution, I believe in evidence and results between our and other species that can be proven over and over”
>
> “I do believe that we come from other animals, most people will disagree with me and now I, because I debated with myself now I am open to such information. I do believe strongly that we have evolved from closest ancestors. We have evolved adapted and that is why we are all here.”
>
> “Mam I won’t lie, I was confused at first but now because of the information that I got from here I can say that I do believe we come from our ancestors which were animals before.”

Nine learners indicated that they believed that there is enough evidence to support evolution, as could be seen from the following quotes:

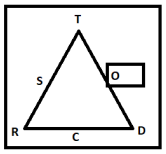
> "I believe so yes, because maybe we have a DNA strand that is similar to that of fruit flies and so on, but the differences for example between us and a chimpanzee are much more. The differences indicates, I believe, it is not directly from chimpanzee to *Homo sapiens*, but there were links which had to happen. So, it would be a chimpanzee, then a next phase, then a next over the years and so on…… so I believe it."
>
> "Similar, yes, it is similar, but they are not exactly done, they still getting a few more fossils and getting the correct evidence. That is why is probably likely but I think the evidence…. you can't ignore the evidence I suppose it is irrefutable"

Eight learners indicated that they were not sure about evolution, while six felt that religion and evolution should be kept separately.

> "I like to agree and disagree at the same time. If I disagree I will take it in a form of a biblical way. In the Bible God created Adam and Eve so they were the first species that show that evolution didn't take place. Adam was created and then Eve was created from the bone from Adam. So I can't believe it. But in terms of Life Sciences as we go to natural selection, no its not natural selection, but I'll take in terms of like human evolution, but the first part of the evolution which is natural selection. Natural selection states that a number of offspring will be produced and there will be a great deal of variation. There will be a great deal of competition between the offspring, the ones with the favourable characteristics will survive and reproduce. This also involves that as time goes in terms of Life Sciences I will agree but in terms of Biblical reference I will disagree. So I am on both sides."

Two learners indicated that God enabled evolution, while two thought that humans evolved from hominins but not other animals, which points to teleological thinking. Two learners indicated that we evolved within our species and adapted to our environment. This was essentialist reasoning which assumes that categories are stable and cannot mutate into something else (Gelman & Rhodes, 2012):

> "I believe people was there from the beginning, but we didn't look the same as now, but we were still humans."
>
> "Yes I think so. God made humans, he made animals first and they evolved to humans"
>
> "I don't think we came from gorillas and chimpanzees but I think the *Homo naledi* and the other hominin species, there are similarities between us and their species"



4.7.2. CHALLENGES WITH PHYLOGENETIC TREES/CLADOGRAMS

The last part of the worksheet required learners to complete a phylogenetic tree using the diagram we provided and the evidence that they gathered during the workshop (Figure 4.21). All of the learners struggled to do this activity. Not even one group could get it right without assistance. We took a mentoring approach. Referring to genetic differences and asking them leading questions. Unfortunately, there was no formal assessment of this activity at the end of the workshop. This would have indicated how many learners understood this activity after the workshop. I made observations during the activity while we mentored them. If they needed more help, we gave them more guidance. Some learners needed less guidance than others. This activity was also the one that linked everything together at the end of the session. When the lecturer discussed this during the feedback session, he referred to the various evidence they collected and discussed the concepts; speciation, common ancestor, extinct and the fact that we did not originate from apes but that we had a common ancestor with apes. Learners usually asked a lot of questions here and some had strong opinions during the interviews on this statement.

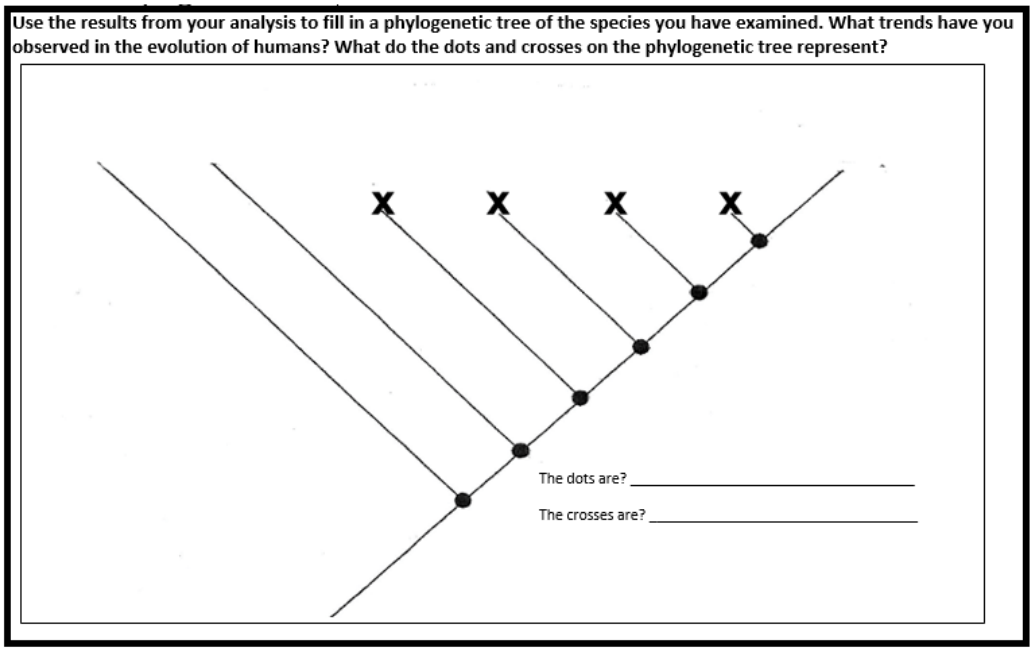
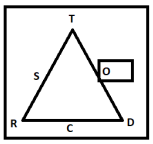


Figure 4.21: The activity requiring learners to complete a phylogenetic tree.

Following are some views that learners expressed during the interviews regarding evolution and the phylogenetic trees:

> "Yes, I think evolution is possible, when you look at a phylogenetic tree and the characteristics that we all have, it is sort of the same, you can be convinced that a human descended from a previous species."
>
> "Yes I think we could've evolved from other species, if you look at a phylogenetic tee and to the genetic similarities, how close we are to each other, then I think it is possible that we come from one common ancestor"
>
> "Today I learnt about hominins and I now understand phylogenetic trees"
>
> "I learnt a lot about phylogenetic tree and where humans came from"

Through observations and some feedback of the learners we could deduct that learners learnt more about phylogenetic trees and that the majority understood it better. We cannot however state that all learners understood phylogenetic trees when they left the workshop.



4.7.3 PRE-AND POST-TEST RESULTS

As previously mentioned, the learners wrote a pre-and post-test. These tests contained the same questions. The percentages of the test's results, out of a total of 7, were used. A paired two tailed t-test was used to calculate the p-value. A critical value of .05 was chosen as this is the value chosen by most statisticians (Frost, 2019). Table 4.11 contains the results of the pre-test and the post-test using the learners' results out of the total of 7. The t-test indicated that the differences are statistically extremely significant ($p<0.0001$, 95%, $t= 23.7825$, $df =686$, standard error of difference = 0.078). The null hypothesis was rejected. The 95% CI [-1.68,-1.43], indicated that there was a 95% certainty that the confidence interval contained the true mean of the population (McLeod, 2021). The Standard error of the mean (SEM) which evaluates how closely the sample estimates the population, was small also indicating a more precise estimate (Frost, 2019). Hence, the data indicated that the learners' performance improved from the pre-test to the post-test. This indicates that

the workshop improved learners' knowledge about the topic. The SEM for both the pre-test and post-test remained small, which indicated that the sample closely resembled the population.

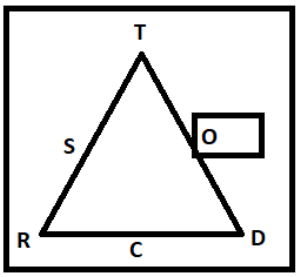
Sample size=687	**Mean**	**Standard Deviation**	**SEM**	**Minimum**	**Maximum**
Pre-test	2.74	1.31	0.05	0	7
Post-test	4.29	1.55	0.06	0	7

Table 4.11: The mean, standard deviation and SEM of the pre-and post-tests of 687 learners.

When we compared the school-based and university-based workshops (Table 4.12) the t-test indicated a statistically extremely significant difference for both workshops. For the university-based workshop it was ($p<0.0001$, 95%, $t= 18.1862$ d*f* =330, standard error of difference = 0.088), with a 95% CI [-1.77, -1.43]. For the school-based workshops it was ($p<0.0001$, 95%, $t= 13.3043$ d*f* =276, standard error of difference = 0.110) with a 95% CI [-1.67, -1.24]. It also seemed as if there was a greater improvement in the post-test results at the university-based workshop than the school-based workshop, though it was a small difference.

	University-based workshop		**School-based workshop**	
	Mean	Standard deviation	Mean	Standard deviation
Pre-test	2.84	1.21	2.69	1.45
Post-test	4.44	1.49	4.15	1.65

Table 4.12: The comparison of the pre-test and post-test data between university-based workshops and school-based workshops.



4.7.4 PRELIMINARY EXAMINATIONS RESULTS COMPARISON

The preliminary examination during the first year of the study contained an essay question that addressed human evolution. The question expected learners to describe the characteristics of the skull of *Homo sapiens* that differentiates them from African apes. They had to explain how the differences in the human skeleton and that of African apes results in different modes of locomotion. As previously stated, this was a standarised examination paper and all the schools in Gauteng wrote the paper. After a year, schools in the educational district were approached and they were asked if they still had their provincial paper scripts from the previous year. A total of thirteen schools still had the scripts available. Permission was asked from the schools to analyse the essay question of paper two. The value out of a total of 20 marks were used in the statistical calculations.

The data from the preliminary examinations were compared using the unpaired two tailed t-test. The two groups were learners from different schools, one group attended the workshop while the other group did not. Both groups contained a mixture of well performing and non-well performing schools. In the group that attended the workshop there were five township schools and three ex-model C schools. In the group that did not attend the workshop there were four township schools and one ex-model C school. The schools that attended the workshop, scored higher marks for the examination question on human evolution, compared to those schools that did not attend (Table 4.13). An unpaired t-test found that the differences were extremely statistically significant ($p<0.0001$, 95%, $t= 10.9467$, $df =567$, standard error of difference = 0.362).

The SEM values were small which indicated a more precise estimate. The SEM was very small in both samples which indicated that it was representative of the population group.

Group attended/did not attend workshop	Sample size	Mean	Minimum	Maximum	SD	SEM
Attended the workshop	246	8.20	0	18	3.99	0.25
Did not attend the workshop	323	4.24	0	20	4.48	0.25

Table 4.13: Comparison between the schools that attended the workshop and those that did not, using the minimum value, maximum value, mean, SD and SEM of the preliminary examinations question on human evolution.

4.8 OUTCOME

The overall outcome could be summarised as follow:

- The learners mostly found the workshop beneficial, enjoyable, exciting, interesting and felt that they learnt new facts and gained a deeper understanding of human evolution. Only a small percentage of learners did not enjoy the workshop.
- Learners' acceptance of evolution increased after the workshop, while the learners with strong convictions did not change their views.
- Learners' performance in the topic improved significantly.
- Teachers felt that the workshop was enjoyable, educational and that the hands-on activities link theory to practice. They also felt that the workshop will assist learners with preparation for the examinations and would like a repeat of the workshop every year.
- The principals are in favour of sending learners on fieldtrips as long as it is educationally sound. They indicated that lack of money, disciplinary problems with learners, transport and loss of teaching time are the biggest challenges when sending learners on fieldtrips.
- The main difference between the university -based workshop and the school-based workshop was that learners enjoyed the university-based workshop and fieldtrip more.

The overall findings linked to the CHAT framework is depicted in Figure 4.22 below.

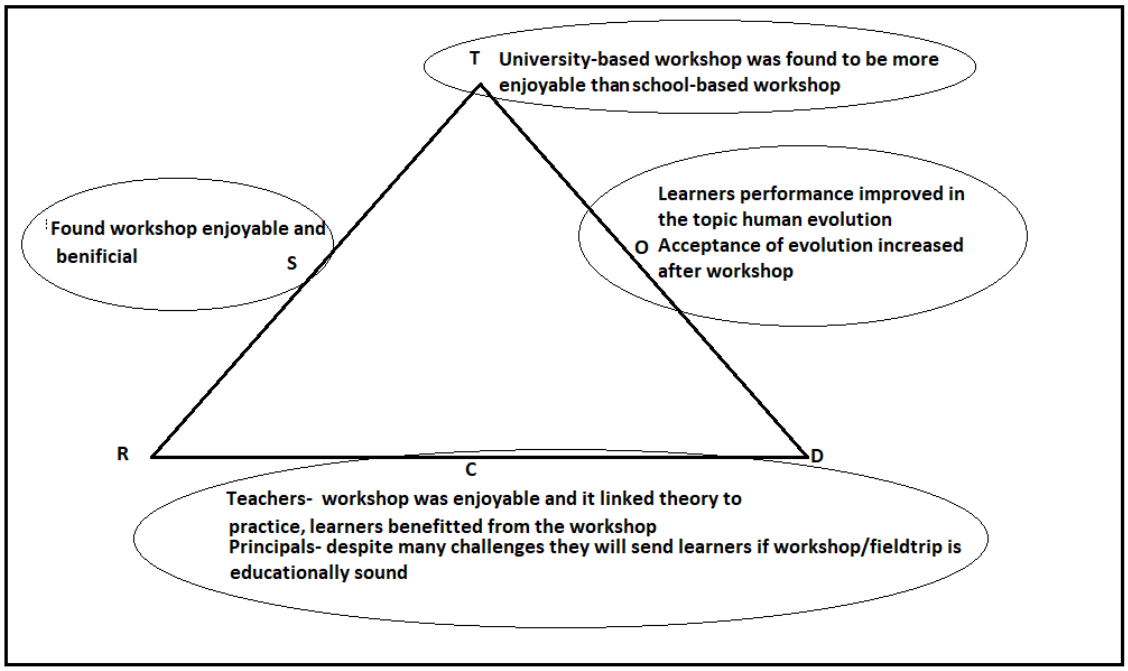


Figure 4.22: Summary of outcomes depicted in CHAT framework

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1 MAIN FINDINGS

In this study, the effectiveness of a Palaeosciences University Museum Programme (PUMP) was researched. The programme focused on human evolution and was presented either at Wits, or individual schools. In summary, my main findings are depicted in Figure 5.1 below followed by detailed discussions.

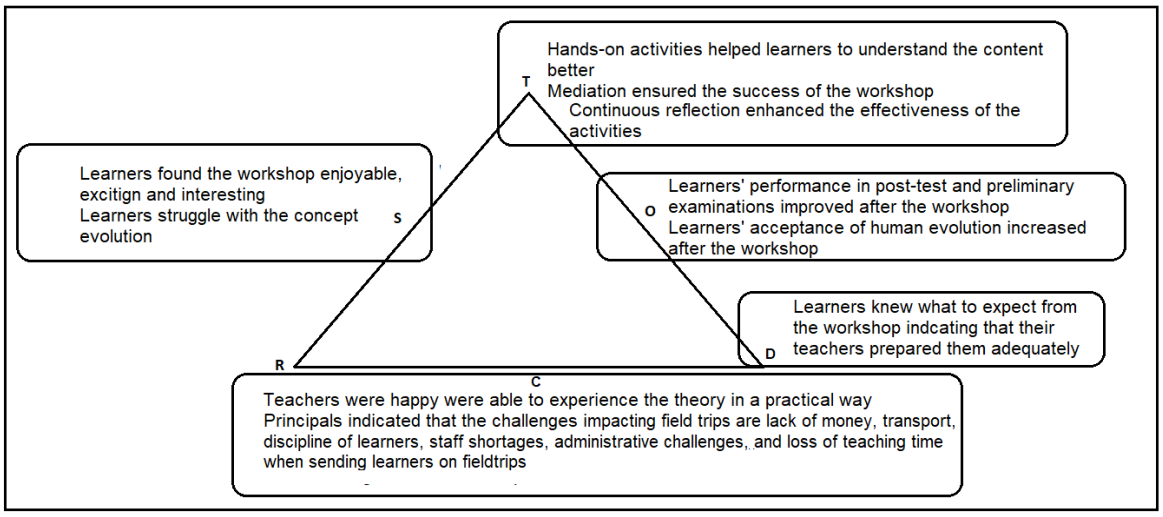


Figure 5.1: Main findings summarised in CHAT framework

1.) *Principals indicated that the challenges impacting on field trips are a lack of money, transport, discipline of learners, staff shortages, administrative challenges, and loss of teaching time when sending learners on field trips.*

This theme is reiterated in international studies (Anderson et al., 2006; Connealy, 2018; Kenna, 2019; Kisiel, 2014; Kisiel, 2005) where it was found that the decline in field trips is usually blamed on:

- A lack of funding.
- Liability issues.

- Important testing or examinations, and schools have to prepare learners for the (NSC) exit examinations. Schools are judged according to the results the learners achieve in these examinations.
- Logistics such as transport and cost.
- Great differences in teacher's skills.
- Time constraints and conflict with school timetables.
- Poor learner behaviour.

South Africa was plagued with existing inequalities and many schools had negative socioeconomic factors, overcrowded classrooms and poor infrastructure, impacting on the school (Amnesty International, 2020). Ex-model C schools (previously advantaged during Apartheid) were generally well equipped, with adequately qualified sciences teachers (Fish, 2016). Township schools were typically poorly resourced and overpopulated, with too many students for their facilities. This was true for the schools from the townships that participated in this research. South African schools struggled with educational outcomes where about 60-80% of schools were seen by educationalists as being dysfunctional (Bloch, 2009). The reasons being that teachers were not able to teach, or they engaged in physical and sexual violence against learners. There was a total lack of discipline in schools and in some cases, it was so bad, that the learners injure teachers and their colleagues. Learners' lack of discipline had become such a problem in South African schools that many teachers quit the profession because of this (Beger, 2003; Smit, 2013; Taylor, 2008), which also impacted on field trips. ISE staff expected teachers to monitor learners' behaviour, while the museum educator would oversee the instruction (Tran, 2007). In the South African context, it became a challenge due to reasons listed above. Internationally, it was also found that some teachers were passive and did not participate with learners during field trips (Tal & Steiner, 2006).

Principals in this study also indicated that when teachers accompany the learners on a field trip, their classes were left behind and not being taught and they had to be looked after by the remaining teachers at school. This had a negative impact on the available human resources at school. It also impacted on the coverage of the curriculum. Learners missed out on other subjects that they were supposed to have on that day. Thus, these subject teachers had to catch up with the loss of teaching time. At the end of grade 12, the learners had to write a high-stake exit examination.

This was the main priority of every school and the school district office, as it was very important that learners do well in these examinations. This was also put forward as a reason not to send learners on field trips internationally (Connealy, 2018; Kenna, 2019). Some principals indicated that they had fund raising initiatives to assist the learners who could not afford to go on the field trip. Kenna (2019) stated that so-called “zero dollar” field trips, had hidden costs such as time and effort. The fundraising activities had an impact on teachers’ time and their workload. All the principals interviewed stressed that they were in favour of sending learners on field trips. They all spoke about connecting the real-life experience to theory. They said that this was an invaluable experience for learners, which motivated them and gave them a ‘big picture” of the world outside their lives, which was also in accordance with previous studies (Anderson *et al*., 2006; Kenna, 2019; Kisiel, 2014; Kisiel, 2005).

However, 20% of principals referred to field trips organised by the GDE that were not aligned to the curriculum, and according to them had no value. w Internationally, it was found by Connealy (2018) that there was sometimes a mismatch between what teachers expected, and the outcomes achieved during field trips. This points to the importance of aligning field trips to curriculum and classroom learning (Kisiel, 2014; Patrick, 2010; Whitesell, 2016). Another point that was raised by 20% of principals was administrative challenges when sending learners on a field trip. Usually, each learner’s parents had to complete a three-page document which had to be submitted to the district office three months in advance of any field trip, tour or sporting event.

In summary, though there were many negative factors weighing on the sending of learners on a field trip, principals would continue to do so if funding is available, and if it is aligned to the school curriculum. It is important that these field trips are educationally sound.

2.) *Hands-on activities helped learners to understand the content better.*

It was recommended that hands-on activities rather than teacher centred methods should be used to enhance scientific understanding (Brumby, 1984; Fail, 2008; Nehm & Reily, 2007; Nickels *et al*. 1996). The degree of conceptual change could be linked to the degree of active learning (Dole & Sinatra, 1998, Nehm & Reilly, 2007). Active participation in the learning process was the best way to obtain ownership of the process (Antiwi & Oppong, 2014). Experiential hands-on learning might develop

curiosity, interest and a desire to learn more (Behrendt & Franklin, 2014). Observation and communication skills develop and learners might connect previous knowledge and experiences to new concepts. Teachers often did not have the time, experience or the necessary skills to design these type of learner activities (Connealy, 2018). The learners in this study indicated that the lecturer explained the content well. Some learners in this study felt that this was better than a lecture from their teacher at school or their textbook. Connealy (2018) supported this finding, indicating that staff at science institutes possessed more detailed knowledge than teachers. In this regard, a teacher gave the following response when asked about the value of science institutes: “The work that they do brings something new and engaging to our kids that maybe not every teacher can provide” (Connealy, 2018:93). Learners that attended field trips went to locations that were often unique and could not necessarily be duplicated in classrooms (Anderson *et al*., 2006; Behrendt & Franklin, 2014). Each learner thus created their own personal relevant meaning of the experience. The topic became relevant as learners assimilated and accommodated new understanding and cognition. Learners in this research viewed the workshop as beneficial. They indicated that they learnt a lot about human evolution.

According to Hutson and colleagues (2011), a field trip with a single focus would likely impact on the cognitive skills, knowledge, interests and future careers of learners. They found this to be particularly true for academically challenged learners. Field trips provided opportunities to create connections which would help with understanding classroom concepts, developing an enjoyment of learning and skills (Anderson *et al*.,2006; Kelton, 2021; Shaby *et al*., 2019; Whitesell, 2016). Moreover, it helped to promote further learning and increased learners’ knowledge foundation, while increasing higher level thinking strategies (Behrendt & Franklin, 2014). Teachers in this research indicated that learners who were usually troublesome were surprising them with their interest and willing participation in the workshop.

Data from international tests such as the Programme for International Student Assessment (OECD, 2011) which was conducted in 88 countries (not in South Africa), showed that ISL experiences were positively associated with interest and achievement in science (Woods-McConney *et al*., 2014). Whitesell (2016) for example, found small positive effects in science performance of learners exposed to

field trips in America. It was found that it was most effective for relatively disadvantaged learners and that it could be an important tool for closing racial and socioeconomic achievement gaps in science. The pre-and post-tests of this study indicated that the learners' performance improved in the post-tests. The learners who attended the workshop, also performed better in their preliminary examinations' essay question on human evolution than the learners who did not attend the workshop. Hence, this workshop had a positive outcome on learners' performance in human evolution.

3.) *Learners found the workshop enjoyable, exciting and interesting*.

The learners at the university-based workshop had a higher enjoyment (79%) than the learners at school-based workshop (66%). The university-based workshop included a visit to the palaeontology museum and fossil preparatory laboratory. This clearly added to the enjoyment and learning experience, thus pointing to the fact that it was preferable to send learners to a science centre with exhibits and interactive learning experiences. Mujtaba *et al*. (2018) reported that interest, motivation, enjoyment and career aspirations was positively impacted by the interactions during a museum or sciences centre visit. Salmi (2003) found that learner's intrinsic motivation increased at a Finnish science centre and that ISE institutions had a huge impact on the career choices of students at the University of Helsinki. High-quality experiences were more effective in improving motivation and interest in science (Anderson *et al*., 2006; Whitesell, 2016). Furthermore, teachers expected learners to develop positive attitudes toward their subject during a visit to a museum (Winterbotham, 2005).

4.) *Learners' acceptance of human evolution increased after the workshop*.

Overall, 41% of the 595 learners agreed or strongly agreed with human evolution at the start of the workshop, while it increased to 51% after the workshop. Forty eight percent of learners who selected the options 'disagreed' or 'strongly disagreed' in the pre-test, chose "agree" or "strongly agree" in the post-test. This could be a result of the learners participating in a hands-on workshop, where they could observe, measure and analyse the differences. They were able to apply scientific thinking to the scientific evidence in front of them. The university lecturer was well trained in the content and could answer all the difficult questions and even pose some questions

that made the learners think more about the topic. Sutherland and L'Abbè (2019:4) noted that "Even though an acceptance of evolution is positively correlated with understanding evolution, it is not necessary. A person can understand evolutionary theory without accepting it as true". This was evident in the learners that indicated that they disagreed/strongly disagreed in the pre-test and stayed with that choice in the post-test (58% stayed at strongly disagree and 35% stayed at disagree). The way in which teachers taught evolution to learners would have an influence on the learner's acceptance and performance in the topic (Abrie, 2010; Naude & de Beer, 2014; Stears *et al*., 2016). In the early years of teaching evolution in South Africa, some teachers still held strong religious beliefs against evolution, and they chose to ignore evolution resulting in no guarantee that they would follow the curriculum policy (Abrie, 2010). Five years later, teachers still had poor content knowledge concerning human evolution (Kyriacou *et al*., 2015). Religion and the non-acceptance of evolution was a stumbling block which hindered the understanding of evolution by teachers (Sutherland & L'Abbè, 2019). ISEs were valuable tools to address these shortcomings in teacher knowledge as their professional development was positively influenced by visits to these centres (Adams & Gupta, 2017). In contrast, all the teachers in this study taught the topic in the required detail and did not have any objections to the teaching of the topic. No teacher indicated that they had resistance from learners when teaching the topic. They seemed happy to be part of the programme, as they felt that they learnt something new about human evolution. Hence, the workshop also assisted teachers to address their own misconceptions or understanding of human evolution.

5.) *Learners knew what to expect.*

The majority of the learners also indicated that their expectations were met. The reason could be that we had a WhatsApp group between the teachers and me, where I (in my role as subject advisor) kept them up to date with the dates of the workshops. The schools shared photos of their field trips and this caused a level of excitement between the teachers, thus using our community of practice to prepare teachers for the field trip. This was in contrast with the findings of Mosabala & Lelliott's (2012) study on South African learners visit to a museum. They interviewed teachers and learners that went to Hartebeesthoek Radio Astronomy Observatory (HartRAO), the Adler Museum of Medicine at Wits, the Sci-Bono Discovery Centre (Science

Museum) and the Wits Planetarium. They found that the majority of learners (and teachers) didn't know why they were going to the museum, or what sort of museum it was. Furthermore, Tal and Steiner (2006) classified teachers into three groups when dealing with a field trip;

1. Teachers who were involved in the preparation and in the activities during the field trip.
2. Teachers that organised the same field trip every year.
3. Passive teachers who did not participate during the field trip and had nothing to do with the preparation.

Teachers in this study were either in category one or three. Overall, the teachers cooperated well during the day, taking charge of their learners and ensuring discipline.. Most of the teachers participated in the activities themselves or tried to facilitate the activities with learner groups. During my observations, teachers would indicate that they specifically prepared their learners for this content. One teacher even indicated that he was happy about the logistical problems with the busses, as he had more time to teach his learners about human evolution before the workshop. The schools that came earlier in the year, indicated that they made special arrangements to teach the content before the learners attended the workshop. Afterwards, during a subject meeting, a teacher indicated that they would rather have the workshop later in the year because they wanted to teach the content first. In interviews held afterwards, the teachers indicated that the learners referred to the skulls and pelvic bones they saw during the workshop when they were dealing with the content in class.

A teacher that took the learners to the workshop during their grade 11 year, indicated that the learners still had the photos on their phones in grade 12. Even though they could not remember most of the content, they could still link some of their experiences of that field trip to the content taught in class. They referred to the photos of the different skulls and understood the content much faster and better than previous cohorts of grade 12s. Overall, the teachers in this research study, were participatory and very positive towards the process.

6.) *Teachers were happy that the learners were able to experience the theory in a practical way*.

This workshop was designed with the curriculum in mind. The activities were addressing the content and scientific skills Life Sciences learners need. This was in line with research done by Anderson *et al*. (2006) where teachers in the United States of America, Canada and Germany viewed the alignment with the curriculum of the highest importance when judging the success of a workshop. This was also corroborated by research done by Tal *et al*., (2014) as well as DeWitt and Storksdieck (2016).

The learners had to measure, observe, record their findings and make conclusions. They also had to make inferences from their findings. Teachers thought that this was very beneficial to learners, as they did not usually practice all these skills in one lesson. The purpose of this workshop was aligned to Tal and Morag's (2009) purpose of field trips, namely to:

- to provide firsthand experiences,
- stimulate interest in science,
- adding relevance to learning, and
- to strengthen observation skills.

This experiential learning was authentic, first-hand and sensory-based learning. The learners touched, explored moved things and learning consisted of acquiring an experience and transforming it into an application (Kolb, 1983). Many teachers in South Africa were still using transmission teaching methods, which were mainly content-based, while hands-on and self-discovery methods should be used to teach scientific methods (Riga *et al*., 2017). Many South African teachers neglected to teach practical-based lessons, because they felt that this will take them out of their comfort zone. Subsequently, they were not confident conducting hands-on practical sessions with learners (De Beer & Petersen, 2016).

The teachers seemed to enjoy the workshop and they also commented on the learners enjoying themselves. They felt that the learners were having fun while learning. According to the National Research Council of the United States of America (2009) learners that has a hands-on, authentic experience may develop an interest and curiosity, leading to a desire to learn more. Social skills develop as learners share

their own perceptions and knowledge with each other. Learners may begin to look forward to class and connect prior knowledge and their experiences to the new concepts. This may lead them to following a career in science.

International research on the interactions between museum educators, learners and teachers indicated that the museum educator usually provided content but did not encourage social interactions between the members of the group (Cox-Petersen *et al*., 2003). This was not the case in the field trip and workshop conducted in this research. The visit to the museum was in the format of a treasure hunt and the workshop was interactive, and learners had to work in groups, measuring, discussing and concluding. This was a definitive benefit of this field trip.

The teachers indicated that the university lecturer was very knowledgeable and that they themselves benefitted from the workshop. The university lecturer taught Honours-degree students at the university and had a deeper knowledge of human evolution than teachers who did a short course on evolution during their teacher training. This was in accordance with findings from DeWitt and Storksdieck (2008) that informal educators could provide high quality experiences for learners. Lawrence and Tinkler (2015) stated that science museums give learners (and in this case teachers) opportunities to engage directly with scientists and real scientific activities.

The teachers also indicated the mediation during the activities benefited the learners. The scaffolding of questions to assist learners with the solutions helped the learners to get to the answers on their own. The mediation was done by the university lecturer, helped by other university staff members and the researcher/district subject advisor.

Teachers indicated that the workshop was better than the learners only referring to pictures and diagrams in textbooks. Textbooks are two-dimensional, while this was a three-dimensional experience. The learners were able to hold the skulls. Furthermore, there were many mistakes in the South African Life Sciences textbooks, which perpetuate misconceptions in teachers (Dempster & Hugo, 2006; Sanders & Makotsa, 2016; Tshuma & Sanders, 2015). When teachers had misconceptions about evolution, they were unable to identify or filter them from inaccurate textbooks that contain these misconceptions (Abrie, 2010; Sanders & Ngxola, 2009). Misconceptions concerning evolution that were identified were; that individuals evolve; that this occurs within their lifetime; that they ‘decide’ to undergo changes

which they ‘know’ will be favourable for them (anthropomorphic and teleological thinking); that this is done so that they do not die or become extinct (anthropomorphic and teleological thinking); and that changing food types or environments cause organisms to change (teleological thinking) (Tshuma & Sanders, 2015:360).

All the teachers indicated that they would like to attend the workshop every year, but only two teachers followed up on this statement. The funding for the field trips was only for one year, and teachers did not organise the field trips on their own. The biggest reason cited was lack of funding. This reason was one of the reasons cited by teachers and school management internationally (Connealy, 2018; Kenna, 2019).

7.) *Learners struggle with the concept evolution.*

Evolution was difficult to understand, even for college-educated adults (Shtulman & Calabi, 2012). Learners struggled with the concept and this was corroborated by international research (Glaze and Goldston, 2015; Sickel & Friedrichsen 2013; Yates & Marek 2014), as well as the annual subject diagnostic reports released by DBE (refer to Table 2.2). Some teachers indicated learners find the topic uninteresting, whilst others said that they only had four weeks allocated to teach all the evolution topics and they had to rush through it. This finding was corroborated by research done by Sutherland and L’Abbè, (2019), who performed research in South Africa as well as the United Kingdom. Teachers’ role in the understanding of evolution should not be underestimated. A study done by Abrie (2010) in South Africa, found that student teachers held many misconceptions and did not want to teach evolution, but despite this, 76% agreed that the theory about evolution was important for biology/life science teachers to understand. This study was done during the year that evolution was introduced (2008) and many student teachers only learnt of evolution when they had to teach it (Abrie, 2010). There was some improvement in the teaching of evolution later on as novice teachers were schooled in evolution. Furthermore, in my experience as a subject advisor, human evolution was taught in an abstract way, tabulating the differences and similarities. The learners did not do any practical work or hands-on activities because of the shortage of time. Instruction was mostly examination driven, where learners had to work through questions of past papers on human evolution.

8.) *Mediation ensured the success of the workshop*.

Kozulin (1998) stated that when specialised social activities took place, people acquired skills and learnt using cognitive tools such as images, symbols and models. These tools provided mediation in the learning process. A sociocultural approach (Vygotsky, 1978) was used as a lens to observe learning during workshops in this study. Vygotsky studied the development of psychological tools for remembering, organising experiences, planning, self-regulation of behavior and problem solving. Rowe and Bachman (2012) stated that Vygotsky's work was important for science learning and development of scientific thinking. These scientific skills included deductive and inductive reasoning, identifying and manipulating variables as well as making arguments based on evidence. This was the basis for mediated action.

According to Linell (2001), appropriation of physical and psychological tools for thinking and communication occurred through participation in collective meaningful activities. Learning through mediated action was defined by Linell (2001) as:

- Interaction between people is the foundation of all cultural and social development.
- Sign use is the basis of all thinking.

In this research, mediated acts, signs, scientific thinking and social interaction between learners were studied. Signs were identified as gestures, body language and the interaction with tools (Rowe & Bachman, 2012). Social interaction and scientific thinking were the most frequently used codes, followed by signs and symbols and interactions with tools. Mediation by the facilitator helped the learners during the activities to make sense of human evolution (especially when they performed the skull arrangement activity). Furthermore, learning was always tied to a sociocultural and historical context (Rowe & Bachman, 2012). Learners from township schools as well as ex-model C schools showed an improved performance in their preliminary paper as compared to schools (ex-model C as well as township schools) that did not attend the workshop. Both township and ex-model C schools had a marked improvement in their post-test scores, thus indicating that learners from diverse backgrounds benefited from this workshop.

9.) *Continuous reflection enhanced the effectiveness of the activities.*

Reflection on teaching improved the learning experience (Loughran, 2002). Schön (1987) proposed that reflection-on-action was a retrospective analysis of one's performance to gain knowledge from experience. After each field trip and school-based workshop, reflection sessions were held between the university lecturer and me. Content and premise reflection (Kreber & Cranton, 2000) were used as we reflected on our activities and approaches taken. We discussed learners' levels of motivation, whether a certain approach worked, and I also gave feedback on the learners' comments during the interviews. Through reflection, some changes were made, by adding some new props and pictures when we saw that learners had difficulty understanding certain concepts. Another example is that we picked up that some of the learners had trouble understanding the instructions in English. This led to our making use of the university assistants who could speak African languages and mediate the instructions to the learners. We reflected on the feedback of the principals and decided to bring the workshop to the schools. During the reflection sessions after the school-based workshops, we discussed the group sizes and decided that it could not be bigger than 60 and that we would rather split big schools into more than one afternoon. This flexible approach to the workshop shaped the workshop into a workshop that provided more efficiently for school's needs.

10.) *Learners' performance in post-test and preliminary examinations improved after the workshop.*

There were 687 learners that wrote the pre-and post-tests which had a total of seven marks, and the mean of the pre-test was 2.7 and that of the post-test was 4.3. This was a percentage increase of 59%. The learners wrote a common exam with a question on human evolution, which counted 20 marks. The learners who attended the workshop obtained a mean of 8.2, while those who did not, obtained a mean of 4.2, which was a difference of 20% The learners at the university-based workshop had a slightly larger improvement than those at the school-based workshop, but the difference was small (1.9%). The sample was a mixture of well performing and poor performing schools.

5.2 CONTRADICTION CHAT

According to Engeström (1987), there are four levels of contradiction within an activity system, the first being within each constituency in the activity system. These contradictions/conflicts could lead to change and improvement in the activity system. The contradiction in this activity is depicted in figure 5.2 below after which it is discussed in detail.

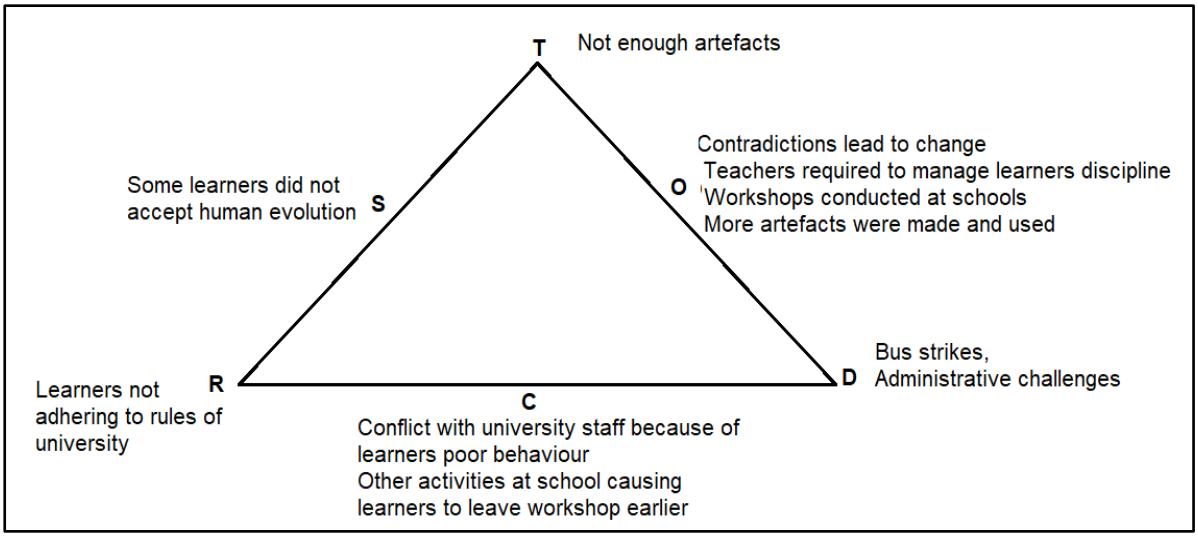


Figure 5.2: Contradictions outlined in the CHAT framework

. In this research, level one contradiction was apparent within the division of labour. It relates to the first year of the programme where the bus strikes had a negative impact on the workshops. Dates were plotted and agreed on with the schools, only to be changed as there was no bus transport available. The administrative challenges that had to be followed by university staff also caused the bus transport to be more expensive than if we were to choose our own transport. This depleted the funding. There were instances where the bus company didn't turn up or turned up late, impacting on our workshop. It led us to consider taking the workshops to the schools, hence changing the programme.

Within the community, there was sometimes some conflict at the university as some school learners caused tension within the venue. These were the schools where the teachers didn't manage the discipline of the learners and they subsequently made a big noise and were running around without any supervision (because they were chased out of the museum because of their bad behaviour). This was addressed with the specific school and teachers were told to manage their learners better. The same school had a learner who didn't return with the busses back to school as they wanted

to stay behind and visit some friends. The school principal was phoned and made aware of the situation. Schools were subsequently instructed to send enough teachers with the learners and to manage discipline more effectively. Another level one conflict/contradiction occurred in the subject, and it was concerning the learners' acceptance of human evolution. Many learners did not except human evolution as a fact at the beginning of the workshop. After the workshop, many learners changed their minds. When asked to explain why they accepted human evolution as fact, they used scientific reasoning to explain their answer. Some, however, still did not accept human evolution as a fact as it was seen to conflict with their religion. A framework for border crossing was used by Sanders and Kagan (2013) to describe grade 12 learners' understanding and acceptance of evolution. Some learners had smooth transition from one worldview to another, hence in this study, it was the learners who moved to acceptance after the workshop. A managed transition is where learners still need time to make an adjustment to their world view, but they cope with the transition. In this study, this was evident in some learners who understood the scientific evidence, but still wanted some more information. A hazardous crossing is when the transition is extremely difficult for the learner, but they still cross. An example of hazardous crossing within this study was seen in the interviews where learners quoted their religion and the scientific facts, and they decided to keep the two separate because they believed in both but they were conflicted. Insurmountable crossing is when learners do not make the transition because the two world views are too far apart, we had one learner who was very upset and told us in no uncertain terms that he found this to be nonsense. Other learners also indicated that they don't believe in it because it is against their religion.

The second level of contradiction is between two constituencies in the activity system. In this study, there was a level of contradiction between the subject and the tools. For example, they said we did not have enough artefacts so we provided more artefacts during the second year of the study. The continuous feedback from the learners helped us to make small improvements to the programme.

The third level of contradiction (Engeström, 1987) is identified as tension developed between the activity centres' object and the object of a more advanced form of the activity centre. The focus of this study was not on a more advanced form of the activity as it was the first of its kind in South Africa.

Level four or quaternary contradictions are identified as tensions developing between the communities of different activity systems. Each school represented a different community and activity system. The activities of the schools impacted on our workshop. Learners left during the workshop due to other extra-mural activities. From this we learnt that it is crucial to communicate with schools at the beginning of the year, for them to plan the best dates for the workshops.

5.3 OUTCOMES OF CHAT

The outcomes of this research are depicted in Figure 5.3 where the two activity centres namely university-based workshops and school-based workshops are juxtaposed.

When comparing the two activity centres the differences are as follow:

University-based workshops:

- The learners were motivated and enjoyed the field trip to the university more than school-based workshops.
- Learners were exposed to the palaeontology museum and the fossil extraction laboratory.
- Learners linked the exhibitions that they saw in the palaeontology museum to the artefacts in the workshop.
- Schools often arrived late at the university during the field trips, which impacted on our time management. We had to shorten the workshops in order to finish on time.
- During the bus strike, the programme was negatively affected, and new dates had to be negotiated with schools.
- During one workshop, three learners had to leave early because of extra-mural activities during the afternoon.

School-based workshops:

- The workshop was completed in two hours' time, as learners had to make use of transport to go home.
- The learners did not see the other exhibitions at the university.

- The learners did not miss out on a day of schooling, so they didn't miss out on other subjects.
- Learners seemed tired and hungry because they had a whole day of schooling before the workshop.
- Other schooling activities such as extramural activities and other subject activities sometimes impacted on our workshop. Learners had to leave early.
- The soda bottle and pictures activities during the feedback sessions were cut for the school-based workshops, to save on time and also space because everything had to fit into the lecturer's vehicle.
- The learners did not sequence the skulls at the end of the workshop due to time constraints.
- The very big groups at schools (above 60 learners) were challenging to handle, whereas we split the groups in two at the university and never had more than 60 learners in a workshop.
- We had electricity power outages at the schools and had trouble being heard in the large school halls without the use of a microphone. In most cases, we were given a xylophone, which helped, but learners still complained that they couldn't hear.
- We were reliant on the teacher at the schools for choosing the correct venue, as well as providing us with a sound system etc.
- The learners enjoyed the field trip to the university more than at schools.

Thus, both approaches had its own benefits and challenges. The learners benefitted more from the university-based experience, but the schools benefited more from the school-based experience. Learners enjoyed the out of school activities, which brought a break from the daily school routine (Shaby *et al*., 2019). The university-based experience developed learners' social and motor skills, as well as increasing their motivation to learn (Alon & Tal, 2015). The exhibits at the university palaeosciences museum were an appealing alternative to the everyday classroom environment and the treasure hunt, workshop and fossil extractions were stimulating, multisensory and conveying complex sciences topics (Adams & Gupta, 2017). Despite this, the learners had an improvement in their post-test results that indicates that the workshop improved learners' understanding of the topic, irrespective of the

venue. This finding is supported by Harker & Badger (2015) who found traveling museum/science exhibition to be significant learning opportunities for learners.

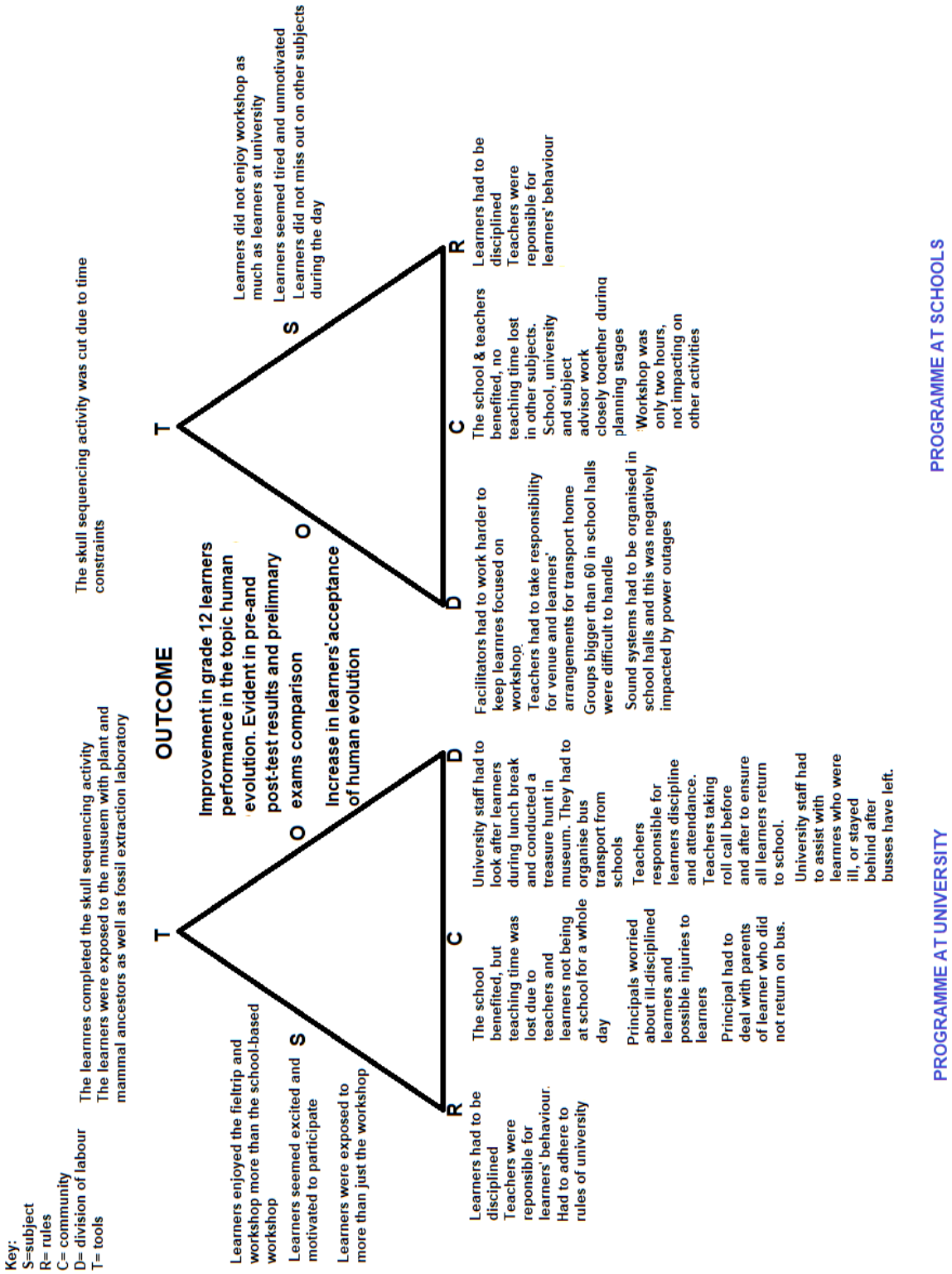


Figure 5.3: The results of the third generation CHAT for this study.

5.4 IMPLICATIONS

Learners in South Africa struggle with the concept of human evolution, as well as evolution in general. This is confirmed in the annual DBE subject diagnostic reports, where it is always one of the topics that are answered the worst in the final examination (there are other topics such as homeostasis, meiosis, genetics and plant hormones which are also regularly answered very poorly by the grade 12 learners). Gauteng province has a diverse range of schools, such as well resourced (usually the ex-model C and private schools) as well as under-resourced rural and township schools. Schools in Gauteng were severely overcrowded and there is a shortage of teachers (Equal Education, 2020). A study that was performed in the district involved in this research, found that learners were often ill-disciplined, missing classes, prone to substance abuse and that teachers did not prepare for lessons, frequently came late and did not go to class (Dhlamini, 2014). This impacted on the quality of teaching. It is not always possible to take learners on field trips to the university museum or paying the museum staff to do the workshop at the school. The reasons being lack of funding and ill-discipline of learners, as cited by the principals participating in this research.

1.) Teaching of Human Evolution

This research concurs with international research that this contentious topic should be taught in a hands-on way (Ash & Rahm, 2012; Connealy, 2018; Lazonder & Harmsen, 2016). This study shows that there is a solution for this problem by addressing this content in an activity-based manner, and/or to make use of a palaeontology museum such as the one at Wits to address the content with the learners. The advantage of making use of the university-based museum is that the facilitators are people with qualifications within the field of palaeontology. They have a deeper knowledge of the content and can effectively address misconceptions that learners, and in some cases their teachers, may have.

Seeing that it is impossible for all schools in Gauteng to attend this workshop at Wits, a solution is that Life Sciences teachers should be trained on the content, as well as the pedagogy, to be used when teaching these concepts. Common misconceptions

of teachers can be identified through a survey, and workshops should be planned around these misconceptions. The GDE currently has a teacher professional development programme with a website where all teachers are able to enrol for free training. They offer weekend training sessions on subject specific matters. The training is promoted by head office and the district offices and there is usually a very high number of teachers in attendance. They also offer training on assessment, moderation and all other educational matters. Moreover, GDE offer these content-based workshops for all grade 12 teachers at the beginning of each term. They are well attended by the teachers and novice teachers are usually instructed to attend by their subject advisors. Training in evolution is usually done during the third term.

Through the partnership with the ESI at Wits, the GDE has also provided some schools with human evolution kits from Wits in order to assist with the teaching of human evolution. These kits contain fossil casts of *Homo sapiens, Gorilla gorilla, Pan troglodytes, Australopithecus sediba and Homo naledi* as well as three stone age tools. Gauteng has 625 schools offering Life Sciences and so far, 268 schools (all non-fee-paying schools) received these human evolution kits. This partnership has evolved from the interaction between the university lecturer and the provincial coordinator for Life Sciences and it is an ongoing partnership as more kits are procured every year.

Another implication that should be considered is the teaching of human evolution when people have religious objections to the content. It is a policy requirement that this should be taught to all learners taking grade 12. It is clear from this study that even though learners enjoyed the hands-on practical, some learners still did not support the findings. From a policy point of view, it is required to know the facts (transitional species, comparison between humans and African apes), but a learner will not be required to state whether they believe in evolution or not. This research indicates that learners do not have to believe in human evolution in order to know the facts.

2.) Field Trips to ISE's

It is recommended that schools send their learners to ISEs to assist with improvement in science performance (Alon & Tal, 2015; Shaby *et al*. 2019). Currently, museums/science centres that have human evolution exhibits in Gauteng are Wits, the Ditsong National Museum of Natural History in Pretoria, Maropeng and

Sterkfontein Caves. The Sci-Bono Discovery Centre currently have dinosaur exhibits. The Ditsong National Museum of Natural History has large exhibitions of animal, plant and evolution, but it dates from several decades ago. Maropeng and Sterkfontein are modern museums with interactive exhibits and the opportunity to visit the caves where several *Australopithecus africanus* and other hominin fossils were found. The Maropeng and Sterkfontein museums work closely with the GDE and provide funding for a few disadvantaged schools each year to visit them. As subject advisors, we have to choose the schools that go on these funded field trips. When learners visit these science centres in earlier grades, they will be exposed to the concept of evolution before they get to grade 12, which will assist with their understanding of the topic. It is recommended that GDE promote school visits (especially the lower grade learners) to these places annually.

Apart from the research indicated in Chapter 1 of this study, not a lot of research on school field trips to ISE's have been done in South Africa. More research into school field trips to ISE's are recommended. Some challenges impacting on this are that principals from schools who are able to afford to send their learners on field trips indicated that there is an administrative burden when doing so. Twenty percent also added that some field trips funded by the GDE were not aligned to the curriculum which made them ineffective. A suggestion is to send an anonymous questionnaire to all principals in Gauteng so that it could be determined which field trips are most beneficial, and which are not. Also, to recognise the administrative burdens, in order to make it easier for schools to go on field trips. Moreover, such as questionnaire can ascertain the challenges and what principals would like these field trips to adhere to.

5.5 LIMITATIONS OF THE STUDY

While every possible method was used to ensure that learners gave their true feelings about how they felt about human evolution, it was still possible that learners could have given an answer that they felt we wanted. They attended the workshop as it was aligned with the curriculum and it benefited them academically, so in turn it is possible that they indicated that they agreed with humans evolving from other animals for the sake of compliance only. This has an effect on the generalisability of

the results. It should be stated that the learners from the Model C schools were much more vocal and voiced their disagreement with the topic. The learners from township schools were more reserved and only a few in the interviews indicated that they did not agree. This could possibly also have been the case in the question asking about human evolution.

Another limitation of the study is the fact that I was the subject advisor of the schools that attended the workshop. As subject advisor, I met with the district director and teachers to motivate the attendance of the workshop. Teachers were willing to bring their schools to the workshop because I motivated them to attend. Hence, attendance of such a workshop in other districts could possibly be different. Teachers in other districts could probably not feel inclined to have their learners attending such a workshop because of all the challenges listed in this research.

During the interviews teachers could have given me answers that they thought I wanted to hear. I tried to prevent this by phrasing my questions in such a way that I asked them for their advice on how to improve the programme so that they were helping me by identifying challenges. Some teachers did give inputs on how to improve the programme, but it is not possible to know for sure whether they were being truthful in their answers.

5.6 RECOMMENDATIONS FOR FUTURE RESEARCH

These are my recommendations for possible future studies:

- A more detailed study of the logistical and administrative decision-making processes concerned with field trips. A proceeding activity system could be used to establish fieldtrip policies and logistical decisions.
- The role of museum or other ISL in the enhancement of teaching and learning of human evolution in South Africa.
- Research on actions taken by teachers to identify topics which could be enhanced by field trips or outside partners.

- Research on the types of activities that ISL are doing or could do to enhance curriculum delivery in South African schools, for example demonstrations at schools, workshops at schools and traveling exhibitions.
- Research on learners' views on human evolution in the different types of schools.
- The role of subject advisors in field trips in South Africa.

5.7 MY OWN THOUGHTS

As a researcher I had to acknowledge the fact that the research was done on schools that are from my educational district. I knew all the teachers and knew which schools were well-performing and not so well- performing. I had to continuously remind myself that during the workshops my role was that of researcher and not subject advisor. The continuous reflective sessions I had with Dr Ian Mckay (the university lecturer) after each workshop helped me to check my bias. At one stage we had behavioural problems with learners from certain schools and my suggestion was that we screen the learners and only allow the well-performing learners (as a subject advisor would do). Dr Mckay reminded me of the fact that this was research and that we had to observe and record and not try to fix the problem. In future, I would not do research on schools in my own district to reduce bias.

I do recognise the fact that I am in a power relationship with my teachers, so I realise that there was a chance that they would give me answers that I would like to hear. Subsequently, I phrased my questions in such a way to try and overcome this bias. So, my feeling is that the overall positive response that I got from my teachers is trustworthy.

This study has contributed a lot to my community of practice. The learners in my district benefitted from this experience, but they have since left the system. The major benefit of this research was that my teachers were developed during the sessions and that they are now imparting this knowledge with every new cohort of grade 12 learners.

As a subject advisor I have to ensure curriculum policy implementation. Hence, a bias is that I do not have a problem with the teaching of human evolution. I had to ensure that I did not come across as enforcing this on learners. In one workshop some learners took offence when I tried to explain to another learner that it does not necessarily go against his religion. Afterwards, I reflected on how I could have handled this differently.

Overall, I feel that this research shows a different method of teaching this controversial topic. It also shows that there are benefits for schools to engage with universities and other ISLs.

5.8 CONCLUSION

This palaeosciences university museum programme (PUMP) was found to be effective in improving learners' knowledge of human evolution. There was also a shift in the acceptance of human evolution as some learners indicated that they accepted it after the workshop. The programme was shown to be a positive influence on their affective domain, as 73% of the learners indicated that they enjoyed the workshop. The learners interviewed indicated that they would bring their own children to a science museum one day, which also indicated a positive attitude toward museums. It was also found that a community of practice could be formed between the schools and the university with the district subject advisor as an intermediate. This could ensure the longevity of the programme. No study involving grade 12 learners in South Africa has been done in the palaeosciences. The contributions of this study could be summed up as follow:

1. Teachers find these programmes beneficial when they are strictly aligned to the CAPS document.
2. Only under very special conditions are grade 12 learners allowed to go on educational field trips, and these field trips must be educationally sound. It is useful to use the CAPS document as well as the diagnostic analysis (published by the DBE each year) to design a workshop for grade 12 learners.
3. It is important that these types of workshop/field trips are situated in inquiry-based learning as research have shown that this approach is not followed in South African classrooms (Riga et al., 2017; De Beer & Peterson, 2016).

Learners indicated this as a major benefit of the programme and found that they benefitted a lot from the workshop.

4. Using these types of workshops could also assist in improving teachers' content knowledge on difficult topics as specialists in the respective fields are conducting the workshops.
5. Logistical problems could be bridged by taking the workshops to the schools after hours. This is more cost-effective and less time consuming for schools.
6. Saturdays are a good alternative, because the learners are rested and there is enough time to conduct the workshops and give breaks in between.
7. The topic human evolution taught in an inquiry based, hands-on method is very effective in improving learners' results on the topic.
8. This research was done with previously disadvantage schools (township schools) and ex-model C schools. The data shows that there was a big improvement in the performance in the pre-and post-test in all the schools, regardless of the school's situation. There was also a marked improvement in the preliminary examinations results in all the schools that attended the workshop.
9. The active participation in activities and the inquiry-based nature of the workshop made it possible for learners in grade 10 and 11, who have not been taught the concepts yet, to participate and understand the concepts at the end of the workshop.
10. This research shows that a community of practice can be established between an educational district official, schools in the educational district and a university. The district official plays an intermediate role between the university and the schools, motivating the schools to make use of the programme and liaising with the university.
11. When conducting such programmes with schools the service providers (in this case the university) should follow a reflective approach. Reflection should be done after each workshop/field trip on what worked and what didn't work. This helps with the improvement of the programme.

Overall, this research shows that such inquiry-based programmes at universities could benefit schools in the community and help to improve the overall results of learners in specific topics.

REFERENCE LIST:

Abrie, A. 2010. Student teachers' attitudes towards and willingness to teach evolution in a changing South African environment. *Journal of Biological Education*, 43(3):102–107.

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D. &.Tuan, H.L. 2004. Inquiry in science education: International perspectives. *Science Education*, 88(3):397-419.

Adams, J. D., & Gupta, P. 2017. Informal science institutions and learning to teach: An examination of identity, agency, and affordances: informal science institutions and learning to teach. *Journal of Research in Science Teaching*, 54(1):121-138. https://doi.org/10.1002/tea.21270

Aikenhead, G. 2006. *Science education for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. 2011. Does discovery based instruction enhance learning? *Journal of Educational Psychology*, 103:1–18.

Alon, L. N., & Tal, T. 2015. Student self-reported learning outcomes of field trips: The pedagogical impact. *International Journal of Science Education*, 37(8):1279–1298. https://doi.org/10.1080/09500693.2015.1034797

Amnesty International. 2020. *Broken and unequal. The state of education in South Africa.* https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode . Date of access: 3 Nov 2020.

Anderson, D., Kisiel, J., & Storksdieck, M. 2006. Understanding teachers' perspectives on field trips: discovering common ground in three countries. *Curator*, 49(3):365–386.

André, L., Durksen, T. & Volman, M. L. 2017. Museums as avenues of learning for children: a decade of research. *Learning Environment Research*, 20:47-76.

Antwi, V. & Oppong, C. 2014. Using fieldtrip to promote active participation among pupils of Mumford community JHS Ghana to improve their performance in science. *Journal of Education and Curriculum Development Research*, 2(4):152-166.

Ash, D., Brown, C., Kluger-Bell, B. & Hunter, L. 2009. Creating hybrid communities using inquiry as professional development for college science faculty. *Journal of College Science Teaching*, 38(6):68-76.

Ash, D. & Rahm, J. 2012. Introduction: Tools for Research in Informal Settings. In: Ash, D.B, Rahm, J., Melber, L.M. eds. *Putting theory into practice*. Rotterdam: Sense publishers. pp. 1-9.

Auerbach, E. R. 1993. Re-examining English only in the ESL classroom. *TESOL Quarterly*, 27(1):9-32.

Babbie, E. 2008. *The basics of social research. International student edition.* 4th ed. Belmont: Thomson Higher Education.

Bandura, A. 1989. Human agency in social cognitive theory. *American Psychologist*, 44(9):1175–1184.

Bhatti, M. & Kim, J. 2020. Towards a New Paradigm for Statistical Evidence in the Use of p-Value. *Econometrics*, 9(2):1-3. http://dx.doi.org/10.3390/econometrics9010002

Baum D. A. & Offner, S. 2008. Phylogenies and tree-thinking. *The American Biology Teacher,* 70:222–9.

Barab, S. & Squire, K. 2004. Design-based Research: Putting a Stake in the Ground. *The Journal of the Learning Sciences*, 13(1):1-14.

Beauchamp, J. 2011. *A case study of South Africa teachers' understandings of the nature of science and classroom instructional practices*. Johannesburg: University of the Witwatersrand. (Thesis- Masters).

Beger, R. 2003. The 'Worst of both Worlds': School security and the disappearing fourth amendment rights of students. *Criminal Justice Review*, 28:336-354.

Behrendt, M. & Franklin, T. 2014. A Review of Research on School Field Trips and Their Value in Education. *International Journal of Environmental and Science Education*, 9:235-245.

Bell, P., Lewenstein, B., Shouse, A. & Feder, M. A. 2009. *Learning science in informal environments: People, places and pursuits*. Washington, DC: National Academic Press.

Benjamin, N., Haden, C. A. & Wilkerson, E. 2010. Enhancing building, conversation, and learning through caregiver-child interactions in a children's museum. *Developmental Psychology*, 46(2):502-515.

Bhengu, T. T., Mthembu, T. T. 2014. Effective leadership, school culture and school effectiveness: A case study of two 'sister' schools in Umlazi Township. *Journal of Social Sciences*, 38(1):43-52.

Bloch, G. 2009. *The toxic mix. What's wrong with South Africa's schools and how to fix it*. Cape Town: Tafelberg.

Bobick, B. & Hornby, J. 2013. Practical partnerships: Strengthening the museum-school relationship. *Journal of Museum Education*, 38(1):81–89.

Borko, H., Jacobs, J., Eiterjorg, E., & Pittman, M. E. 2008. Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24:417-436.

Braund, M. & Lelliot, A. 2017. Opening up the dialogic space. Using questions to facilitate deeper informal learning. In: Patrick, P.G. ed. *Preparing informal science educators. Perspectives from science communication and education*. Switzerland: Springer. pp. 561-574. Available from Springer eBook collection: DOI 10.1007/978-3-319-50398-1. Date of access: 20 June 2021.

Brewer, G. H., Hunter, A. 1989. *Multimethod research: A synthesis of styles*. Newbury Park, CA: Sage.

Brumby, M. N. 1984. Misconceptions about the concept of natural selection by medical biology students. *Science Education*, 68:93–503.

Bryman, A., Bell, E., Hirschsohn, P. Dos Santos, A., Du Toit & J., Masenge, A. 2014. *Research Methodology: Business and Management Contexts.* 8th ed. Johannesburg: Oxford University Press Southern Africa.

Bush, T. 2013. Instructional leadership and leadership for learning: Global and South African perspectives. *Education as Change*, 17(1):S5-S20.

Centre of Development and Enterprise. 2020. *No Longer Business as Usual Private sector efforts to improve schooling in South Africa.* https://www.cde.org.za/wp-content/uploads/2020/11/Education-Document-1.pdf. Date of Access: 3 Apr 2021.

Charmaz, K. 2006. *Constructing grounded theory. A practical guide through qualitative analysis.* London: Sage.

Cheng, M. A. L., Folta, E., & Holmes, S. Y. 2011. Drugs and the brain: Learning the impact of methamphetamine abuse on the brain through a virtual brain exhibit in the museum. *International Journal of Science Education*, 33(2):299–319.

Chi, M. T. H. 2009, Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science*, 1:73-105.

Christie P. 1991. *The right to learn: The struggle for education in South Africa*. 2nd ed. Johannesburg: Ravan Press.

Cimi, P. V., Ngcoza, K. & Dold, T. 2020. The role of ethnobotany in integrating indigenous knowledge in the discipline of science education: a study by the herbarium of the Albany Museum in South Africa. *South African Museums Bulletin*, 42:1-8.

Connelly, L. M. 2014. Ethical Considerations in Research Studies. *MEDSURG Nursing*, 23:54-55.

Connealy, S. S. 2018*. Institutional and Organizational Influences on Collaborations between Informal Science Education Organizations and Schools.* Lubbock: Texas Technology University. (Thesis-PhD).

Cox-Petersen, A. M., Pfaffinger, J. A. 1998. Teacher preparation and teacher-student interactions at a Discovery Centre of Natural History. *Journal of Elementary Science Education*, 10:20–35.

Cox-Petersen, A. M., Marsh, D. D., Kisiel, J., & Melber, L. 2003. Investigation of guided school tours, student learning, and science reform recommendations at a museum of natural history. *Journal of Research in Science Teaching*, 40(2):200–218.

Coleman, J., Stears, M., & Dempster, E. 2015. Student teachers' understanding and acceptance of evolution and the nature of science. *South African Journal of Education*, 35(2), art. # 1079. https://doi.org/10.15700/saje.v35n2a1079

Creswell, J. W. 2005. *Educational research. Planning, conducting, and evaluating quantitative and qualitative research. International edition.* 2nd ed. Boston: Pearson Education.

Creswell, J. W. 2009. *Research Design. Qualitative, Quantitative and Mixed Methods Approaches.* 3rd ed. Thousand Oaks, California: Sage.

Creswell, J. 2014. Research design: Qualitative, quantitative, and mixed methods approaches. 4th ed. Los Angeles: SAGE.

Creswell, J. W., & Creswell, J. D. 2018. *Research design: qualitative, quantitative, and mixed methods approaches.* 5th ed. Los Angeles: SAGE.
Creswell J. W., Plano Clark, V. L. 2018. *Designing and conducting mixed methods research.* 3rd ed. Los Angeles: Sage

Dawson, E. 2014. "Not Designed for Us": How science museums and science centres socially exclude low-income, minority ethnic groups. *Science Education*, 98(6):981-1008.

De Beer, J. 2016. Re-imagining science education in South Africa: The affordances of indigenous knowledge for self-directed learning in the school curriculum. *Journal for New Generation Sciences*, 14(3):34–46.

De Beer, J., Kriek, J. 2021. Insights provided into the decolonisation of the science curriculum, and teaching and learning of indigenous knowledge, using cultural-historical activity. *South African Journal of Higher Education.* 35(6):47-63. https://journals.co.za/doi/pdf/10.20853/35-6-4217

De Beer, J., & Mentz, E. 2021. Cultural-historical activity theory as a lens in mixed methods research on self-directed learning. *South African Journal of Higher Education*, 35(5):163-183. https://journals.co.za/doi/pdf/10.2853/35-5-4364

De Beer, J. & Petersen, N. 2016. *Decolonisation of the science curriculum: a different perspective (#cookbook-labs-must-fall).* Proceedings of the Conference on Mathematics, Science and Technology Education (ISTE 2016), Kruger National Park. https://uir.unisa.ac.za/bitstream/handle/10500/22869/Josef%20de%20Beer,%20Neal%20Petersen.pdf?isAllowed=y&sequence=1 Date of access: 3 Feb. 2020.

De Beer, J. & Ramnarain, U. 2012. *The implementation of the FET Physical and Life Science curricula: Opportunities and challenges*. Research report prepared for the Gauteng Department of Education. Johannesburg: University of Johannesburg.

Dempster ER, & Hugo W. 2006. Introducing the concept of evolution into South African schools. *South African Journal of Science*, 102:106–112. file:///C:/Users/14657678/Desktop/Wits%20Phd/evolution%20articles/Dempster-Hugo2006.pdf Date of access: 12 Apr. 2021.

Department of Education (South Africa). 2003. *National curriculum statements for Life Sciences.* Pretoria: Government printers.

Department of Basic Education (South Africa). 2011. *Curriculum and assessment policy statement (CAPS) Grades 10–12. Life Sciences.* Pretoria: Government printers.

Department of Basic Education (South Africa). 2017. *Life Sciences Examination guidelines.* https://www.education.gov.za/?fileticket=ehmyEM8M7r4%3D&tabid=1465&portalid=0&mid=5988. Date accessed: 2 Oct 2018.

Department of Basic Education (South Africa). 2022. *Diagnostic report 2021 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 3 March 2022.

Department of Basic Education (South Africa). 2021. *Diagnostic report 2020 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 3 March 2022.

Department of Basic Education (South Africa). 2020. *Diagnostic report 2019 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 6 April 2020.

Department of Basic Education (South Africa). 2019. *Diagnostic report 2018 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 4 March 2020.

Department of Basic Education (South Africa). 2018. *Diagnostic report 2017 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 3 Feb 2019.

Department of Basic Education (South Africa). 2017. *Diagnostic report 2016 National Senior Certificate examination Part 1.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 2 Feb. 2018.

Department of Science and Technology (South Africa). 2011. *South African strategy for Palaeosciences. Government Gazette 34624.* Pretoria: Government printers.

Department of Basic Education (South Africa). 2017. *National senior certificate*. *Schools subject report 2016.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 2 Feb 2018.

Department of Basic Education (South Africa). 2018. *National senior certificate. Schools subject report 2017*. https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 2 Feb 2018.

Department of Basic Education (South Africa). 2019. *National senior certificate. Schools subject report 2018.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 4 Feb 2019.

Department of Basic Education (South Africa). 2020. *National senior certificate. Schools subject report 2019.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 5 Feb 2020.

Department of Basic Education (South Africa). 2021. *National senior certificate. Schools subject report 2020.* https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 3 Feb 2021.

Department of Basic Education (South Africa). 2022. *National senior certificate. Schools subject report 2021*. https://www.education.gov.za/Resources/Reports.aspx. Date accessed: 2 March 2022.

Department of Basic Education (South Africa). 2011*. Curriculum and assessment policy statement (CAPS) Grades 10–12. Life Sciences.* Pretoria: Government printers.

Dees, J. Momsen, J. L., Niemi, J. & Montplaisir, L. 2014. Student Interpretations of Phylogenetic Trees in an Introductory Biology Course. *CBE- Life Sciences Education*, 13(4):666-676.

Dekkers, P. 2006. Reconstructing the creature - developing understandings of NOS through inquiry and reflection. *African Journal in Science Mathematics and Technology Education,* 10(1):81–92.

Denzin, N.K. & Lincoln, Y.S. 2018. *The SAGE Handbook of Qualitative Research*. 5th ed. Thousand Oaks, CA: SAGE.

DeWitt, J. & Osborne, J. 2007. Supporting teachers on science-focused school trips: Towards an integrated framework of theory and practice. *International Journal of Science Education*, 29(6):685–710.

DeWitt, J., & Storksdieck, M. 2008. A short review of school field trips: Key findings from the past and implications for the future. *Visitor Studies*, 11(2):181–197.

Dhlamini, J. 2014. Behavioural manifestation of discipline: A case study in secondary schools in Heidelberg Gauteng province. *Mediterranean Journal of Social Sciences*, 5(27):839-846.

Dole, J. A. & Sinatra, G. M. 1998. Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, 33:109–128. https://psycnet.apa.org/doi/10.1207/s15326985ep3302&3_5

Doidge, M., Dempster, E., Crowe, A., & Naidoo, K. 2008. The Life Sciences content framework: A story of curriculum change. *Conference proceedings*. The 4th Biennial Conference of the South African Association for Science and Technology Educators (SAASTE 2008). University of the Witwatersrand, Johannesburg. South African Association for Science and Technology. pp. 9–14.

Dunk, R., Petto, A. J., Wiles, J. R., & Campbell, B. C. 2017. A multifactorial analysis of acceptance of evolution. *Evolution: Education and Outreach* (4), e4. https://doi.org/10.1186/s12052-017-0068-0 ,10

Duschl, A. R., Schweingruber, A. H., & Shouse, W. A. 2007. *Taking science to school: Learning and teaching science in grades K-8.* Washington DC: The national Academies Press.

Education Labour Relations Council. 2017. Job descriptions for office-based educators. http://desd.nwpg.gov.za/wpcontent/uploads/2019/05/ELRC_CA_4_OF_2017.pdf. Date of access: 3 Feb 2022.

Eisenhart, M. & Howe, K. 1992. Validity in Educational Research. In: LeCompte, M., Millroy, W. & Preissle, J. eds. *The Handbook of Qualitative Research in Education*. San Diego: Academic Press. pp. 642-680.

Engeström, Y. 1987. *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultitl.

Engeström, Y. 2001. “Making expansive decisions: An activity-theoretical study of practitioners building collaborative medical care for children.” In: Allwood, C. & Selart, M. eds. *Decision making: Social and creative dimensions*. Dordrecht: Springer. pp. 281-301.

Engeström, Y. 2009. “The future of activity theory: A rough draft In: Sannino, A., Daniels, H., Gutierrez, K. eds. *Learning and expanding with activity theory*. Cambridge: Cambridge University Press. pp. 303–328.

Engeström, Y. 2011. From design experiments to formative interventions. *Theory & Psychology,* 21(5):598–628.

Engeström, Y., & Sannino, A. 2016. An interview with Yrjö Engeström and Annalisa Sannino on activity theory. *Bellaterra Journal of Teaching & Learning Language & Literature*, 9(4):87-98. http://dx.doi.org/10.5565/rev/jtl3.709

Emmerson, D. 2019. The use of synchronous and asynchronous technological tools for socio-constructivist language learning. *The Journal of Language Teaching and Learning*, 9(2):1-6.

Emmons, N. A., & Kelemen, D. A. 2015. Young children's acceptance of within-species variation: Implications for essentialism and teaching evolution. *Journal of Experimental Child Psychology*, 139:148–160.

Equal Education. Overcrowding Gauteng. 2020. https://equaleducation.org.za/campaigns/overcrowding-gauteng/. Date accessed: 2 March 2022.

Esterhuysen, A., & Smith, J. 1998. Evolution: “The forbidden word?” *The South African Archaeological Bulletin*, 53(168):135-137.

Evans, E. M., & Lane, J. D. 2011. Contradictory or complementary? Creationist and evolutionist explanations of origins. *Human Development*, 54:144–159.

Falk, J.H. 2016. *Identity and the museum visitor experience*. New York: Routledge.

Falk, J. H., Dierking, L. D. 2000. *Learning from museums: Visitor experiences and the making of meaning.* Walnut Creek, CA: AltaMira Press.

Falk, J., Needham, M., Dierking, L., & Prendergast, L. 2014. *International science centre impact study: Final report.* Corvallis, OR: John H. Falk Research. https://visitors.org.uk/wp-content/uploads/2012/07/international-science-centre-impact-study-international-science-centre-impact-study-final-report.pdf. Date of access: 5 Jun 2020.

Fail, J. A. 2008. No-holds-barred evolution curriculum for elementary and junior high school students. *Evolution: Education Outreach*, 1:56–64.

Falk, J. H., & Storksdieck, M. 2005. Learning science from museums. *História, ciências, saúde--Manguinhos,* 12:117–143. https://doi.org/10.1590/s0104-59702005000400007

Filippoupoliti, A. & Koliopoulos, D. 2014. Informal and Non-formal Education: An Outline of History of Science in Museums. *Science and Education*, 3:781-791. https://doi.org/10.1007/s11191-014-9681-2

Fish, D., Allie, S., Pelaez, N., & Anderson, T. 2017. A cross-cultural comparison of high school students' responses to a science centre show on the physics of sound in South Africa. *Public Understanding of Science*, 26(7):806–814. https://doi.org/10.1177/0963662516642725

Fish, D. B. 2016. *Probing the conceptions and mental models of students from diverse educational backgrounds in the context of a science centre show on sound*. Pietermaritzburg: University of KwaZulu-Natal. (Thesis-PhD).

Frost, J. 2019. *Introduction to statistics. An intuitive guide for analysing data and unlocking discoveries*. https://www.amazon.com/Introduction-Statistics-Intuitive-Analyzing-Discoveries/dp/1735431109. Date of access: 2 Jan 2021.

Fullan, M. 2016. *The new meaning of educational change*. New York, NY: Teachers College Press.

Gelman, S. A., & Rhodes, M. 2012. Two-thousand years of stasis. How psychological essentialism impedes evolutionary understanding. In: Rosengren, K.

S., Brem, S. K, Evans, E. M. & Sinatra, G. M. Evolution challenges: Integrating research and practice in teaching and learning about evolution. Cambridge, UK: Oxford University Press. pp. 3-21.

Gelman, S. A. 2003. *The essentialist child: Origins of essentialism in everyday thought*. New York: Oxford University Press.

Glaze, A. L., & Goldston, M. J. 2015. U.S. Science teaching and learning of evolution: A critical review of the literature 2000–2014. *Science Education*, 99(3):500–518. https://doi.org/10.1002/sce.21158

Gregory, T. R. 2008. Understanding evolutionary trees. *Evolution: Education and Outreach*, 1:121-137.

Griffin, J., & Symington, D. 1997. Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education*, 81:763–779, https://doi.org/10.1002/(SICI)1098-237X(199711)81:6%3C763::AID-SCE11%3E3.0.CO;2-O

.

Hallinger, P. (2009*). Leadership for 21st Century Schools: From Instructional Leadership to Leadership for Learning*. Hong Kong: Chair Professors Public Lecture Series of the Hong Kong Institute of Education. https://repository.eduhk.hk/en/publications/leadership-for-the-21st-century-schools-from-instructional-leader-3. Date of access: 2 Feb 2021

Halverson, K. L. 2011. Improving tree-thinking one learnable skill at a time. *Evolution Education Outreach,* 4:95–106.

Hardman, J. 2008. Researching pedagogy: An activity theory approach. *Journal of Education*, 45:63–93.

Hardman, J. 2015. Pedagogical variation with computers in mathematics classrooms: A Cultural Historical Activity Theory analysis. *Psychology in Society*, 48: 47–76.

Hardman, J. & Amory, A. 2015. Introduction to cultural-historical activity theory and tool mediation. In: Bozalek V., Ng'ambi, V. Wood, D., Herrington, J. Hardman, J.,

Amory, A. eds. *Activity theory, authentic learning and emerging technologies*. Oxon, United Kingdom: Routledge. pp. 1–21. Available from Routledge eBook collection. https://doi.org/10.4324/9781315771823. Date of access: 15 Feb 2019.

Harker, R. J. W., & Badger, J. 2015. Traveling Exhibitions as Sites for Informal Learning: Assessing Different Strategies with Field Trips to Traveling Exhibitions at Non-museum Sites. *The Journal of Museum Education*, 40(3):268–277. https://doi.org/10.1179/1059865015Z.000000000103

Henderson, T. Z., & Atencio, D. J. 2007. Integration of play, learning, and experience: What museums afford young visitors? *Early Childhood Education Journal*, 35:245-251.

Henning, E., Smit, B., & Van Rensburg, W. 2004. *Finding your way in qualitative research.* Pretoria: Van Schaik.

Hermann, G. D. 1969. Learning by discovery: A critical review of studies. *The Journal of Experimental Education,* 38(1):58-72.

Herrmann, P. A., French, J. A., DeHart, G. B., & Rosengren, K. S. 2013. Essentialist reasoning and knowledge effects on biological reasoning in young children. *Merrill-Palmer Quarterly*, 59:198–220.

Hlengwa, C.D. & Kholeka, A.Z. 2018. The perspectives of rural high school learners on the value of fieldtrips in tourism education: A case of Pholela Circuit in KwaZulu Natal. *African Journal of Hospitality,Tourism and Leisure,* 7(2):1-11.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. 2007. Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42:99-107. https://psycnet.apa.org/doi/10.1080/00461520701263368Hutson, T., Cooper, S., & Talbert, T. 2011. Describing connections between science content and future careers: Implementing Texas curriculum for rural at-risk high school students using purposefully designed field trips. *Rural Educator*, 31:37-47.

Jackson, C., De Beer J. & White, L. 2020. The affective affordances of frugal science using foldscopes during a life sciences water quality practical. *Perspectives in Education*, 38(1):224-241. http://dx.doi.org/10.18820/2519593X/pie.v38i1.16

Jewkes, R., Gevers, A., Chirwa, E., Mahlangu, P., Shamu, S., Shai, N. & Lombard, C. 2019. RCT evaluation of Skhokho: A holistic school intervention to prevent gender-based violence among South African Grade 8s. *PLoS ONE*, 14(10): e0223562. https://doi.org/10.1371/journal.pone.0223562. Date of access: 14 March 2021.

Johnson, R. B., & Turner, L. A. 2003. Data collection strategies in mixed methods research. In: Tashakkor A. & Teddlie, C. eds., *Handbook of mixed methods in social and behavioural research.* Thousand Oaks, CA: Sage. pp. 297-319.

Jonassen, D. H., Rohrer-Murphy, L. 1999. Activity theory as a framework for designing constructivist learning environments*. Educational Technology, Research and Development,* 47(1):61–79.

Johnson, R. & Onwuegbuzie, A. 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come*. Educational Researcher*, 33(14):14-26. https://doi.org/10.3102/0013189X033007014

Kelton, M. L. 2021. Mathematics Learning Pathways on a School Fieldtrip: Interactional Practices Linking School and Museum Activity, *Visitor Studies*, 24(2): 220-242. https://doi.org/10.1080/10645578.2021.1939984

Kenna, J. L. 2019. Field Trips Among Secondary Social Studies Teachers in Florida. *Journal of Social Studies Education Research*, 10 (3):1-16.

Kisiel, J. F. 2003. Teachers, museums and worksheets: a closer look at learning experience. *Journal of Science Teacher Education*, 14(1):3–21.

Kisiel, J. F. 2005. Understanding elementary teacher motivations for science fieldtrips. *Science Education,* 89(6):936–955.

Kisiel, J. 2006. An examination of fieldtrip strategies and their implementation within a natural history museum. *Science Education*, 90(3):434-452.

Kisiel, J. F. 2010. Exploring a school-aquarium collaboration: An intersection of communities of practice. *Science Education*, 94(1):95–121.

Kisiel, J. F. 2014. Clarifying the complexities of school-museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching*, 51(3):342–367.

Kreber, C. & Cranton, P. A. 2000. Exploring the scholarship of teaching, *The Journal of Higher Education*, 71(4):476-495.

Kretzer, M., Kaschula, R.H. 2019. *South African teachers switch languages in class: Why policy should follow.* Rhodes University website. https://www.ru.ac.za/perspective/latestnews/southafricanteachersswitchlanguagesinclasswhypolicyshouldfollow.html#:~:text=This%20is%20a%20practice%20known,languages%20of%20learning%20and%20teaching. Date of access: 29 Jan 2021.

Krugell, J. F. 2019. Die rol van gevallestudies in die bevordering van selfgerigte leer in Ekonomie onderrig op skool [The role of case studies in promoting self-directed learning in Economics teaching at school]. Potchefstroom: North-West University. (Thesis-PhD).

Kolb, D. 1983. *Experiential learning, experiences as the source of learning and development.* Englewood Cliffs, New Jersey: Prentice Hall.

Kozulin, A. 1998: *Psychological Tools. A socio-cultural approach to education.* Cambridge MA: Harvard University press.

Kyriacou, X., De Beer, J. & Ramnarain, U. 2015. Evolutionary ideas held by experienced South African Biology Teachers. *African Journal of Research in Mathematics, Science and Technology Education*, 19(2):118-130.

Lautenbach, G. & Batchelor, J. 2013. *Streamlining Processes with Technology: The Research Ethics Committee*. World Conference on Educational Media and Technology, Victoria. https://www.learntechlib.org/primary/p/111922/. Date accessed: 14 Nov 2020.

Lave, J., & Wenger, E. 1991. *Situated learning: Legitimate peripheral participation*. New York, NY: Cambridge University Press.

Lawrence, M., & Tinkler, A. 2015. What can you learn about science in a natural history museum? *School Science Review*, 97(358):68-73.

Lazonder, A. W., & Harmsen, R. 2016. Meta-Analysis of Inquiry-Based Learning: Effects of Guidance. *Review of Educational Research*, 86(3):681–718. https://doi.org/10.3102/0034654315627366

Leavy, P. 2017. *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches*. New York: The Guilford Press

Lelliot, A., D. 2007. Learning about Astronomy: A case study exploring how grade 7 and grade 8 students experience sites of informal learning in South Africa. Johannesburg: University of the Witwatersrand. (Thesis-PhD).

Lelliot, A., D. 2009. *Teacher practices during science school visits in Gauteng*. Proceedings of the Seventeenth Annual Meeting of the Southern African Association for Research in Mathematics, Science and Technology Education. Grahamstown. (PDF) Teacher practices during science school visits in Gauteng (researchgate.net). Date of access: 5 Jun. 2018.

Lelliott, A. 2016. Visitors' views of human origins after visiting the Cradle of Humankind World Heritage Site. *South African Journal of Science*, 112(1/2):132–139.

Lelliot, A. 2017. Recent research on science communication and engagement in informal settings in South Africa. In: Leggon, C.B., Gaines, M.S. eds. *Stem and social justice: Teaching and learning in diverse settings*. Cham, Switzerland: Springer. pp. 77-94. https://doi.org/10.1007/978-3-319-56297-1_5

Legare, C. H., Lane, J., & Evans, E. M. 2013. Anthropomorphizing science: How does it affect the development of evolutionary concepts? *Merrill-Palmer Quarterly*, 59:168–197.

Legare, C. H., & Visala, A. 2011. Between religion and science: Integrating psychological and philosophical accounts of explanatory coexistence. *Human Development*, 54:169–184.

Legare, C. H., Opfer J. E., Busch, J. T. A., & Shtulman, A. 2018. A field guide for teaching evolution in the social sciences. *Evolution and Human Behaviour,* 39:257–268.

Leont'ev, A. N.1981. The problem of activity in psychology. In: Wertsch, J. V. ed. *The concept of activity in Soviet psychology*. Armonk, NY: M. E. Sharpe. pp. 37-71.

Linell, P. 2001. *Approaching dialogue: Talk, interaction, and contexts in dialogical perspectives.* Amsterdam: John Benjamins.

Mai, T. & Ash D. B. 2012.Tracing our methodological steps: Making meaning of diverse families' hybrid "figuring out" practices at science museum exhibits. In: Ash, D. B, Rahm, J., Melber, L. M. eds. *Putting theory into practice*. Rotterdam: Sense publishers. pp. 97-117.

McLeod, S. A. 2019. *What a p-value tells you about statistical significance*. Simply Psychology. www.simplypsychology.org/p-value.html. Date accessed: 2 Feb 2022.

Meir, E., Perry, J., Herron, J. C. & Kingsolver, J. 2007. College students' misconceptions about evolutionary trees. *American Biology Teacher*, 69:71–76.

Melber, L. M. 2003. Partnerships in Science Learning: Museum Outreach and Elementary Gifted Education. *Gifted Child Quarterly*, 47(4):251–258. https://doi.org/10.1177/001698620304700402

Merriam, S.B. 2002. Assessing and evaluating qualitative research. In: Merriam, S.B. and Associates, eds. *Qualitative Research in Practice*. San Francisco: Jossey-Bass. pp. 18-36.

Merriam, S. B. 2002. *Qualitative research* in *practice. Examples for discussion and analysis.* San Francisco: Jossey-Bass.

Miles, M., Huberman, A. M., & Saldana, J. 2014. *Qualitative data analysis: A methods sourcebook*. 3rd ed. Los Angeles, CA: SAGE.

Mitchell, J. K. & Cater, W. E. 2000. Modelling antimicrobial activity of Clorox using an agar diffusion test. *Bioscience*, 26(3):9–13.

Mji, A., Makgato, M. 2006. Factors associated with high school learners' poor performance: a spotlight on mathematics and physical science. *South African Journal of Education*, 26(2):253-266.

Mkgobanama, D. 2011. *Learning about evolution: The influence of educational visits and intervention on teachers' knowledge and attitudes*. Johannesburg: University of the Witwatersrand. (Thesis-MSc).

Mortensen, M. F. & Smart, K. 2007. Free-choice worksheets increase students' exposure to curriculum during museum visits. *Journal of Research in Science Teaching*, 44:1389–1414.

Mosabala, M. & Lelliott, A. D. 2012. *Investigating perceptions of teachers and their learners about museums visits.* Paper presented at the 20th Annual Southern African Association for Research in Mathematics, Science and Technology Education Conference. Lilongwe. https://www.researchgate.net/publication/262106208_Investigating_perceptions_of_teachers_and_their_learners_about_museums_visits. Date of access: 7 May 2022

Moswela, B. 2010. Instructional supervision in Botswana secondary schools: An investigation. *Educational Management Administration & Leadership*, 38(1):71-87.

Mthembu S. G. 2015. *Subject advisors as instructional leaders: a case study of six subject advisors in Ilembe district*. Pietermaritzburg: University of KwaZulu-Natal. (Thesis-MEd).

Mujtaba, T., Lawrence, Oliver, M. & Reiss, M.J. 2018. Learning and engagement through natural history museums, *Studies in Science Education*, 54(1):41-67. https://doi.org/10.1080/03057267.2018.1442820

Murphy, J. 2016*. Creating instructional capacity: A framework for creating academic press*. Thousand Oaks, CA: Corwin.

Naicker, I., Chikoko, V. & Mthiyane, S. E. 2013. Instructional leadership practices in Challenging school contexts. *Education as Change*, 17(1):137-150.

National Research Council 2009. *Learning science in informal environments: People, places, and pursuits*. Washington, DC: The National Academic Press.

Naude, F., & de Beer, J. 2014. *The theory of 'evilution': Christian teachers' and learners 'perspectives on evolution.* In Proceedings of the International Conference

on Mathematics, Science and Technology Education (ISTE 2014). Mopani Camp in Kruger National Park, South Africa. Pretoria: UNISA. pp. 263–274.

Neisser, U. 1967. *Cognitive Psychology*. New York: Appleton-Century-Crofts.

Nehm, R. H. & Reilly, L. 2007. Biology majors' knowledge and misconceptions of natural selection. *BioScience,* 57:263–272.

Nickels, M., Nelson, C. & Beard, J. 1996. Better Biology Teaching by Emphasizing Evolution &the Nature of Science. *The American Biology Teacher*, 58:332–336.

Novick L. R., & Catley, K. M. 2007. Understanding phylogenies in biology: the influence of a Gestalt Perceptual Principle. *Journal of Experimental Psychology Applied,* 13:197–223.

Numan, D. & Carter, D., 2001, *Teaching English to speakers of other languages*. Cambridge: Cambridge University Press.

Nyampangedengu, E. 2010. *Worksheets and learning in South African museums*. Johannesburg: University of the Witwatersrand. (Thesis-MSc).

Nyamupangedengu, E., & Lelliot, A. D. 2012. An exploration of learners' use of worksheets during a science museum visit. *African Journal of Research in Mathematics, Science and Technology Education*, 16(1):82-99.

Organization for Economic Co-operation and Development (OECD). Programme for International Student Assessment (PISA). 2016. *Science competencies for tomorrow's world.* https://www.oecd.org/pisa/pisaproducts/37474503.pdf. Date of access: 2 Nov. 2020.

Orb, A., Eisenhauer, L., & Wynaden, D. 2000. Ethics in Qualitative Research. *Journal of Nursing Scholarship,* 33(1):93–96.

Oswald, M. M. 2019. Teachers need scientific and experiential knowledge on learning support: recommendations for a teacher educator. *South African Journal of Higher Education,* 33(4):237-252.

Patrick, A. 2010. Effects of field studies on learning outcomes in Biology. *Journal of Human Ecology*, 31(3):171-177.

Patton, M. Q. 1990. *Qualitative evaluation and research methods.* 2nd ed. Newbury Park: Sage.

Patton, M. Q. 2002. *Qualitative Research & Evaluation Methods*. 3rd ed. Thousand Oaks: Sage Publications.

Piaget, J. 1929. *The child's conception of the world*. New York: Harcourt Brace.

Pillay, C. 2011. *The difficulties faced by some teachers with strong religious beliefs when they teach evolution*. Johannesburg: University of the Witwatersrand. (Thesis-MEd).

Pirie, S. E. B. 1996. *Classroom Video-Recording: When, Why and How Does It Offer a Valuable Data Source for Qualitative Research?* Paper presented at the Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Panama City. https://files.eric.ed.gov/fulltext/ED401128.pdf. Date accessed: 2 Feb 2018.

Poling, D. A., & Evans, E. M. 2002. Why do birds of a feather flock together? Developmental change in the use of multiple explanations: Intention, teleology and essentialism. *British Journal of Developmental Psychology*, 20:89–112.

Potgieter, M. ,Potgieter, A., Ramaila, P. & Wildschut, L. 2021. An evaluation of the Science Learner Assisted Program (SLAP) at the University of Limpopo Science Centre, South Africa. *Technium Social Sciences Journal*. 26:278-293. https://doi.org/10.47577/tssj.v26i1.4991

Rallis, S. F., & Rossman, G. B. 2003. *Learning in the field: An introduction to qualitative research*. 2nd ed. Thousand Oaks, CA: SAGE.

Rall, M. 2016. Museums, communication and literacy: The education programme at the Iziko South African museum, Cape Town. *South African Museums Bulletin*, 38:32-38.

Rapule, S. 2007. *Assessing the impact science centres have on the holistic development of science learners*. Potchefstroom: North-West University. (Thesis – PhD).

Riga, F., Winterbottom, M., Harris, E. & Newby, L. 2017. Inquiry-based science education. In: Taber, K. S., Akpan, B. eds. *Science education. New Directions in Mathematics and Science Education*. Rotterdam: Sense Publishers. pp. 247-261.

Rogoff, B. (1990). *Apprenticeship in Thinking. Cognitive Development in Social Context.* New York: Oxford University Press.

Rose, J. & Johnson, C.W. 2020, "Contextualizing reliability and validity in qualitative research: toward more rigorous and trustworthy qualitative social science in leisure research", *Journal of Leisure Research*, 51(4):432-451.

Rowe, S., Bachman, J. 2012. Mediated action as a framework from exploring learning in informal settings. In: Ash, D.B, Rahm, J., Melber, L.M. ed. *Putting theory into practice*. Rotterdam: Sense publishers. pp.143-162.

Roth, W. M. & Lee, Y. J. 2007. 'Vygotsky's neglected legacy': Cultural-historical activity theory. *Review of Educational Research,* 77(2):186–232.

Saldana, J. 2009. *The Coding manual for qualitative researchers.* Thousand Oaks, CA: Sage.

Saldana, J. 2013. *The coding manual for qualitative researchers*. 2nd ed.. Thousand Oaks, CA:SAGE.

Salmi, H. 2003. Science centres as learning laboratories: Experiences of Heureka, the Finnish Science Centre. *International Journal of Technology Management*, 25(5): 460–476.

Sanders, M. 2018. The unusual case of evolution education in South Africa. In: Deniz, H., Borgerding, L. A. eds. *Evolution education around the globe*. Cham, Switzerland: Springer. pp. 409-428.

Sanders M, & Makotsa D. 2016. The possible influence of curriculum statements and textbooks on misconceptions: The case of evolution. *Educational Change*, 20:216–238. https://doi.org/10.17159/1947-9417/2015/555

Sanders, M., & Ngxola, N. 2009. Identifying teachers' concerns about teaching evolution. *Journal of Biological Education*, 45(5):113-122.

Schön, D.A. 1987. *Education the reflective practitioner*. San Francisco, CA: Jossey-Bass.

Shaby, N., Assaraf, O. B, & Tal, T. 2019. 'I know how it works!' student engagement with exhibits in a science museum, *International Journal of Science Education*, Part B, 9(3):233-252. https://doi.org/10.1080/21548455.2019.1624991

Shaby, N., Assaraf, O. B. & Tal, T. 2019, An examination of the interactions between museum educators and students on a school visit to science museum, *Journal of Research in Science Teaching*, 56(2):211-239.

Sharma, S. 2012. Instructional leadership model through Asian principals' perspectives. *In International conference on education and management innovation*, Singapore. http://ipedr.com/vol30/4-ICEMI%202012-M00004.pdf. Date accessed: 13 Jun. 2020.

Shenton, A. K. 2004. Strategies for Ensuring Trustworthiness in Qualitative Research Projects. *Education for Information,* 22:63-75. https://doi.org/10.3233/EFI-2004-22201. Date accessed: 3 March 2021.

Shtulman, A. 2006. Qualitative differences between naïve and scientific theories of evolution. *Cognitive Psychology*, 52:170–194.

Shtulman, A., & Calabi, P. 2013. Tuition vs. intuition: Effects of instruction on naïve theories of evolution. *Merrill-Palmer Quarterly*, 59(2):141–167. https://doi.org/10.1353/mpq.2013.0010

Shtulman, A. & Checa, I. 2012. Parent-child conversations about evolution in the context of an interactive museum display *International Electronic Journal of Elementary Education*, 5(1):27-46.

Sickel, A. J., & Friedrichsen, P. J. 2013. Examining the evolution education literature with a focus on teachers: major findings, goals for teacher preparation, and directions for future research. *Evolution: Education and Outreach*, 6:1-15.

Sinatra, G. M., Brem, S. K., & Evans, E. M. 2008. Changing minds? Implications of conceptual change for teaching and learning about biological evolution. *Evolution: Education Outreach*, 1:189–195.

Smit, M. 2013. Compatibility of democracy and learner discipline in South African schools. *De Jure*, 44(1):345-365. https://hdl.handle.net/10520/EJC136260 Date accessed: 2 Nov. 2020.

Speight, V. M. & De Beer, J. 2020. Contextualising science and mathematics teacher professional development in rural areas. *Perspective in Education*, 38(2):213-226. http://dx.doi.org/10.18820/2519593X/pie.v38.i2.14

Spinuzzi, C. 2014. How non employer firms stage-manage ad hoc collaboration: An activity theory analysis. *Technical Communication Quarterly,* 23(2):88–114. http://www.tandfonline.com/doi/abs/10.1080/10572252.2013.797334

Stears, M., Clément, P., James, A., & Dempster, E. 2016. Creationist and evolutionist views of South African teachers with different religious affiliations. *South African Journal of Science*, 112(5/6):76–85.

Stetsenko, A. 2010. Teaching-learning and development as activist projects of historical Becoming: Expanding Vygotsky's approach to pedagogy, *Pedagogies: An International Journal*, 5(1):6–16.

Stott, A.E. 2019. The Efficacy of an Extracurricular Inquiry Programme on Grade 8 and 9 South African Low Quintile Learners' Science Learning, *African Journal of Research in Mathematics, Science and Technology Education*, 23(2):157-168. https://doi.org/10.1080/18117295.2019.1630112

Sutherland C., & L'Abbé E. N. 2019. Human evolution in the South African school curriculum. *South African Journal of Science*, 115(7/8), Art. #5672, 7 pages. https://doi.org/10.17159/sajs.2019/5672

Tal, T., Alon, N. L., & Morag, O. 2014. Exemplary Practices in Field Trips to Natural Environments. *Journal of Research in Science Teaching,* 51(4):430-461.

Tal, R., Bamberger, Y. & Morag, O. 2005. Guided school visits to natural history museums in Israel: teachers' roles, *Science Education*, 89(6):920-935.

Tal, T. & Morag, O. 2007. School visits to natural history museums: Teaching or enriching? *Journal of Research in Science Teaching*, 44(5):747–769.

Tal, T. & Steiner, L. 2006. Patterns of teacher–museum staff relationships: School visits to the educational center of a science museum. *Canadian Journal of Science, Mathematics and Technology Education*, 6:25–46.

Taylor, N. 2008. *What's wrong with South African Schools*? In: Proceedings of the conference on "What's working in school development". JET Education Services. https://www.jet.org.za/resources/Taylor%20Whats%20wrong%20with%20SA%20schools%20JET%20Schools%20Conf%20final.pdf. Date of access: 2 Feb 2017.

Taylor, S.J., Bogdan, R. & De Vault, M.L. 2016. *Introduction to Qualitative Research Methods: A Guidebook and Resource*. 4th ed. Hoboken,New Jersey: John Wiley & Sons, Inc.

Thomas, L., MacMillan, J., McColl, E., Hale, C., & Bond, S. 1995. Comparison of focus group and individual interview methodology in examining patient satisfaction with nursing care, *Social Sciences in Health*, 1:206–219.

Timans, R., Wouters, P. & Heilbron, J. 2019. Mixed methods research: What it is and what it could be. *Theory and Society,* 48:193–216.

Torrens, E., & Barahona, A. 2012. Why are some evolutionary trees in natural history museums prone to being misinterpreted? *Evolution: Education and Outreach*, 5:76-100.

Tshuma, T., & Sanders, M. 2015. Textbooks as a possible influence on unscientific ideas about evolution. *Journal of Biological Education*, 49(4):354–369.

Tran, L. U. 2007. Teaching science in museums: The pedagogy and goals of museum educators. *Science Education*, 91(2):278–297.

Van den Heever, J. 2009. *Creationism in the colonies: Science, religion and the legacy of apartheid in South Africa*. In Proceedings of the Fourteenth conference of the South African Science and Religion Forum of the Research Institute for Theology and Religion, Pretoria. http://hdl.handle.net/10500/4291. Date of access: 12 Feb 2020.

Van der Berg, S. 2008. How effective are poor schools? Poverty and educational outcomes in South Africa. *Studies in Educational Evaluation*, 34:145–154.

Van der Westhuizen P. C., Legotlo, M. P., Mosoge, H. D. Niewoudt, H. D, Steyn, H. J., Maaga, M. P. & Sebego, M. G. 2002. Perceptions of stakeholders on causes of poor performance in Grade 12 in a province in South Africa. *South African Journal of Education*, 22(2):113–118.

Van Wyk, G. & De Beer, J. 2019. Bridging the Theory–Practice Divide: Life Sciences Student Teachers' Perceptions of Teaching in Communities of Practice at a Teaching School*, African Journal of Research in Mathematics, Science and Technology Education*, 23(3):276-285. https://doi.org/10.1080/18117295.2019.1658454Vygotsky, L. S. 1978. *Mind in society.* Cambridge, MA: Harvard University press.

Yates, T. B., & Marek, E. A. 2014. Teachers teaching misconceptions: a study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions. *Evolution Education Outreach,* 7, e7. https://doi.org/10.1186/s12052-014-0007-2

Wenger, E. 1998. *Communities of practice: Learning, meaning, and identity*. New York, NY: Cambridge University Press.

Williams, D. R., Brule, H., Kelley, S. S., & Skinner, E. A. 2018. Science in the learning gardens (SciLG): A study of students' motivation, achievement, and science identity in low-income middle schools*. International Journal of STEM Education*, 5(1):8–22. https://doi.org/10.1186/s40594-018-0104-9

Whitesell, E. R. 2016. A Day at the Museum: The Impact of Field Trips on Middle School Science achievement. *Journal of Research in Science Teaching,* 53(7): 1036–1054.

Winterbotham, N. 2005*. Museums and schools: Developing services in three English counties 1988–2004*. Nottingham: University of Nottingham. (Thesis – PhD).

Wolberg, R. I. & Goff, A. 2012. Thinking Routines. *Journal of Museum Education*, 37(1):59-68. https://doi.org/10.1080/10598650.2012.11510718

Woods-McConney, A., Oliver, M., McConney, A., Schibeci, R. & Maor, D. 2014. Science Engagement and Literacy: A retrospective analysis for students in Canada

and Australia. *International Journal of Science Education,* 36:1588-1608. https://doi.org/10.1080/09500693.2013.871658

Zhou, M. & Brown, D., 2015. *Educational Learning Theories*: 2nd ed. Available from Education Open Textbooks: https://oer.galileo.usg.edu/education-textbooks/1 Date accessed: 2 March 2020.

APPENDICES

Gauteng Province approval letters

Wits approval letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

6/4/4/1/2

GDE GROUP RESEARCH APPROVAL LETTER

Date:	**09 March 2018**
Validity of Research Approval:	**05 February 2018 – 28 September 2018** **2017/387**
Name of Researcher:	**van Wyk G**
Address of Researcher:	**13 Verbena Street**
	Arconpark
	Vereeniging 1939
Telephone Number:	**084 736 9258**
Email address:	**Grizelda.vanwyk@gauteng.gov.za**
Research Topic:	**Evaluating the effectiveness of a school visit to a university based palaeontology museum**
Type of Degree:	**PhD**
Number and type of schools:	**Thirteen Secondary Schools**
District/s/HO	[redacted]

Re: Approval in Respect of Request to Conduct Research

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

14/03/2018

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	08 February 2019
Validity of Research Approval:	04 February 2019 – 30 September 2019 2018/395
Name of Researcher:	Van Wyk G
Address of Researcher:	13 Verbena Street
	Arconpark
	Vereeniging, 1939
Telephone Number:	084 738 9258
Email address:	grizelda.vanwyk@gauteng.gov.za
Research Topic:	Where formal education meets the informal: Fruitful co-creation of Museum palaecseince learning programme to enhance teaching and learning in the grade 10 and 12 South African Life Science classroom
Type of qualification	PhD
Number and type of schools:	Twenty-Seven Secondary Schools
District/s/HO	[redacted]

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be

08/02/2019

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

OFFICE OF THE DEPUTY REGISTRAR

29 August 2019

Grizelda Van Wyk
Student number 1889741
PhD Candidate
Evolutionary Studies Institute

TO WHOM IT MAY CONCERN

"Where formal education meets the informal: The co-creation of Museum palaeoscience learning programmes to enhance Teaching and Learning in the Grade 10 & 12 South African Life Science classroom"

This letter serves to confirm that the above project has received permission to be conducted on University premises, and/or involving staff and/or students of the University as research participants. In undertaking this research, you agree to abide by all University regulations for conducting research on campus and to respect participants' rights to withdraw from participation at any time.

If you are conducting research on certain student cohorts, year groups or courses within specific Schools and within the teaching term, permission must be sought from Heads of School or individual academics.

Ethical clearance has been obtained. (Protocol number: **H18/07/28**)

Carol Crosley
University Registrar

Private Bag 3, Wits, 2050, South Africa | T +27 11 717 1204/8 | F +27 86 553 2271 | www.wits.ac.za